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Growth performance, body and fatty acid composition of cultured and wild-derived pikeperch, *Sander lucioperca* (Linnaeus, 1785) fed different live feed

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ABSTRACT

The effects of feeding with different types of live feed on growth performance, proximate body composition and fatty acid profile of juvenile pikeperch, *Sander lucioperca* derived from cultured (C) or wild (W) broodstocks were studied. Fish in two groups with an initial body weight of 3.76 ± 0.01 g were fed with three diets *ad libitum*, including CH: frozen larvae of *Chironomus* sp., A: frozen *Artemia* (*Artemia franciscana*) biomass and M: a combination of CH (50%) and A (50%) in triplicates. After ten days, growth indices, body composition and fatty acid profile were compared among different groups. The results showed that final weight, weight gain and specific growth rate in the wild-origin groups fed CH and M were significantly lower than the cultured-origin group fed CH ($p < 0.05$). Addittionally, the survival rate of juveniles from cultured broodstock, which fed with *Artemia* was significantly lower compared to the other groups ($p < 0.05$). No significant difference was observed in body composition of pikeperch from different origins ($p > 0.05$), and feeding with different diets significantly affected n-6 polyunsaturated fatty acids, n-6/n-3 or the ratio of alpha-linolenic acid/linoleic acid in pikeperch fatty acid composition ($p < 0.05$). In conclusion, the cultured pikeperch showed higher growth performance than wild-derived fish, and using *Chironomus* alone or in combination with *Artemia* is recommended during the initial adaptation of cultured pikeperch.

Keywords: Adaptation, Fatty acid profile, Feeding strategies, Live feed, Pikeperch.
Article type: Research Article.

INTRODUCTION

Aquaculture trend has been focusing on the development and rehabilitation of endemic fish due to their high adaptation capacity to environmental conditions, ability to survive and grow, and conserve genome-wide genetic variation in the populations (Bourret *et al.* 2013). Pikeperch, *Sander lucioperca* originated from Eastern Europe, has great importance in the ecological cycle and aquaculture economics, as well as the delicate and favorable quality of flesh, satisfactory growth, and high potential for rearing in intensive and super-intensive culture systems (Kestemont & Mélard 2000; Falahatkar *et al.* 2018). In recent years, many aspects including broodstock propagation, larval rearing, feeding behavior, growth under captivity, and the selection process have been extensively studied to develop technologies for pikeperch culture (Baekelandt *et al.* 2018; Milla *et al.* 2021; Falahatkar *et al.* 2022, 2024). However, little is known about the nutritional requirements of this species, particularly between cultured and wild pikeperch stocks, which is very important for developing the culture industry. Domestication refers to the transformation of physiological and developmental features, during

adaptation to human-made conditions. Through the domestication process, morphology, technological yields and nutritional values are altered (Neira *et al*. 2004; Teletchea & Fontaine 2014), causing heritable differences between wild and cultured populations (Teletchea & Fontaine 2014). Since wild fish are introduced to captivity, they expose severe alternations, which may induce changes in physiological and behavioral responses. Thus, providing biological and rearing conditions consistent with optimal species requirements at all husbandry levels (breeding, hatchery and grow-out production) is one of the important goals of a successful selection program that may ensure final product quality (Milla *et al*. 2021). Furthermore, survival in captivity depends on how fish learn to adapt to culture conditions including feeding on new diets (Brown & Laland 2001). Different diets and feeding techniques seem to impact flesh quality and growth of wild and cultured fish (Johnston *et al*. 2006; Lenas *et al*. 2012). Therefore, it is worth to study the innovative feeding approaches for developing fish growth performance and survivability. In aquaculture, one of the crucial parts of pikeperch life history is weaning to compound feed through a transitional approach, often using natural food organisms. However, the total production of pikeperch worldwide fluctuates, and studies on the weaning of this species have shown poor results in terms of survival and growth, usually due to a lack of technical knowledge about choosing the suitable time and dietary regime for feeding initiation, differences in size and cannibalism (Policar *et al*. 2013; Hamza *et al*. 2015). The best method for transition of pikeperch to dry diet is using live food organisms such as rotifer, *Daphnia*, *Artemia* and chironomid, because in the early life stages, pikeperch is unable to excrete enzymes to digest dry feed and the autolysis induced by these live feeds combined with their high nutritional values may help enhance digestion and growth performance (Hamza *et al*. 2015; Javid Rahmdel & Falahatkar 2021). However, some issues including lower accessibility to main organisms and related production facilities or lack of important micro and macronutrients may restrict the application of live feeds during initial adaptation (Kestemont & Mélard 2000; Hamidoghli *et al*. 2014). According to the observations, using live food organisms in different feeding strategies can influence the adaptation to artificial diets and improve growth performance and survival rate in pikeperch and compensate for deficiencies (Kestemont *et al*. 1996; Horváth *et al*. 2013; Policar *et al*. 2013). Evidence compiled by Hubenova *et al*. (2015) showed that weaning success in pikeperch varies widely across larval age (days post-hatch), primary live feed used, weaning diet composition, and duration of transition. Ljunggren *et al*. (2003) demonstrated that pikeperch could be weaned with low mortality using marine commercial diets following natural zooplankton feeding. Studies employing pond zooplankton as the initial live feed commonly transitioned to mixed frozen chironomid and dry diets, achieving moderate mortality (18-46%) depending on weaning duration and feed combination (Baránek *et al*. 2007; Policar *et al.* 2013; Hubenova *et al.* 2015). Use of chironomid larvae directly as the weaning feed yielded relatively low mortality (13.3%), suggesting high acceptance and digestibility (Bódis *et al.* 2007). Novel strategies such as reshaped artificial bloodworm pellets flavored with chironomid extract have also been tested as sensory bridges to dry diets (Horváth *et al.* 2013). Overall, the comparative data indicated that gradual transitions, mixed feeding with natural or frozen invertebrates, could improve acceptance of formulated diets and reduce mortality in pikeperch. However, despite the progress made in defining effective weaning protocols, there remains a lack of knowledge regarding how fish from different origins (wild-derived versus cultured) respond to distinct live feed transition strategies. Selection programs in pikeperch, along with innovative techniques in intensive systems, are progressing and can lead to different characteristics that are crucial for improving adaptation to varying dietary regimes. Hence, it is essential to evaluate the effectiveness of new live feeds and the associated physiological responses, body composition, and behavioral patterns in pikeperch from both wild and cultured origins. To clarify the different responses and determine appropriate feeding strategies in transition stage, this study investigated performance of live feed regimes in juvenile pikeperch from wild and cultured-derived broodstock.

