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SHORT COMMUNICATION

Taurine supplement improved growth performance and digestive capacity of pikeperch larvae

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Abstract

Pikeperch (*Sander lucioperca*) intensive aquaculture development has been slowed down by high mortality rates (>70%) during larval rearing. The use of taurine during larval development in other species has been reported to improve survival as well as growth. This trial aims to find out whether supplementation of taurine during the larval stage will benefit pikeperch larval performance and if digestive enzyme production can be promoted. A 21-day trial was carried out, in which taurine live feed enrichment for pikeperch larvae was tested. Overall, growth parameters, such as total length (TL), myomere height (MH) and eye diameter (ED), were significantly higher, whereas survival between treatments remained equal. Specific activities of digestive enzymes in the control group were low compared to the taurine group during the first 7 days post hatching (dph) but reached the peak values for alkaline proteases, lipase and pepsin at 14 dph. Taurine supplementation increased specific pepsin, alkaline proteases and lipase activities in early larval stages where larvae presented enhanced levels of alkaline proteases and pepsin activities at 7 dph, while that of lipase tended to be higher although not significantly. Such enhancement of enzyme activity can improve nutrient availability, which has had a direct effect in improving pikeperch larvae growth and development. However, these differences in digestive activity were compensated at the end of the experimental period (21 dph).

KEYWORDS
digestive enzymes, larval rearing, live feed supplementation, pikeperch, RNA/DNA ratio, taurine

1 | INTRODUCTION

Pikeperch (*Sander lucioperca*) has been selected by several programmes looking for diversification within European aquaculture (Policar et al., 2019). This fresh and brackish water species, commonly found in central, eastern and northern Europe (FAO, 2013), has a high demand and value (Kestemont & Henrotte, 2015). Its high market value and fast growth rate (Blecha et al., 2016; Dalsgaard et al., 2013; Policar et al., 2013; Schäfer, 2016) have boosted its interest in the aquaculture industry. Most of the production for pikeperch comes from wild fisheries, but its production in recirculating aquaculture systems (RAS) is on the rise (FAO, 2013).

Currently, research is focused on improving larval culture since nutritional requirements of juvenile pikeperch are well known (Kestemont et al., 2007; Nyina-wamwiza et al., 2005). In this sense, great progress has been made in improving the efficiency and reducing the high costs of pikeperch culture in RAS as it is widely accepted that the commercial development of this species relies on the optimization of recirculation culture techniques (FAO, 2016; Steffens et al., 1996). In an effort to meet such an objective, the introduction of rotifers during

first feeding has contributed to improved larval quality, survival and growth (Imentai et al., 2019, 2020; Yanes-Roca et al., 2018; Yanes-Roca, Leclercq, et al., 2020; Yanes-Roca, Mráz, et al., 2020).

Traditionally, poor fish larval survival under controlled culture conditions has been difficult to understand, but there are many factors that might be involved including water quality, nutrition, cannibalism, genetic factors and poor egg quality (Holt et al., 2007; Kestemont & Henrotte, 2015). Nutrition plays an important role in larval development due to its influence on growth, survival and the physiological control of such process (Cahu & Infante, 2001; Péres et al., 1998; Yúfera & Darias, 2007).

During the ontogeny of fish larvae, numerous morphologic and functional changes take place in the digestive system before being fully functional (Gisbert et al., 2018; Papadakis et al., 2009, 2013; Pérez et al., 2020; Rønnestad et al., 2013). Over this period, factors, such as feed, water temperature and feeding regime, have a direct effect on the specific activity of the digestive enzymes and their total production (Alarcón et al., 1997; Koven et al., 2019; Pérez et al., 2020). Therefore, adjusting feeding protocols to meet the larval dietary needs during first feeding is key for digestive enzyme development (Alarcón et al., 1997; Campoverde et al., 2017; Teles et al., 2019; Zambonino-Infante et al., 2008).

