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The effect of three different feeding schemes on production parameters of European catfish (*Silurus glanis* L.) larvae reared in flow-through production system

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Abstract

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This paper presents the results of the rearing of European catfish (*Silurus glanis* l.) larvae in a flow-through production system using three feeding schemes – Variant A was control and consisted of dry pellet food; Variant B – dry pellet food and supplement of frozen *Chironomus*, Variant C – dry pellet food and supplement of frozen *Artemia*. Each of the experimental variants was applied in 2 tanks with the same stocking density – 15 ex/l^{-1} at 40 l maintained volume.

The growth performance of the larvae in the three experimental variants was compared in terms of final biomass (FB), individual weight gain (IWG), total weight gain (TWG), specific growth rate (SGR), daily growth rate (DGR), feed conversion ratio (FCR) and survival rate (SR). The highest final biomass was reported in Variant B with nutritional supplement of *Chironomus*, with significant difference when compared to Variant A and Variant C ($P \leq 0.05$). The daily growth rate was the highest in Variant B and the lowest in Variant C ($P \leq 0.05$). The specific growth rate confirmed the daily rate values and was again the highest in Variant B and lowest in Variant C ($P \leq 0.01$). The highest survival rate was achieved in Variant B, with a difference of 15.93% with Variant C ($P \leq 0.05$).

Based on the results of the fish production parameters it can be concluded that the most effective nutritional option, for rearing *S. glanis* larvae, was Variant B with supplement of frozen *Chironomus*.

Keywords: European catfish; *Silurus glanis*; larvae; rearing; *Artemia*; *Chironomus*

Introduction

The European catfish (*Silurus glanis* Linnaeus, 1758) is one of the most valuable predatory fish species for breeding. Its meat is white, low in fat (6-8%), devoid of intermuscular bones, has got a high rating in satisfactory food consumption and a pleasant consistency. European catfish has a high growth rate with sufficient food availability, is resistant to processing and has relatively low water quality requirements (Linhart et al., 2002; Pronina et al., 2022). In fish farms, it can be used as an ameliorator, as it willingly eats weed fish and unwanted offspring resulting from carp (*Cyprinus carpio*) rearing (Zaikov et al., 2008; Woynarovich et al., 2010; Pronina et al., 2022).

European catfish is raised as a monoculture in cages and pools, or as a polyculture with carp and other fish (Szabo et al., 2015). Monoculture uses high protein pellets for feeding (Filipiak et al., 1997; Haffray et al., 1998; Linhart et al., 2002). Under polyculture conditions, catfish are fed mainly with natural food (Linhart et al., 2002; Zaikov, 2006; Jankowska et al., 2007; Pronina et al., 2022).

Nutritional value of farm-raised fish depends on the chemical composition of the fish diet. The industrial fish food tends to mimic the natural food, containing approximately 50% of proteins (including all the essential amino acids), 10–15% of carbohydrates (without remarkable fiber content) and 12–15% of lipids (including the necessary essential fatty acids) (Bogut et al., 2007). Nevertheless, some authors prefer and recommend natural food for fish diet, especially in nutrition of younger fish (Jirásek, 2001). The outlined advantages of the natural food compared to the industrial one are: a high digestibility (particularly of proteins), high water content (85–95%), soft and elastic food structure which allows its deformation short after ingestion, and the food movability, allowing fish to react on the "food" motions. Additionally, unconsumed industrial food, containing high dry matter content, contaminates water manifold, compared to natural food (Bogut et al., 2007).

Of the live food used in aquaculture, *Artemia* is the most used organism, closely related to shrimp and belonging to order Anostraca, class Crustacea, phylum Arthropoda. *Artemia* has high nutritional value and high conversion efficiency. All life stages of *Artemia* (cyst, nauplii, juveniles, sub-adults) can be used as feed. Frozen adult *Artemia* are widely used by aquarists, fish breeders and aquaculturists (Das et al., 2014).

Chironomids (non-biting midges) are one of the most diverse and ecologically important groups of macroinvertebrates (Coffman and Ferrington, 1984). They belong to order Diptera, class Insecta, phylum Arthropoda. Chironomid larvae are excellent source of protein, lipid, vitamins and minerals (McIarney et al., 1974; De la Noue & Choubert, 1985). The relatively high protein content (56%) and high digestibility (73.65%) (De la Noue & Choubert, 1985) make chironomid larvae rich food for many organisms (Das et al., 2014). Thipkonglars et al. (2010) have established that chironomid larvae have a proximate nutrient composition of moisture 88.34%, protein 55.62%, fat 4.57% and ash 44.45%. The authors conclude that the level of protein and fiber contents in chironomid larvae is lower than those of rotifer (Thipkonglars et al., 2010).