MATERIALS and METHODS

Ethics statement

The study was carried out following the recommendations in the ARRIVE guidelines for Reporting Animal Research and approved by the University of Guilan, Vice Presidency for Research and Technology (101708/P15).

Fish origin and feeding trials

Juvenile pikeperch used in the study were prepared from wild (W, Aras dam, Iran) and cultured (C, reared at National Center for Stock Enhancement and Conservation of the Caspian Sea Sturgeons and Perch Genetic Resources, , Siahkal, Iran) broodstock. In June 2021, fish (n = 2400) with an initial mean weight of 3.76 ± 0.01 g

and mean length 8.61 ± 0.22 cm were randomly assigned to 12 circular concrete tanks (180 cm diameter, 32 cm depth, 830 L volume) in three replicates. Fish were kept in an outdoor flow-through system supplied by filtered river water (8.80 ± 1.13 L min^{-1}). Stocks of frozen bloodworm larvae (*Chironomus* sp., protein content: 48.50%, lipid content: 10.90%) and frozen *Artemia* (*Artemia franciscana*, protein content: 52.30%, lipid content: 10.60%) biomass were purchased from Guar Kavir Aria Agro-Industrial Company (Iran Artemia, Tehran, Iran). After fish adaptation to the experimental tanks, both wild and cultured fish were fed *ad libitum* (16% biomass/day) using three live feed regimes: CH: frozen larvae of bloodworm, A: frozen *Artemia* biomass and M: a combination of CH (50%) and A (50) for ten days. Feeding was performed from 8:00 to 20:00 every 1.5 h (8 times per day; Policar *et al*. 2013), and the light regime was 16L:8D. Twenty five percent of the water volume of each tank was siphoned every morning to remove uneaten feeds and wastes. Dead fish were daily removed and counted in each replicate. Water parameters (temperature = 26.60 ± 0.48 °C, dissolved oxygen = 7.20 ± 0.18 mg L^{-1}, and pH = 7.50 ± 0.25) were routinely recorded throughout the 10-day experiment.

Growth and survival rate

At the end of the feeding experiment, fish were starved for 24 h, and growth indices such as initial (W_i) and final weight (W_f), weight gain (WG), specific growth rate (SGR), condition factor (CF), body weight increase (BWI), and survival rate (SR) were assessed using the following formulas (Hubenova *et al*. 2015):

$WG = W_f - W_i$

$SGR\ (\%\ day^{-1}) = 100 \times [Ln\ W_f\ (g) - Ln\ W_i\ (g) / t\ (days)]$

$CF = 100 \times (W_f / L_f^3)$

$BWI\ (\%) = [WG\ (g) / W_i\ (g)] \times 100$

SR (%) = [(Number of fish at the beginning/ Number of fish at the end) / Number of fish at the beginning] × 100

Proximate body composition

After starving for 24 h, ten fish were randomly sampled and euthanized by a high dose of clove powder extract (250 mg L^{-1}; Faeed *et al.* 2025). Then, the fish whole body was immediately frozen at -20 °C for chemical analyses. Moisture content was determined by drying each sample in an oven at 105 °C until a constant weight was obtained. Crude protein and fat contents were measured by the Kjeldahl and the Soxhlet extraction methods, respectively. Ash content was determined in a muffle furnace at 550 °C for 8 h (AOAC 2012).