One amino acid derivative that has the ability to improve digestive enzyme development and that has been tested with several species is taurine (Kim et al., 2005; Li et al., 2009; Martínez et al., 2004; Matsunari et al., 2005; Salze et al., 2011, 2012; Takahashi et al., 2005). Taurine plays many roles in mammals, including lipid's digestion, health, immunity, the formation of bile salts and the regulation of body fluids. It is also important for stabilizing cell membranes and fighting oxidative stress (Bouckenooghe et al., 2006; Huxtable, 1992; Salze & Davis, 2015). Such an amino acid derivative has been successfully supplemented in the diet of several species meeting quantitative requirements for both larvae and broodstock (Salze et al., 2017).

The current state of knowledge on taurine concerns mostly marine carnivorous species; however, evidence shows that several omnivorous and/or freshwater species also benefit from feeds supplemented with taurine (Rotman et al., 2017; Salze et al., 2017). Currently, no work has been carried out on the potential benefits, if any, that taurine supplementation might have on pikeperch larval rearing (Rotman et al., 2017).

The aim of this study is to assess the potential effect of taurine supplementation on pikeperch larvae during the first 21 days post hatching (dph).

2 | MATERIALS AND METHODS

2.1 | Larval rearing

Experimental larvae were obtained from pikeperch broodstock (3 pairs) reared in ponds at the aquaculture facilities from the University of South Bohemia located in Vodňany, Czech Republic. Spawning and fertilization techniques followed protocols by Blecha et al. (2016) and Malinovskyi et al. (2018, 2019). Ninety-five percent of hatching took place after 7 days from fertilization at a water temperature of 17 ± 0.2°C and under a 15:9 L:D photoperiod in one 400-litre tank connected to an RAS. After 3 dph, one hundred larvae per litre were stocked in the experimental rearing tanks (6-litre cuboidal tanks, four tanks per group) which were part of RAS. Rearing conditions were set at 17 ± 0.4°C, salinity of 4 ± 0.4 ppt and following the same photoperiod as the incubation period (15:9) and at a light intensity of 300 LUX. Dissolved oxygen was kept over 7.0 mg/L. Ammonia, nitrite and nitrate levels were monitored every 3 days and were kept within the following range respectively (NH_3 = 0.19 ± 0.05, NO_2 = 0.02 ± 0.01, NO_3 = 0.09 ± 0.02 mg/L). Daily cleaning and maintenance were done in order to keep clean conditions within the experimental tanks.

Two groups were tested. The control Group A, where larvae for the first 11 days (15 dph) were fed rotifers (*Brachionus plicatilis*, ≃280 μm) fed with *Nannochloropsis oculata* (Nanno 3600, Reed Mariculture) and unenriched *Artemia* nauplii (Micro *Artemia* cysts, Ocean Nutrition^{tm}) until day 21 post hatching. Larvae from Group B were fed the same live feed and followed the same feeding regime as Group A, with the only difference that live feed was enriched with taurine (2-aminoethanesulphonic acid, Sigma-Aldrich).

Live feed was supplied three times per day from the end of the endogenous feeding (4 dph) until 21 dph. Rotifers and *Artemia* from Group B were enriched with only taurine through the addition of 1 g of powered taurine per litre to 15-L enrichment tanks in which rotifers and *Artemia* were placed for 14 h and held at 15°C prior to feeding. Non-enriched live feed was exposed to the process but without taurine (blank treatment). Rotifers and *Artemia* densities at both enrichment and blank tanks were 500 and 250 individuals per ml respectively. *Artemia* nauplii's average size was 430 μm.

Daily feeding amounts were calculated after residual counts from the day before. Detailed description from the feeding regime and system water flows are displayed in Table 1. Prior to each feeding, flow was stopped and re-started 2 h after, to improve larval feeding efficiency.

2.2 | Sampling procedure

Throughout the experimental period, pooled samples of one hundred 4 dph larvae (initial) and 21 dph were sampled. At day 7 and 14, another two sets of 40 larvae (10 per tank) were collected. Growth parameters (total length [TL], myomere height [MH] and eye diameter [ED]) were measured to the nearest mm and recorded (Olympus BX41 connected to a Canon-72 digital camera and Olympus cellSens imaging software, version 1.3 [Tokyo, Japan]).