Live food is used as a larval feed to help for the highest survival of the larval stage of fish. Some researchers have reported a live food for the best survival of larval rearing period of larvae (Lal et al., 2022). Singh et al. (2019) observed the better survival of climbing perch, *Anabas testudineus* larvae after feeding with highly unsaturated fatty acids (HUFA) and vitamin C enriched *Moina*. The highest survival with HUFA enriched *Moina* was recorded 24±1.53% and while the lowest survival (9.3±0.88%) was in the control unit. Sontakke et al. (2019) recorded the highest body weight (4.59±0.17 g) and survival (72.66±2.90%) of Indian featherback, *Notopterus chitala* fry after the feeding with enriched *Artemia*. Araújo et al. (2016) observed the highest survival (86.92±6.01%) of *Prochilodus lineatus* larvae after feeding with docosahexaenoic acid (DHA) and arachidonic acid (ARA) enrich *Artemia*. Action-Nzeh et al. (2012) observed higher survival (95%) and growth rate (6.41±1.59%) of African catfish, *Clarias gariepinus* larvae after the feeding with *Artemia nauplii* and formulated diets. Okunsebor et al. (2011) reported a higher survival rate (88.83%), percentage weight gain (4.96%), and specific weight gain (3.09) of *Heteroclarias* fry after the feeding with live *Moina micrura* (Lal et al., 2022).

The purpose of the present study is to assess the effect of different feeding schemes on the main fish production indicators of European catfish *(Silurus glanis* L.) larvae reared in a flow-through production system.

Material and Methods

The research was carried out at the Institute of Fisheries and Aquaculture, Plovdiv in 2022. The duration of the experiment was 35 days.

Experimental individuals and technological set-up

The experimental individuals were European catfish larvae with initial body weight of 0.02±0.01 g and initial age of 5 days. The number of the individuals used in the experiment was 3900. The larvae were obtained from semi-artificial propagation. The experimental food variants and the technological parameters in which the larvae were reared during the experiment are presented in Table 1.

Variant A was control, only dry pellet food was applied, in Variant B – dry pellet food and frozen *Chironomus*, Variant C – dry pellet food and frozen *Artemia*. Each of the variants was applied in 2 tanks, in which the same density was applied – 15 ex/l^{-1} at 40 l maintained volume of the tanks.

At the start of the experiment, the biometric parameters weight (BW, g) and length (TL, cm) of 100 randomly selected larvae were measured, the values of which were considered the same in all experimental variants. At the end of the experiment, 50 fish from each tank or 100 fish from each variant were measured. An electronic scale "Kern AEJ" (accuracy 0.001 g) was used to measure the mass of the larvae, and an electronic caliper "Digital Caliper" (accuracy 0.01 mm) was used for their length. In order to preserve the good condition of the larvae and to protect them from injuries, an anesthetic solution in a low concentration of lavender oil (0.02 ml/l^{-1}) was applied. The experimental unit was a flow-through production system consisting of 6 tanks – 60x40x40 cm in size and volume of 30 l. Water flow rate was 0.7 l.min^{-1} and a complete water cycle took 43 min. The water for the experimental system was supplied from a drill with an average temperature of 12ºC and warmed up by heaters installed

Table 1. Feed variants and technological parameters for rearing of European catfish larvae

Food variant	Variant A Dry pellets	Variant B Dry pellets+Chironomus	Variant C Dry pellets+Artemia
Tanks №	1 & 2	3 & 4	5 & 6
Volume/ tank (l)	40	40	40
SD[1] (ex/l^{-1})	15	15	15
IBW[2] (g)	0.02±0.01	0.02±0.01	0.02±0.01
ITL[3] (cm)	1.24±0.72	1.24±0.72	1.24±0.72
IB[4] (g)	26.92	26.92	26.92
INF[5]/ tank	650	650	650
INF[5]/ variant	1 300	1 300	1 300
TNF[6]	3 900		

[1] SD – Stocking density
[2] IBW – Initial body weight
[3] ITL – Initial total length
[4] IB – Initial biomass
[5] INF – Initial number of fish
[6] TNF – Total number of fish

in the collecting reservoir. In each tank microcompressors for continuous air supply were installed. For the sterilization of the water UV lamp was used.