Fatty acid profile

Samples of pikeperch whole body were taken at the end of 10 days from all replicates and immediately stored at −80 °C. For analyzing the total fatty acid composition, lipids were first extracted by the addition of methanol and chloroform [1:1 (v v^{-1})] method, followed by lipid esterification using 2% methanolic sodium and BF3 (boron trifluoride). Subsequently, the fatty acid samples were analyzed using a gas chromatograph (Philips, Sussex, England) equipped with a capillary column of SGE BPX70 (0.25 mm internal diameter × 0.22 µm film thickness × 30 m length). The flame ionization detector operated at a temperature of 300 °C, with the injector set at 250 °C. A volume of 0.2 µL of the ester sample was injected into the gas chromatograph for analysis. The column's initial temperature was set at 160 °C, gradually increased to 230 °C, and maintained at this temperature for 5 min until all the compounds eluted. Helium served as the carrier gas, with hydrogen as the fuel, nitrogen as the auxiliary gas, and synthetic air in this method. The relative amounts of fatty acids in each replicate were expressed as a percentage of the total content (AOCS 1998).

Statistical analysis

Data are presented as mean values ± standard errors and evaluated for normality and homogeneity of variances using the Kolmogorov–Smirnov and Levene's tests, respectively. Two-way analysis of variance (ANOVA) was conducted to analyze the growth indices, survival rate and body composition followed by Tukey HSD test to determine any significant difference. The level of significance chosen for all analyses was $p < 0.05$. The statistical analyses were performed with IBM SPSS software (ver. 22.0, Armonk, USA).

RESULTS

The results of growth parameters are given in Table 1. There was a significant difference in W_f, WG, SGR and BWI among the groups ($p < 0.05$). Moreover, two variables, origin and the interaction of fish origin were observed to be significant in these indices ($p < 0.05$). Final weight, SGR, WG and BWI were significantly lower in the wild-

origin groups fed CH (CHW) and M (MW) than the culture-origin groups fed CH (CHC; $p < 0.05$) and there were no significant differences among the culture-origin groups fed A (AC) and M (MC), and the wild-origin group fed *Artemia* (AW; $p > 0.05$). No significant difference was observed in L_f and CF values with respect to the fish group fed different diets, or between wild and cultured origins ($p > 0.05$). Based on Two-way ANOVA, the diets had a significant effect on survival rate and the lowest amount (70.25 ± 1.25%) was recorded in AC group ($p < 0.05$); however, treatments MW (87.25 ± 4.75%) and AW (78.75 ± 5.75%) had similar insignificant values ($p > 0.05$). The chemical composition of the pikeperch whole body is illustrated in Table 2. According to the results, there was no significant difference among the experimental groups ($p > 0.05$).

Table 1. Growth performance and survival rate of juvenile pikeperch, *Sander lucioperca* after 10 days feeding with different dietary regimes (mean values ± standard errors).

Growth indices	Cultured (C)			Wild (W)			*P* values		
	CH	M	A	CH	M	A	Diet	Origin	Diet × Origin
W_i (g)	3.76 ± 0.00	3.77 ± 0.01	3.76 ± 0.01	3.77 ± 0.01	3.76 ± 0.01	3.76 ± 0.01	0.39	1.00	0.70
W_f (g)	4.40 ± 0.11^{a}	4.17 ± 0.17^{ab}	3.99 ± 0.05^{ab}	3.79 ± 0.01^{b}	3.84 ± 0.04^{b}	4.13 ± 0.13^{ab}	0.67	0.02	0.02
L_i (cm)	8.29 ± 0.08	8.55 ± 0.18	8.74 ± 0.17	8.75 ± 0.14	8.75 ± 0.10	8.60 ± 0.11	0.50	0.15	0.15
L_f (cm)	9.28 ± 0.35	9.48 ± 0.04	9.11 ± 0.04	8.85 ± 0.25	9.51 ± 0.10	9.27 ± 0.20	0.17	0.63	0.36
SGR (% day^{-1})	0.82 ± 0.13^{a}	0.53 ± 0.22^{ab}	0.32 ± 0.07^{ab}	0.03 ± 0.02^{b}	0.11 ± 0.07^{ab}	0.23 ± 0.17^{ab}	0.68	0.02	0.03
WG (g)	0.64 ± 0.11^{a}	0.40 ± 0.17^{a}	0.24 ± 0.08^{ab}	0.02 ± 0.01^{b}	0.08 ± 0.05^{ab}	0.37 ± 0.13^{ab}	0.68	0.02	0.03
CF	0.55 ± 0.07	0.48 ± 0.04	0.53 ± 0.02	0.55 ± 0.05	0.45 ± 0.01	0.52 ± 0.03	0.09	0.49	0.81
BWI (%)	16.89 ± 2.79^{a}	10.63 ± 4.53^{ab}	6.26 ± 1.47^{ab}	0.54 ± 0.27^{b}	2.00 ± 1.20^{ab}	9.86 ± 3.48^{ab}	0.68	0.02	0.03
SR (%)	90.50 ± 3.50^{A}	90.00 ± 0.50^{A}	70.25 ± 1.25^{B}	91.25 ± 0.25	87.25 ± 4.75	78.75 ± 5.75	0.01	0.47	0.31