For the study of digestive enzyme activities, larvae were taken from each experimental tank (4 tanks per treatment) and pooled

TABLE 1 Pikeperch larval daily feeding regime (Dph, Days post hatching) and flow rates for 18 days. Daily feed (rotifers-*artemia*/ml) shows the density of rotifers and/or artemia fed at each day per ml

Dph	Daily feed: Rots-*art*/ml	Flow (ml/min)
3	No feeding	100
4	10–0	100
5	10–0	100
6	10–0	100
7	10–0	100
8	14–0	160
9	14–0	160
10	14–0	160
11	14–0	160
12	14–2	200
13	10–3	200
14	8–4	200
15	0–7	250
16	0–7	250
17	0–8	250
18	0–8	250
19	0–8	250
20	0–8	250
21	End of trial	250

according to their age and at different ontogenic periods: one hundred 4 dph larvae (25 per tank), twenty 7 dph larvae (5 per tank), twenty 14 dph larvae (5 per tank), and four 21 dph larvae (1 per tank). After collection, larvae were shock frozen and immediately stored at −80°C until analysis.

In addition, 36 larvae per treatment (9 pooled larvae per replicate) were collected for RNA–DNA ratio analysis and fixed in RNAlater®.

2.3 | Digestive enzyme activities

Pancreatic (α-amylase, bile salt-activated lipase, total alkaline proteases) and gastric (pepsin) enzyme activities were determined according to Solovyev and Gisbert (2016) in order to prevent sample deterioration. Pooled samples of whole-body pikeperch larvae at 4, 7 and 14 dph, and free of heads and tails at 21 dph, were homogenized in quadruplicate by using an Ultra-Turrax T8 (IKA©-Werke) in 10 volumes (v/w) of ice-cold Milli-Q water and centrifuged at 3300×*g* for 3 min at 4°C. Finally, 1-ml aliquots of supernatant were kept at −80°C until their analysis for enzyme quantification.

Alkaline protease activity was determined following García-Carreño and Haard (1993) using azocasein as substrate. After centrifugation, absorbance of the supernatant was read at 366 nm. One unit of activity was defined as 1 μmol of azo dye released per min and per ml.

Using 0.3% soluble starch as substrate, alpha-amylase (E.C. 3.2.1.1) activity was quantified (Métais & Bieth, 1968). The absorbance was measured at 580 nm. Alpha-amylase activity was defined as the mg of starch hydrolysed at 37°C per 30 min per ml.

Bile salt-activated lipase (BAL, E.C. 3.1.1) activity was determined by incubation with *p*-nitrophenyl myristate, and the increase in absorbance of the supernatant determined at 405 nm (Iijima et al., 1998). BAL activity corresponded to the μmol of myristate hydrolysed per min per ml.

Finally, pepsin (E.C. 3.4.23.1) activity was measured by incubating the extracts with 2% haemoglobin solution. The absorbance of the supernatant was read at 280 nm (Worthington Biochemical Corporation, 1972). One unit of activity was defined as the μmol of tyrosine released per min per ml.

Soluble protein of extracts was quantified as described by Bradford (1976), using bovine serum albumin as the standard. Absorbance was read using a spectrophotometer (Beckman Coulter DU800, Fullerton, CA). All the enzymatic assays were made in quadruplicate from each pool of larvae, and specific activity expressed as U/mg protein.

2.4 | RNA/DNA ratio

The All-Prep RNA/DNA Mini Kit (Qiagen) was used to extract the DNA and RNA from seven larvae per group. Assessment of concentrations, quality and purity (260/280 and 260/230 ratios) of DNA and RNA was done using NanoDrop™ (ND-ONE-W, ThermoFisher Scientific).

2.5 | Statistical analysis

Statistical analyses were conducted in R Statistical software (V2.1.2; R Development Core Team, 2014) and statistical significance was set at $\alpha = 0.05$.

Linear mixed models (LMM, package *lme4*, version 1.1–7; [Bates et al., 2014]) were run to analysed morphometric data, enzymatic activity variability and concentration between the two treatments (at 7, 14 and 21 dph). With regard to treatment effect evaluation, response variables (TL, MH, ED and tank) were incorporated as random effect. Power estimate for the response variables were done by Box-Cox transformations (package *car*, version 2.1.2; [Fox & Weisberg, 2011]).