The experimental tanks were cleaned twice a day – in the morning, before the first feeding, and in the evening, before the last feeding, with the help of a siphon. The number of dead larvae was recorded daily, as was the health status of the larvae.

Technological scheme of feeding

The larvae were fed according to an established daily ration, which was 30% of the average total weight of the fish and equal to 5.32 g/tank. The larvae were fed by hand 4 times a day, and the food was sprinkled in the places of aggregation for 2-3 min. For Variant B frozen larvae of the nonbiting midges of genus *Chironomus* were used, and for Variant C – frozen adult forms of the crustaceans of the species *Artemia salina*. The two types of natural foods were purchased from the commercial trade network. During the experiment, the natural nutritional supplements were stored in a freezer. The amount of natural food additives represented 10% of the daily ration. When the food is thawed, it is separated according to the established food scheme and left at room temperature to dry overnight. The preparation of the three food variants for each tank was carried out in the morning, and the dried *Chironomus* and *Artemia* were crushed and mixed with the feed by adding vegetable fat and stirring until a homogeneous mixture was obtained. The *Chironomus* and *Artemia* food supplements and the dry pellets were prepared according to the feeding scheme presented in Table 2. The used commercial dry pellet food was "Ocean nutrition" with pellet size 0.5 mm and protein content 58%.

Hydrochemical parameters

The main physicochemical parameters of water, dissolved oxygen (O_2 mg.l^{-1}), temperature (T˚C), hydrogen indicator (pH) were measured daily, while nitrogen compounds were monitored once a week.

Fish production indicators

The growth performance of the larvae in the three experimental variants was compared in terms of final biomass (FB), individual weight gain (IWG), total weight gain (TWG), specific growth rate (SGR), daily growth rate (DGR), feed conversion ratio (FCR) and survival rate (SR) using the following formulas:

Final biomass (FB, g): mean final weight*number of survived fish

Individual weight gain (IWG, g): $IWG = Wt_2 – Wt_1$

Total weight gain (TWG, g): TWG = IWG*number of survived fish

Table 2. Feeding scheme

	Variant A	Variant B	Variant C
Daily ration, % – tank	30%	30%	30%
Natural food extract % – tank	10%	10%	10%
Daily ration, g – tank	5.32 g dry pellets	4.79 g dry pellets+0.53 g *Chironomus*	4.79 g dry pellets+0.53 g *Artemia*
Daily ration, g – variant	10.64 g dry pellets	9.58 g dry pellets+1.06 g *Chironomus*	9.58 g dry pellets+1.06 g *Artemia*

Specific growth rate (SGR, %.day^{-1}): $$SGR = \frac{\ln Wt_2 - \ln Wt_1}{P} * 100$$

Daily growth rate (DGR, g.day^{-1}): $$DGR = \frac{Wt_2 - Wt_1}{P - 1}$$

where:

Wt_1 = initial weight;

Wt_2 = final weight;

P = duration of the experiment (days);

Food conversion ratio (FCR): $$(FCR) = \frac{FI}{WT}$$

where:

FI = total feed intake (g);

WT = total weight gain (g); (Total weight gain = mean individual weight gainnumber of survived fish);

Survival rate (SR, %): $$SR = \frac{NF}{NI} * 100$$

where:

NF = final number of fish;

NI = initial number of fish;

Statistical analysis

The results are presented as mean±S.E.M. and were analyzed via Data Analysis (Excel 2019). T-test (Two Sample for Means, significant level of $P < 0.05$) was used to compare the effect of used feeding scheme on growth performance of the larvae of European catfish. Correlation analysis (Pearson's coefficient) was performed by applying scatter plot and linear regression in order to determine the correlation between final body weight and final total length of the larvae from the experimental food variants.

Results and Discussion

Figure 1 (A, B, C) presents the results of the main hydrochemical parameters (T˚C, O_2, mg.l^{-1} and pH) of the three food variants, which include 16 of the measurements which were performed during the entire experimental period. In all three variants, the temperature was within the range of 24.5°C–26.7°C, and no deviations from the optimal values were reported. The values of the dissolved oxygen fluctuated within the regular range (5.2–7.3 mg.l^{-1}) with an average value of 6.6 mg.l^{-1}. The pH varied from 6.5 to 8.6 with an average value of 7.9.