The significance (Two-way ANOVA, $p < 0.05$) was determined according to the effects of different diet (A/CH/M), origin (C/W) and their interaction (Diet × Origin). Superscript uppercases (A, B, C) indicate significant differences among diets within cultured groups ($p < 0.05$). Superscript lowercases show significant Diet × Origin interaction among the treatments ($p < 0.05$). W_i: Initial weight; W_f: Final weight; L_i: Initial length; L_f: Final length; WG: Weight gain; BWI: Body weight increase; CF: Condition factor; SGR: Specific growth rate; SR: Survival rate. CH: Chironomid; M: Mixture of *Artemia* + Chironomid; A: *Artemia.*

The fatty acid composition of whole body in cultured and wild derived pikeperch is shown in Table 3. As shown, no significant differences was detected among the groups in C14:0, C14:1, C15:0, C15:1, C16:0, C16:1, C17:0, C18:0, C18:1(n-9), C20:1, C20:2, C20:3, C20:3 n-9, C20:4 n-6, arachidonic acid (ARA C20:4 n-3), eicosapentaenoic acid (C20:5 n-3 EPA), C22:0, C22:1, docosatetraenoate (C22:4 n-6, DTA), total saturated fatty acid (SFA), total monounsaturated fatty acids (MUFA), total highly unsaturated fatty acid (HUFA) and total n-3 polyunsaturated fatty acid (n-3 PUFA) values ($p > 0.05$). In contrast, diet type had a significant effect on other fatty acids ($p < 0.05$). Additionally, C18:3 n-6 and C24:0 contents were significantly influenced by diet, origin and the interaction between them ($p < 0.05$). Accordingly, C17:1, C18:3 n-6 and C18:1(n-11) values were significantly lower in CHC and AC than the other groups ($p < 0.05$) and did not have significant difference with each other ($p > 0.05$). C18:2(n-6) values were significantly higher in CHW, CHC, MW, and MC than AC and AW. Moreover, C24:0 values were significantly higher in MC than in the other groups ($p < 0.05$). Total n-6 PUFA value was significantly lower in A than M in both origins ($p < 0.05$). Docosahexaenoic acid/eicosapentaenoic acid (DHA/EPA) ratio was significantly lower in the AC than in CHC group ($p < 0.05$). Furthermore, alpha-linolenic acid/linoleic acid (ALA/LA) ratio was significantly higher in AC than in CHC and CHW ($p < 0.05$).

Table 2. Body composition of juvenile pikeperch, Sander lucioperca after 10 days feeding by different dietary regimes (mean values ± standard errors).

Chemical composition (%)	Before experiments	Cultured (C)			Wild (W)			*P* values		
	W	C	CH	M	A	CH	M	A	Diet	Origin	Diet × Origin
Protein	14.53 ± 1.03	13.10 ± 0.04	15.98 ± 0.28	14.90 ± 0.16	14.88 ± 1.14	14.49 ± 0.51	15.64 ± 0.11	14.90 ± 0.45	0.13	0.70	0.17
Lipid	2.57 ± 1.16	1.99 ± 1.28	2.71 ± 0.71	3.70 ± 0.83	4.45 ± 0.62	2.85 ± 0.38	3.37 ± 0.45	3.89 ± 0.60	0.15	0.91	0.74
Ash	5.16 ± 0.26	4.67 ± 0.04	4.80 ± 0.08	4.65 ± 0.19	4.91 ± 0.03	4.94 ± 0.01	5.18 ± 0.09	4.97 ± 0.37	0.98	0.38	0.48
Moisture	77.82 ± 0.52	78.87 ± 0.65	75.22 ± 2.70	77.99 ± 0.44	76.73 ± 0.99	78.16 ± 0.22	76.41 ± 0.42	76.85 ± 0.59	0.46	0.90	0.25
Dry matter	22.19 ± 0.51	21.13 ± 0.65	24.78 ± 2.70	22.01 ± 0.44	23.28 ± 0.99	21.84 ± 0.22	23.60 ± 0.42	23.16 ± 0.60	0.46	0.90	0.25

CH: Chironomid; M: Mixture of Artemia + Chironomid; A: Artemia; The significance (Two-way ANOVA, $p < 0.05$) was determined according to the effects of different diet (A/CH/M), origin (C/W) and their interaction (Diet × Origin).