Tukey's all-pair comparisons with a Bonferroni correction to adjust the *p*-values were applied to run multiple pairwise comparisons package *multcomp*, version 1.3–3 (Hothorn et al., 2008).

Generalized Linear Mixed Model (GLMM) was applied to compare the groups' treatment effect on survival (alive fish after 21 days as the response variable). Treatment was the fixed effect and tank as random, all under a binomial error structure. Tukey's all-pair comparison test with a Bonferroni correction was applied after the GLMM.

RNA/DNA ratios were analysed using Box-Cox transformations and compared using a LMM, where treatment was the random effect. Pairwise comparisons were done using Tukey's all pair test and corrected by running Bonferroni to adjust *p*-values.

This trial was part of project # NAZVQK1710310 and was run following the national animal protection welfare guidelines (Animal Cruelty, No. 246/1992 and EU-harmonized Animal Welfare Act of the Czech Republic; Licence # 2293/2015-MZE-17214 and No. 55187/2016-MZE-17214).

3 | RESULTS

3.1 | Larval growth and survival

Initial pikeperch larval TL at 4 dph was 5.18 ± 0.50 mm. After 7 and 14 days, larvae from the taurine treatment (B) (Figure 1) were significantly larger in terms of TL (5.58 ± 0.51 mm; 8.12 ± 0.41 mm), MH (0.68 ± 0.06 mm; 1.42 ± 0.11 mm) and ED (0.37 ± 0.05 mm; 0.53 ± 0.05 mm) ($p < 0.05$). By the end of the trial (21 dph), average