In Variant B, the temperature varied within wider limits (21.4°C–25.9°C) compared to Variant A, with the lowest recorded temperatures being 21.4°C and 22.3°C. Dissolved oxygen is also in the optimal range from 5.6 mg.l^{-1} to 7.9 mg.l^{-1} with an average maintained value for the experimental period of 6.9 mg.l^{-1}. In Variant C, the temperature ranged from 20.2°C to 25.5°C, with an average temperature over the period of 23.6°C, which is within the optimal values for rearing European catfish larvae. The dissolved oxygen is within the regular limits (5.6 mg.l^{-1}–7.2 mg.l^{-1}), and no deviations were recorded during the study period.

The results from the rearing of European catfish larvae using three food variants are presented in Table 3.

The highest final biomass was reported in Variant B with nutritional supplement of *Chironomus*, with significant difference when compared to Variant A and Variant C ($P \leq 0.05$).

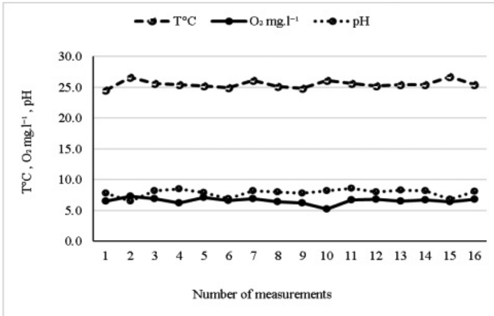

Fig. 1 (A)

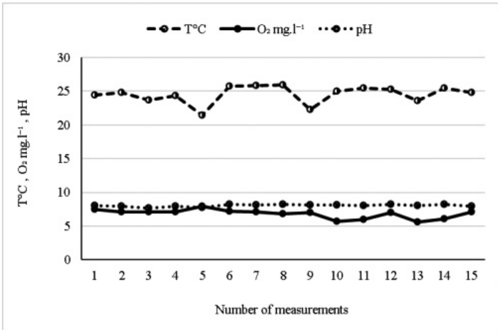

Fig. 1 (B)

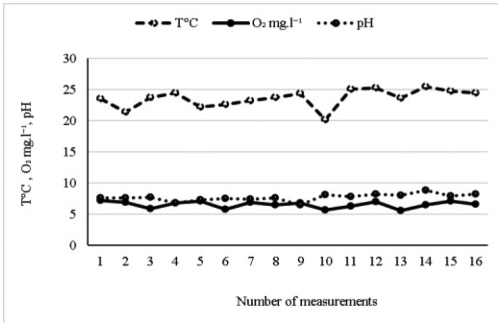

Fig. 1 (C)

Table 3. Technological performance indicators of growth of European catfish larvae reared using different food variants

Growth performance indicators	Food variants			Level of significance
	A	B	C	
FB[1] (g)	650.65^{abc}	1 101.62^{bca}	432.88^{cba}	*
FSD[2] (ex/l^{-1})	13.7	15.1	12.5	NS
SR[3] (%)	84.15±1.52	92.85±2.28^{bc}	76.92±3.26^{cb}	*
MFW[4] (g/ex)	1.19±0.06^{ac}	1.83±0.05^{bc}	0.87±0.04^{cab}	*
IWG[5] (g)	1.17±0.06^{ac}	1.80±0.05^{bc}	0.85±0.03^{cab}	*
TWG[6] (g)	637.49±19.91^{abc}	1 088.89±0.89^{bca}	423.92±35.44^{cba}	*
SGR[7] (%/day^{-1})	11.91±0.14^{ac}	13.17±0.7^{bc}	10.99±0.12^{cab}	**
DGR[8] (g/day^{-1})	39.64±1.96^{ac}	61.36±1.56^{bc}	28.80±1.19^{cba}	*
FCR[9] (g/g)	0.68±0.05^{ac}	0.48±0.02^{bc}	0.99±0.02^{cba}	**

Values connected by different superscripts are significantly different ($P \leq 0.05$)
***$P \leq 0.001$; **$P \leq 0.01$; *$P \leq 0.05$; NS – non significant;
[1] FB – final biomass
[2] FSD – final stocking density
[3] SR – survival rate
[4] MFW – mean final fish weight
[5] IWG – individual weight gain
[6] TWG – total weight gain
[7] SGR – specific growth rate
[8] DGR – daily growth rate
[9] FCR – feed conversion ratio

The final biomass is the lowest in Variant C with *Artemia* supplement. The final biomass depends on the average final weight of the fish and the number of survived fish and it correlates to the initial weight gain (IWG). Higher final biomass means higher growth (Placinta et al., 2012), as confirmed by the present experiment. The highest individual growth was recorded in Variant B ($P \leq 0.05$), where the obtained final biomass was also the highest.