Table 3. Fatty acid profile of juvenile pikeperch, *Sander lucioperca* after 10 days feeding by different dietary regimes (mean values ± standard errors).

Fatty acids	Cultured (C)			Wild (W)			*P* values		
	CH	M	A	CH	M	A	Diet	Origin	Diet × Origin
C14:0	1.41 ± 0.01	1.75 ± 0.27	2.38 ± 0.28	1.62 ± 0.08	2.28 ± 0.38	1.82 ± 0.21	0.09	0.75	0.13
C14:1	0.22 ± 0.05	0.28 ± 0.12	0.48 ± 0.03	0.39 ± 0.39	0.39 ± 0.02	0.43 ± 0.11	0.66	0.58	0.81
C15:0	0.58 ± 0.09	0.78 ± 0.01	0.91 ± 0.01	0.67 ± 0.03	0.52 ± 0.22	0.33 ± 0.06	0.12	0.28	0.31
C15:1	0.04 ± 0.04	0.26 ± 0.06	0.39 ± 0.01	0.45 ± 0.29	0.22 ± 0.11	0.34 ± 0.06	0.59	0.36	0.21
C16:0	19.32 ± 0.28	18.37 ± 1.00	18.42 ± 0.27	18.90 ± 0.99	18.70 ± 1.43	17.25 ± 0.11	0.34	0.54	0.65
C16:1	6.03 ± 0.06	6.78 ± 0.55	8.12 ± 0.10	4.27 ± 2.32	8.09 ± 0.10	7.78 ± 1.72	0.12	0.79	0.48
C17:0	0.24 ± 0.04	0.25 ± 0.14	0.27 ± 0.03	0.35 ± 0.08	0.35 ± 0.03	0.32 ± 0.07	0.67	0.07	0.52
C17:1	0.53 ± 0.17^{B}	1.03 ± 0.02^{AB}	1.24 ± 0.09^{A}	0.85 ± 0.10	0.94 ± 0.02	1.19 ± 0.10	0.01	0.42	0.16
C18:0	10.81 ± 0.46	9.93 ± 0.44	8.84 ± 1.16	11.13 ± 1.05	8.94 ± 0.54	9.98 ± 1.05	0.18	0.81	0.48
C18:1(n-9)	17.80 ± 1.08	15.44 ± 0.40	17.30 ± 1.99	18.25 ± 0.10	15.35 ± 1.21	14.57 ± 0.78	0.12	0.41	0.37
C18:1(n-11)	4.81 ± 0.41^{B}	7.44 ± 0.23^{AB}	8.89 ± 1.37^{A}	4.60 ± 0.23^{Y}	8.69 ± 1.03^{XY}	9.78 ± 1.06^{X}	< 0.001	0.38	0.68
C18:2(n-6)	5.91 ± 0.44^{A}	5.52 ± 0.54^{AB}	3.35 ± 0.37^{B}	6.07 ± 0.81^{X}	5.71 ± 0.25^{XY}	2.83 ± 0.07^{Y}	< 0.001	0.88	0.69
C18:3 n-6	0.05 ± 0.05^{B}	0.25 ± 0.01^{A}	0.40 ± 0.03^{A}	$0.18 \pm 0.03^{Y,*}$	$0.41 \pm 0.04^{X,*}$	0.38 ± 0.04^{X}	< 0.001	0.04	0.11
C18:3 n-3	1.21 ± 0.09	1.61 ± 0.21	2.30 ± 0.43	0.80 ± 0.06^{Y}	1.88 ± 0.23^{X}	1.76 ± 0.30^{XY}	0.02	0.31	0.29
C20:0	0.00 ± 0.00^{C}	0.21 ± 0.11^{B}	0.47 ± 0.00^{A}	0.00 ± 0.00^{Y}	0.27 ± 0.12^{X}	0.36 ± 0.10^{X}	< 0.001	0.74	0.52