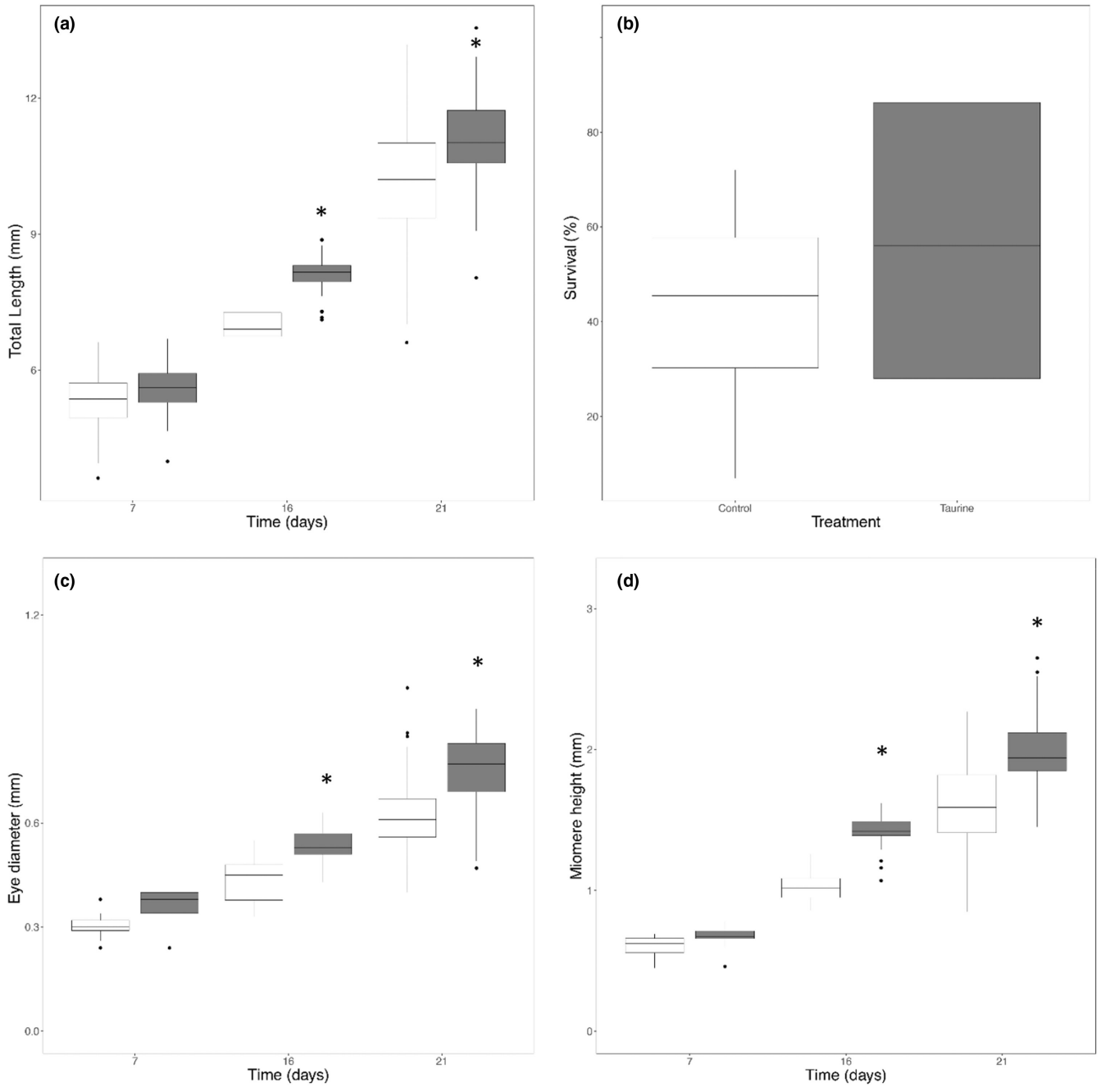

FIGURE 1 Growth parameters (Total length[a], survival[b] and eye diameter[c] myomere height) differences from pikeperch larvae between treatments (control and taurine) at days 7, 16 and 21 post hatching (dph). Treatment larval average survival[d] percentage after 21 days post hatching (control and taurine). Statistically significant differences ($p < 0.05$) between treatments are marked with an asterisk.

TL was significantly greater ($p < 0.05$) in the taurine treatment (B) (11.10 ± 1.00 mm) than in the control one (A) (Figure 1), as well as MH (1.98 ± 0.22 mm) and ED (0.75 ± 0.10 mm).

Survival rates did not significantly vary between treatments ($p > 0.05$), although larvae provided with taurine (B) tended to present higher survival (61%) than those fed without taurine (57%) (Figure 1).

3.2 | Digestive enzymes

In the control fish, both alkaline proteases and bile salt-activated lipase (BAL)-specific activities fluctuated similarly throughout larval development. Thus, a high level of activity from both enzymes was registered at 4 dph (7.43 ± 1.25 and 5.80 ± 2.45 mU/mg protein respectively), followed by a tendency to decrease at 7 dph, and a later peak of activity at 14 dph (18.09 ± 0.01 and 9.06 ± 1.47 mU/mg protein respectively) which slightly tended to decrease to the initial values at the end of the experimental period (Table 2).

The activity of α-amylase tended to increase slightly at 7–14 dph compared to the initial value (0.90 ± 0.48 U/mg protein), reaching its maximum of activity at 21 dph (1.89 ± 0.41 U/mg protein) (Table 2). Pepsin activity was firstly detected at the onset of exogenous feeding (4 dph), and tended to increase with larval age, being two-fold higher at 14 dph than at 7 dph in control larvae (2.24 ± 0.65 vs. 1.07 ± 0.10 mU/mg protein respectively). The limited sample quantity prevented the determination of pepsin activity at 14 dph in the taurine group, and at 21 dph in the control group.

Alkaline proteases and pepsin activities were higher at 7 dph in taurine-enriched larvae compared to the control fish (14.68 ± 4.67 vs. 2.13 ± 0.83, and 3.75 ± 1.00 vs. 1.07 ± 0.10 mU/mg protein respectively; $p < 0.05$) (Table 2). Additionally, both α-amylase and BAL also tended to present higher levels of activity in larvae receiving taurine at 7 and 14 dph, although these differences were not statistically significant. It is remarkable that lipase activity was two-fold higher in taurine-enriched larvae at 14 dph than at 7 dph (12.58 ± 2.83 and 6.11 ± 1.88 mU/mg protein respectively; $p < 0.05$).

3.3 | RNA/DNA ratio

The RNA/DNA ratio analysis showed significant differences (LMM, $p < 0.05$) between treatments, yet a clear pattern was observed where taurine-enriched larvae (B) had a 1.75-time higher RNA/DNA ratio than the Group A respectively. Group B showed the highest variability of RNA/DNA ratios (Figure 2).