Total growth depends on individual growth and the number of survived fish. In the present study, the highest overall gain was reported in Variant B ($P \leq 0.05$). This is correlated to the highest value of individual growth in Variant B. The highest survival rate was achieved in Variant B, with a difference of 15.93% with Variant C ($P \leq 0.05$). The daily growth rate was highest in Variant B and lowest in Variant C ($P \leq 0.05$). The specific growth rate confirmed the daily rate values and was again highest in Variant B and lowest in Variant C ($P \leq 0.01$).

The nutritional coefficient is determined by the amount of feed intake and the total growth. The lower nutritional factor means that the total gain obtained is higher than the amount of the given feed. A feed factor close to 1 means that the value of total growth is equal to the amount of the given feed. In the present study, the nutritional coefficient has the lowest value in Variant B and the highest value in Variant C ($P \leq 0.01$). The lowest nutritional coefficient in Variant B means that the obtained total growth is the highest and the utilization of food is more complete compared to the other variants.

Figure 2 (A, B, C) shows the correlation between the final length and weight of the fish from each food variant. The correlation coefficient is the lowest in Variant C, which means that the larvae have the most heterogeneous biometric parameters (BW, g; TL, cm) compared to the other variants. In general, in all three dietary options, the correlation coefficient was very low, below 0.01, indicating that the fish had heterogeneous sizes (BW, g; TL, cm), something that is highly characteristic for predatory species.

Although there is no research conducted with *S. glanis*, different studies have been carried out with African catfish (*Clarias gariepinus*) regarding the effect of live food and artificial diet supply. Remilekun et al. (2022) used 480 healthy *Clarias gariepinus* fry collected from a commercial hatchery and randomly divided them into four experimental groups of 40 fry with three replicates for each group. The fry were fed with four different feeds (three live feeds and one artificial feed) – Artemia Lush® (AL), Artemia Inve® (AI), Dried-ground Shrimp (S), and artificial feed Durante® (D) for three weeks. The authors state that the final weight, final length, specific growth rate, and survival of fry fed with live feeds Artemia were similar to artificial feed Durante®, but the economic analysis was reduced in artificial feed compared to live feeds while fry fed with Dried-ground Shrimp had poor growth and survival rate.

Ukwe (2018) conducted a feeding trial on *Clarias gariepinus* larvae using two diets: decapsulated *Artemia*, and special formulated feed. After the absorption of yoke,

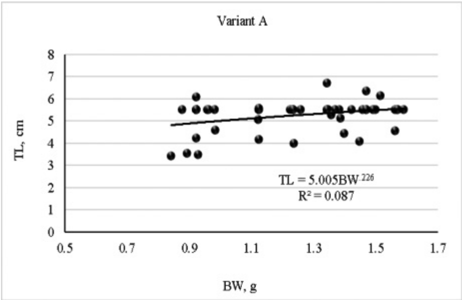

Fig. 2 (A)

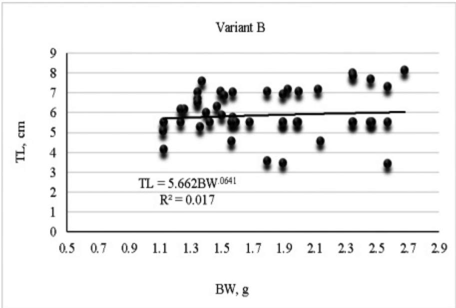

Fig. 2 (B)