C20:1	0.27 ± 0.03	0.29 ± 0.09	0.30 ± 0.03	0.41 ± 0.04	0.20 ± 0.05	0.24 ± 0.07	0.21	0.91	0.14
C20:2	0.47 ± 0.04	0.50 ± 0.01	0.75 ± 0.13	0.76 ± 0.11	0.68 ± 0.51	0.48 ± 0.05	0.99	0.73	0.45
C20:3 n-3	7.37 ± 0.76	6.45 ± 0.80	6.62 ± 0.34	7.72 ± 0.43	5.90 ± 0.48	7.53 ± 1.07	0.11	0.25	0.63
C20:3 n-9	0.07 ± 0.07	0.18 ± 0.17	0.08 ± 0.03	0.20 ± 0.07	0.09 ± 0.09	0.10 ± 0.04	0.78	0.55	0.38
C20:3 n-6	0.36 ± 0.06^{A}	0.25 ± 0.11^{B}	0.16 ± 0.04^{B}	0.45 ± 0.02^{X}	0.19 ± 0.10^{Y}	0.10 ± 0.00^{Y}	< 0.001	0.85	0.22
C20:4 n-6 ARA	0.06 ± 0.06	0.08 ± 0.11	0.09 ± 0.02	0.07 ± 0.01	0.05 ± 0.05	0.06 ± 0.03	0.95	0.76	0.88
C20:4 n-3	0.15 ± 0.04	0.54 ± 0.35	0.33 ± 0.11	0.46 ± 0.15	0.16 ± 0.05	0.37 ± 0.17	0.93	0.95	0.14
C20:5 n-3 EPA	4.59 ± 0.06	4.49 ± 0.18	5.35 ± 0.20	4.34 ± 0.01	4.67 ± 1.07	5.82 ± 0.22	0.09	0.73	0.74
C22:0	1.17 ± 0.38	0.91 ± 0.00	0.55 ± 0.00	0.62 ± 0.04	0.51 ± 0.19	0.64 ± 0.06	0.30	0.09	0.24
C22:1	0.41 ± 0.15	0.69 ± 0.25	0.19 ± 0.03	0.33 ± 0.12	0.13 ± 0.13	0.27 ± 0.07	0.37	0.17	0.15
C24:0	1.25 ± 0.10^{ab}	2.10 ± 0.01^{a}	0.83 ± 0.13^{b}	0.96 ± 0.32^{b}	0.99 ± 0.05^{b}	0.73 ± 0.06^{b}	0.01	0.01	0.04
C22:4 n-6 DTA	1.61 ± 0.38	1.59 ± 0.04	1.31 ± 0.08	1.21 ± 0.00	3.89 ± 2.90	2.94 ± 0.45	0.59	0.27	0.53
C22:5 n-6	2.27 ± 0.01	2.59 ± 0.70	1.43 ± 0.05	2.37 ± 0.10	1.56 ± 0.30	1.50 ± 0.23	0.05	0.27	0.12
C22:5 n-3 DPA	1.43 ± 0.01^{B}	1.64 ± 0.33^{AB}	2.43 ± 0.16^{A}	1.52 ± 0.05^{Y}	1.45 ± 0.07^{Y}	2.49 ± 0.12^{X}	< 0.001	0.98	0.57
C22:6 n-3 DHA	9.65 ± 0.24^{A}	7.85 ± 1.36^{AB}	5.83 ± 0.20^{B}	10.06 ± 0.74	6.85 ± 0.68	7.18 ± 1.20	0.01	0.68	0.37
Total SFA	34.68 ± 0.43	34.29 ± 0.36	32.67 ± 0.72	34.25 ± 2.42	32.55 ± 1.85	31.88 ± 0.77	0.34	0.46	0.88
Total MUFA	30.12 ± 0.66	32.19 ± 1.41	36.90 ± 0.58	29.55 ± 3.07	34.00 ± 0.06	34.58 ± 3.82	0.08	0.84	0.63
Total n-3	24.42 ± 1.18	22.56 ± 2.80	22.87 ± 0.56	24.90 ± 1.31	20.90 ± 0.11	25.15 ± 2.47	0.16	0.71	0.49
Total n-6	10.26 ± 0.11^{AB}	10.29 ± 0.98^{A}	6.74 ± 0.55^{B}	10.36 ± 0.71^{XY}	11.80 ± 2.28^{X}	7.80 ± 0.59^{Y}	0.03	0.32	0.76
n-6/n-3	0.43 ± 0.04	0.46 ± 1.00	0.30 ± 0.05	0.42 ± 0.07^{XY}	0.57 ± 0.15^{X}	0.31 ± 0.01^{Y}	0.03	0.45	0.63
Total PUFA	35.20 ± 1.09	33.53 ± 1.97	30.43 ± 0.13	36.20 ± 0.65	33.45 ± 1.80	33.53 ± 3.05	0.15	0.35	0.64
DHA/EPA	2.10 ± 0.02^{A}	1.75 ± 0.23^{B}	1.09 ± 0.00^{C}	2.32 ± 0.18	1.58 ± 0.51	1.23 ± 0.16	0.01	0.77	0.71
ALA/LA	0.21 ± 0.00^{B}	0.29 ± 0.01^{B}	0.68 ± 0.06^{A}	0.14 ± 0.01^{Y}	0.33 ± 0.05^{XY}	0.62 ± 0.09^{X}	< 0.001	0.51	0.46
Total HUFA	27.56 ± 0.66	25.61 ± 2.74	23.63 ± 0.83	28.39 ± 1.44	24.80 ± 2.29	28.08 ± 3.52	0.42	0.40	0.48
EPA/DHA	0.48 ± 0.01^{B}	0.58 ± 0.08^{B}	0.92 ± 0.01^{A}	0.44 ± 0.04	0.71 ± 0.23	0.83 ± 0.11	0.02	1.00	0.59