4 | DISCUSSION

Pikeperch larvae did significantly improve in TL, MH and ED, when supplemented with taurine, such results matched recent findings from Salze et al. (2011, 2012) in cobia. The overall average larval survival was 60% after 21 days of experiment, with no significant differences found among treatments. In contrast, treatment B had the highest growth parameters. Such differences could lie on the positive effects that supplementation of taurine had on the development of digestive enzymes (protease and pepsin at day 7), and consequently, on feed conversion efficiency and growth (Chatzifotis et al., 2008; Enterria et al., 2011; Kim et al., 2003) matching most conclusions reached by other studies (Lunger et al., 2007) in which taurine deficiency stunts growth and increases mortality (Salze & Davis, 2015).

As reported by several recent studies (Imentai et al., 2019; Yanes-Roca et al., 2018; Yanes-Roca, Leclercq, et al., 2020), pikeperch is a species that has a high dependence on rotifers and may have a high susceptibility for taurine deficiency since rotifers have very low taurine concentrations when compared to *Artemia* and copepods, as described in California yellow tail (*Seriola lalandi*) (Hawkyard et al., 2014, 2015, 2016).

Although the ontogenetic development of the digestive system follows a similar pattern in fish, some inter-specific differences linked to their phylogenetic position and reproductive strategies (Kumar et al., 2019) or even intra-specific variations related to nutritional and environmental rearing conditions (Pérez et al., 2020; Zambonino-Infante & Cahu, 1994) have been described. During the first stages of larval development, the growth and survival of fish larvae is greatly dependent upon their successful feeding which

TABLE 2 Specific activity (U/mg protein for α-amylase and mU/mg protein for alkaline proteases, lipase and pepsin) of digestive enzymes of 4, 7, 14 and 21 dph pikeperch larvae with or without taurine enrichment (control, TAU)

	4 dph	7 dph		14 dph		21 dph	
	Control	Control	TAU	Control	TAU	Control	TAU
Alkaline proteases	7.43 ± 1.25^{xy}	2.13 ± 0.83^{x}	14.68 ± 4.67*	18.09 ± 0.01^{y}	11.78 ± 7.22	12.78 ± 8.21^{xy}	15.23 ± 2.84
α-amylase	0.90 ± 0.48^{x}	1.29 ± 0.21^{xy}	1.75 ± 0.43	1.20 ± 0.20^{xy}	2.14 ± 1.04	1.89 ± 0.41^{y}	1.86 ± 0.43
Lipase	5.80 ± 2.45^{xy}	3.95 ± 1.48^{x}	6.11 ± 1.88^{x}	9.06 ± 1.47^{y}	12.58 ± 2.83^{y}	5.39 ± 1.89^{xy}	7.12 ± 2.75^{xy}
Pepsin	1.37 ± 1.04	1.07 ± 0.10	3.75 ± 1.00*	2.24 ± 0.65	–	–	5.87

Note: Results are presented as means ± SD ($n = 4$) except for pepsin in TAU-21dph, where $n = 1$. ^{x,y} indicate significant differences between larval ages for the same digestive enzyme and dietary treatment ($p < 0.05$). * indicate significant differences with control for the same digestive enzyme and larval age ($p < 0.05$).