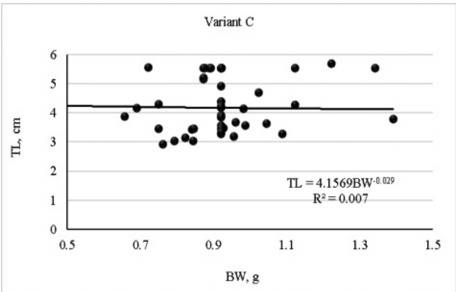

Fig. 2 (C)

the fish larvae were randomly distributed into six plastic tanks at a density of 200 fish per tank. Each treatment which comprised of fish fed with live and artificial feed was carried out in triplicates. Ukwe (2018) states that survival was higher in fish fed with special formulated starter diet than the fish fed *Artemia*. Growth rate, specific growth rate and final weight were higher in fish fed *Artemia*, than the formulated fish feed. The percentage survival was higher in larvae fish fed with special feed than *Artemia*. The author also established that in terms of nutrient utilization between the two feeds, special feed had a better feed conversion ratio of 1.33, while *Artemia* had 1.87. In the current experiment the fish production indicators in Variant C (dry pellets+*Artemia*) were lower compared to Variant A (dry pellets) and Variant B (dry pellets+*Chironomus*).

Faruque et al. (2010) study the effects of different feeding levels on growth performance and survival of *C. gariepinus*. The authors state that fish larvae tend to use *Artemia* more efficiently than artificial food. Faruque et al. (2010) established that the lowest food conversion recorded was 1.88 at feeding level of 0.2 g. The highest fish survival rate recorded was 97.07% with feeding level of 0.25 g which corresponds also to the highest growth rate of fish with fish mortality at feeding levels 0.2 g, 0.3 g, 0.4 g not significantly different.

Musa et al. (2012) study the performance of three dietary feed types: freshwater rotifers with *Artemia nauplii*, freshwater rotifers with fish meal, and freshwater rotifers with maize bran, on the growth performance of African catfish fry reared for 21 days. The authors state that Pearson's correlation showed no relationship (r = 0.1; P >0.05) between growth and water quality parameters, but indicated a strong relationship between survival rate and total length between treatments (r = 0.85; P = 0.02). Treatment A had the highest specific growth rate (SGR) of 6.475% followed by B (5.5320%) and C (4.960%). As in previous studies with African catfish, Musa et al. (2012) also proved that *Artemia* is the best feed for increasing growth of *Clarias gariepinus* which differs from the results established in the current study with European catfish larvae.

Oyero et al. (2009) compare *Artemia* (T1) and liquid-fry (T2) in the rearing of *Clarias gariepinus* fry with initial total length and mean total weight of 7.00 mm and 0.18 g respectively and initial condition factor of 0.052. At the end of the experiment the authors established that the final mean total length for T1 and T2 were 38.67 mm and 25.00 mm respectively while the final mean total weight was 35.25 and 0.63 for T1 and T2 respectively. The authors established that there were significant differences ($p < 0.05$) in the mean total weight and survival rate of T1 and T2 fry and that there was no significant difference ($p > 0.05$) in the mean total length of the two treatments. The Specific Growth Rates (SGR) were 12.56 day^{-1} and 2.98 day^{-1} for T1 and T2 respectively. The final condition factors were 0.061 and 0.004 for T1 and T2 respectively. Based on these findings the authors conclude that *Clarias gariepinus* fry fed on *Artemia* diet had better growth and survival rates.

Unlike the results obtained in the cited experiments above, in the present study the best fish production parameters are obtained in Variant B (dry pellets with frozen *Chironomus* supplement). These results can correlate with the study carried out by Bogut et al. (2017). The authors state that the great quantity of ω-3 fatty acids (15.22%) detected in *Chironomus plumosus* larvae, being significantly higher compared to other animals, represents a rich source of essential fatty acids for fish. It has been established that commonly cultured fish such as rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*) and European catfish (*Silurus glanis*) require between 0.5 and 1.0% HUFAs and polyunsaturated fatty acids (PUFA) (in total lipids) for optimal growth (Takeuchi & Watanabe, 1977; Robinson, 1984; Bogut, 1995; Bogut et al., 2017).

Conclusions

In the present study, the best fish production parameters were registered in Variant B, with individual growth, daily and specific growth, final biomass and survival rate being the highest in Variant B ($P \leq 0.05$). The specific growth rate was the lowest in Variant C ($P \leq 0.01$). The lowest nutrient coefficient in Variant B indicates that the total growth obtained is the highest and the utilization of food is the most complete compared to the other experimental variants.

The obtained results indicate that the most effective nutritional option for rearing *S. glanis* larvae was Variant B with supplement of frozen *Chironomus*.

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