The significance (Two-way ANOVA, $p < 0.05$) was determined according to the effects of different diet (A/CH/M), origin (C/W) and their interaction (Diet × Origin). Superscript uppercases (A, B, C) indicate significant differences among diets within cultured groups ($p < 0.05$). Superscript uppercases (X, Y) indicate significant differences among diets within wild groups ($p < 0.05$). The asterisks (*) show significant differences between origins within the same diet and are placed on the higher mean values ($p < 0.05$). Superscript lowercases show significant Diet × Origin interaction among the treatments ($p < 0.05$). CH: Chironomid; M: Mixture of Artemia ± Chironomid; A: *Artemia.*

DISCUSSION

This study revealed that growth indices were not significantly affected by diet alone; however, a significant interaction between origin and diet was observed for the growth indices. This interaction suggests that the effect of diet on growth indices differs depending on the fish's origin. Specifically, the superior performance of cultured fish compared to wild fish on the CHC diet suggests that this diet may be particularly well-suited to the physiological or digestive capabilities developed through the culturing process. This aligns with previous research indicating that aquaculture conditions can lead to faster growth and more efficient feeding in domesticated fish (Fleming *et al*. 2002; Palińska-Żarska *et al*. 2020). Conversely, the improved performance of wild fish on the AW diet indicates that this diet may better align with the nutritional needs or digestive adaptations of wild populations. The lack of significant differences between cultured and wild fish on the MC diet suggests that this diet may provide a more balanced nutritional profile, minimizing the performance differences between the two origins. The observed interactions likely reflect the complex mechanisms underlying domestication, which influence the phenotypic and genetic potential of fish species under captive conditions (Lorenzen *et al*. 2012; Christie *et al*. 2016). Domestication processes involve both endogenous factors (genetic and epigenetic changes, particularly during the embryonic stage) and exogenous factors (aquaculture facilities, stressors, etc.), which can mediate morphological and physiological adaptations (Milla *et al*. 2021). The up-regulation of growth hormone observed in domesticated Atlantic salmon, *Salmo salar* (Fleming *et al*. 2002) and the reduced growth performance of wild fish fed the same live feed as cultured fish (Palińska-Żarska *et al*. 2020) provide further evidence of these adaptive changes. Based on the results, in the present study, the diets had a considerable effect on survival rate and the lowest was recorded in AC group. In contrast, the higher growth and survival rate were observed in the group fed with frozen chironomid larvae. Before starting the weaning period, which plays a crucial role in the adaptation of fish to an artificial diet and impacts on growth and survival in later life stages, the quality and quantity of supplied natural live food must be considered (Ljunggren *et al*. 2003). Most studies have demonstrated that *Chironomus* sp. has great potential as a source of nutritional compounds in pikeperch production and their successful weaning to a dry diet (Policar *et al*. 2013; Efatpanah *et al*. 2024). Other authors reported a similar outcome when fish fed chironomid larvae before and during the weaning (Ljunggren *et al*. 2003; Policar *et al*. 2013). The time of weaning has a crucial effect on the survival and growth rates of pikeperch (Kestemont *et al*. 1996). In our study, the feeding trial was carried out for ten days. Hubenova *et al.* (2015) observed a higher survival rate when pikeperch transitioned to dry feed during the same time. Additionally, Bódis *et al.* (2007) and Policar *et al.* (2013) observed high growth performance and survival rate when fish transitioned to a dry diet during 9-12 days. Before transition to a dry diet, fish survival depends on different factors, such as water quality, temperature, and natural food availability (Bódis & Bercsényi 2009). In our research, higher mortality rates were detected in AC and AW groups. Ljubobratović *et al*. (2015) reported that using *Artemia* nauplii during the weaning time caused more than 64% mortality in pikeperch. Regardless of the appropriate protein and lipid levels of *Artemia*, this organism is poorly digested by fish due to the high content of chitin (Karlsen *et al*. 2017). Moreover, *Artemia* has a potential deficiency in some essential amino acids such as threonine or tyrosine, fatty acids or vitamins (Saavedra *et al*. 2006). Thus, nutrient insufficiency and expenditure of high energy as a consequence of digesting chitin accompanied by increasing temperature is probably responsible for higher mortality in groups fed only *Artemia* biomass. Based on our findings, lower mortality in the experimental group fed with chironomid in both culture and wild origins probably stems from its larger size, higher protein composition and higher attractiveness than the *Artemia* biomass, as observed by other research (Baranek *et al*. 2007; Policar *et al*. 2013). The present results on the chemical composition of the whole body of pikeperch including protein, lipid, ash, and moisture contents showed no significant difference between groups, whether varied origins or dietary regimes. In agreement with our findings, Cox and Karahadian (1998) reported no significant differences between the body composition of yellow perch, *Perca flavescens* from cultured and wild origins. In contrast, Schulz *et al*. (2008) observed the lowest lipid and dry matter in cultured pikeperch fed by chironomids. Numerous studies have shown that the domestication process, dietary regime or an interaction between them are the key influencing factors on body composition regardless of environmental conditions, species, size or genetics (Zhao *et al*. 2010; Milla *et al*. 2021). According to Mairesse *et al.* (2007), different diet compositions may alter body composition in both cultured and wild Eurasian perch, *Perca fluviatilis*. In another study, lipid and moisture contents of wild gilthead sea bream, *Sparus aurata* were significantly lower and higher than their cultured counterparts, respectively (Grigorakis