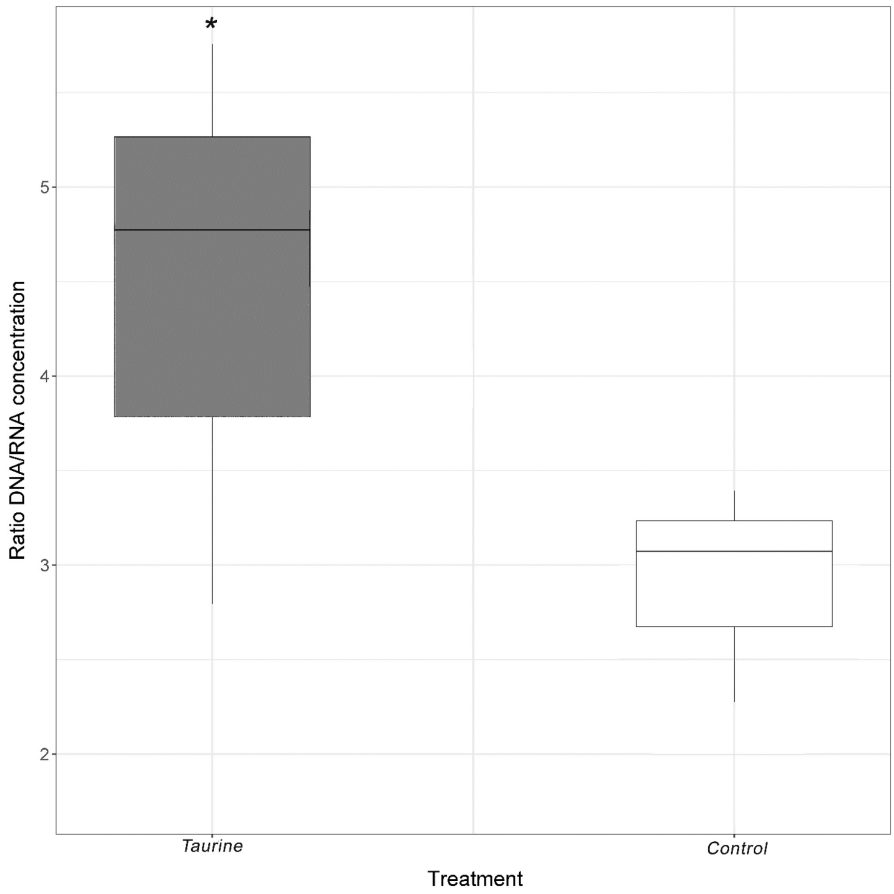

FIGURE 2 Larval RNA/DNA ratio from two treatments (21 dph), whiskers indicate the maximum and minimum values excluding out layers, the line in the middle of box is the median value and upper and lower quartiles are the ends of the box. Statistically significant differences between treatments are marked with an asterisk.

is directly related to the ontogeny of digestive enzymes (O'Brien-MacDonald et al., 2006). In this type of studies, changes in the time of first appearance of digestive enzyme activities, variations throughout development and differences among detection techniques are frequently reported (Teles et al., 2019). At the end of endogenous feeding and the shift to exogenous input, the digestive capacity of fish larvae depends on the production of digestive enzymes by the exocrine pancreas. In the present study, all major pancreatic enzymes involved in the hydrolysis of the main nutrients, alkaline proteases, bile-salt activated lipase and α-amylase, were already detected at the onset of exogenous feeding (4 dph), probably related with the fact that pancreas starts its differentiation at this age. The activity of pancreatic enzymes tended to increase with larval development in parallel to the morphogenesis of the exocrine pancreas (Pérez et al., 2020; Rønnestad et al., 2013). In particular, the main pancreatic alkaline proteolytic enzymes, especially trypsin and chymotrypsin, are particularly relevant in the early life stages of fish larvae before the development of a functional stomach, due to the absence of pepsin secretion, the acid protease (Rønnestad et al., 2013). In our work, alkaline proteases activity tended to decrease in 21 dph pikeperch larvae, possibly coinciding with increasing stomach functionality and acid digestion. However, pepsin activity was already detected at 4 dph, although to a very reduced level, in theory related to the appearance of gastric glands. This result contrasts with the morphological feature described by Ostaszewska et al. (2005) who reported that gastric glands in pikeperch larvae had not been yet formed at this age, appearing about 15–20 dph. Thus, the activity registered might not be gastric pepsin but rather some other acid pepsin-like protease enzymes present in the body, such as cathepsins, which are aspartic lysosomal proteolytic enzymes (Martínez-Lagos et al., 2014).

The high activity of α-amylase detected in pikeperch larvae at the onset of exogenous feeding, matches Cahu et al.'s (2004) results in sea bass and suggest that dietary carbohydrates may fill the energy gap between endogenous and exogenous protein requirements in larvae as proposed by Tanaka (1973). In addition, the relatively high carbohydrate content of live preys used for feeding larvae might stimulate α-amylase activity as previously stated by Ma et al. (2005). The BAL pike of activity observed at 14 dph might be associated with the transition from rotifer to *Artemia* nauplii, the latter containing higher lipid contents, as previously reported in certain marine carnivorous teleosts like greater amberjack (*Seriola dumerili*), yellowtail amberjack (*S. lalandi*) and meagre (*Argyrosomus regius*) (Pérez et al., 2020; Solovyev & Gisbert, 2016; Teles et al., 2019).

The present study suggests a possible improvement in the functional development of the digestive system in taurine-enriched pikeperch larvae around the first 10 days of development based on the significantly higher alkaline proteases and pepsin activities at 7 dph as well as by a trend to present higher lipase and α-amylase activities. Such results might be explained by the positive effects that taurine has on increasing the enzyme activities

of the digestive system, improving prey digestibility and nutrient availability (Espe et al., 2012; Qi et al., 2012; Salze et al., 2012; Salze et al., 2017; Salze & Davis, 2015; Yun et al., 2012). Therefore, better decomposition of dietary macronutrients, such as carbohydrate, lipids and proteins, better feed utilization, nutrient absorption and larval performance takes place (Abdel-Tawwab & Monier, 2017; Salze et al., 2012; Yan et al., 2019). However, in our study this effect was only seen during the first 2 weeks after hatching which also matches the previous result reported by Salze et al. (2012), probably related to the normal increase in tissue proteins in rapid-growing larval tissues (Hamza et al., 2016; Pérez et al., 2020). Hence, we hypothesize here an enhancement of the digestive system maturation in pikeperch larvae fed taurine at least during the first 2 weeks of life.

Due to the carnivorous nature of pikeperch and the results obtained during this study, we can hypothesize that the digestive capacity of the pikeperch larvae has been enhanced followed by the increase in enzyme activity. That hypothesis is confirmed by the higher activity of pancreatic enzymes responsible for nutrient hydrolysis, prior to a fully functional stomach. At the same time, pepsin activity at 7 dph has been significantly increased, improving digestibility at an earlier stage. The direct results of such an improvement can be observed as the significant differences in growth across all documented parameters, which are also supported by RNA/DNA analysis results.

The observed results show that pikeperch larvae does not seem to autoregulate and biosynthesize taurine unlike other carnivorous freshwater species. Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) have been reported to have such ability mostly by regulating taurine homeostatically and biosynthesizing taurine from methionine or cysteine (Boonyoung et al., 2012; Espe et al., 2012; Page, 1978; Yokoyama & Nakazoe, 1992). Yet, a number of recent studies (Gaylord et al., 2006, 2007) indicated that freshwater fish may require exogenous taurine for optimum growth performance, feed consumption, digestion and assimilation and other physiological functions at the beginning of the exogenous feeding. This requirement depends on fish species, size and feed composition. Therefore, even though pikeperch larvae require taurine supplementation, adult pikeperch might not require such supplementation as it might acquire the biosynthesis capabilities mentioned above to obtain taurine through the trans-sulphuration of dietary methionine or cysteine. Our results show a significant effect of dietary taurine on activities of digestive enzymes, yet the precise mechanisms modulating the actions of taurine remain to be elucidated in pikeperch. Just like human liver cells (Park et al., 2006), fish might have a similar mechanism where taurine is a signalling molecule and signify nutrient wealth, thus accelerating growth and development as that observed in the present trial. Alternatively, another possibility resides in the potential role of taurine in meeting the high energetic demands of developing organisms. Further research will be needed to unveil such specific mechanisms. The novelty of the results does not rely so much on the well-known effects of taurine over some fish species but rather on the effect that has over a freshwater species such pikeperch and the improvements in growth during a critical developing stage.

5 | CONCLUSIONS

The digestive enzyme activities studied showed a general enhancement trend in 7 dph pikeperch larvae by the addition of taurine. At the same time, an improvement on growth has been observed and confirmed by RNA/DNA ratio as well as other morphometric measurements. Rotifers and *Artemia* enriched with taurine are supplying the larvae with what seems to be more adequate taurine levels than in the control treatment. Future work is necessary to establish pikeperch taurine base requirements, and to optimize standard dosage.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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