2007). Regarding the results of present study, fatty acid profiles of wild and cultured pikeperch varied after feeding with different dietary regimes. Fatty acid profiles may be affected by many factors including culture condition, season, species or origin, but nutritional values of diet are the main components (Gardeur *et al*. 2007). Mairesse *et al*. (2007) and Zhao *et al*. (2010) observed the impact of domestication process on total SFA content, although the present study showed no significant variation in total SFA among the two different origins. Jankowska *et al*. (2010) found a similarity between SFA content of wild and reared Eurasian perch, which is consistent with our results. This study also showed that the group fed chironomid offered higher PUFA content, particularly C22:6 n-3 DHA and 18:2 n-6. Many studies have demonstrated that *Chironomus* sp. contains high levels of n-3 and n-6 PUFA, which lead to success during the weaning period (Kamler *et al*. 2008; Jankowska *et al*. 2010; Makhutova *et al*. 2017). The contents of C17:1, C18:1(n-11), C18:3 n-6, C20:0, C22:5 n-3 DPA, ALA/LA, EPA/DHA were higher in juvenile pikeperch which only fed on *Artemia*, whereas C20:3 n-6 and DHA profiles were lower than the other groups in both origins. Diets low in DHA probably increase mortality, neurological impairment during the early stage, and reduce resistance against short and long-term stressors, which lead to failure in adaptation process (Lund *et al*. 2014). Moreover, diet significantly influenced the n-6/n-3 fatty acid ratio in juvenile pikeperch, while broodstock origin and the interaction between diet and origin were not significant. Interestingly, the *Artemia*-fed groups (AC and AW) exhibited a decrease in n-6 fatty acids, which likely contributed to the decline in the n-6/n-3 ratio. This highlights the strong influence of dietary fatty acid composition on tissue fatty acid profiles in fish, consistent with findings by Efatpanah *et al*. (2024), who observed a similar decrease in n-6 fatty acids in Persian Sturgeon, *Acipenser persicus* larvae. The higher n-6/n-3 ratio in the M treatment suggests that a mixed chironomid and *Artemia* diet provides a more balanced fatty acid profile, compensating for potential n-6 deficiencies associated with *Artemia* alone, and ultimately improving the nutritional completeness of pikeperch diets during adaptation. Apart from the diet variation among the groups, no significant differences were found in fatty acid profiles of wild and cultured pikeperch. It can be implied that the dietary regime of fish in nature contributes significantly improve the nutritional values of the broodstock and offspring, most likely due to the high spectrum of prey available for consumption (Zhao *et al*. 2010). Therefore, *Artemia* deficiencies may not compromise the fatty acid profiles of juvenile pikeperch derived from wild broodstock. However, it has not been fully investigated in this study and more research will be needed.

CONCLUSION

In conclusion, live food organisms have a crucial role in initial feeding and weaning to artificial diet in pikeperch and their performance could vary in different origins. Regarding the results obtained from the present study, the domestication process positively contributes to improve fish adaptation to various diets. Accordingly, feeding cultured pikeperch solely on *Chironomus* before weaning to an artificial diet may enhance growth and survivability. Furthermore, mixing *Chironomus* with *Artemia* could be an appropriate strategy to improve fatty acid compositions and overcome the deficiencies related to feeding with individual live feeds in both wild and cultured pikeperch.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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