Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 1, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

EFFECT OF LIGHT INTENSITY ON GROWTH PERFORMANCE, PHYSIOLOGICAL STATE AND TISSUE COMPOSITION OF *Polyodon spathula* (Walbaum, 1792) JUVENILES

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Abstract

This study aimed to investigate the effect of light intensity on the growth performance, hematological profile, and biochemical composition of muscle tissue of paddlefish juveniles, reared in a recirculating aquaculture system (RAS). Two experimental variants were created: V1- where the rearing units have green color, and the average of the light intensity was 105 lx (mean fish weight was 21.65 ± 0.6 g), and V2- where the rearing units have white color, and the average of the light intensity was 30 lx (mean fish weight was 22.15 ± 0.8 g). Fish were fed at an intensity of 2.5% BW for 48 days. Growth of juvenile paddlefish under 30 lx was significantly better than that of paddlefish under 105 lx (p < 0.05), as indicated by final weight (1158.20 ± 21.90 g), specific growth rate (2.18% ± 0.07%/day) and feed conversion coefficient (0.80 ± 0.28 g/g). In conclusion, the paddlefish juveniles can adapt to various light intensities and grow favorably under low light conditions in a recirculating aquaculture system.

***Key words**: growth performance, hematology, light intensity, paddlefish, recirculating aquaculture systems (RAS).*

INTRODUCTION

Growing fish outside their natural habitat can negatively impact their appetite for food, health, welfare, and overall growth if environmental conditions differ from the optimal conditions for the farmed species. The physiology of fish is affected by light intensity, time of exposure to light, and color of the rearing environment (Coadă, 2012).
Artificial environments such as rearing systems that are very different from natural fish habitats can negatively affect fish feeding activity, fish health, welfare, and growth, especially if conditions are stressful for the fish (De Silva & Anderson, 1994; Jobling, 1994; Brännäs et al., 2001). Some possible environmental factors influencing the performance of cultured fish include tank color and light intensity.
Some studies point to the fact that light is the result of a combination of different external and ecological factors, including color spectrum (quality), intensity (quantity), and day-night period (Downing, 2002).
The exposure of juvenile beluga to red ambient light negatively affects growth performance, compared to exposure to blue light (Bani et al., 2009). The color of the growth unit and the environmental conditions in a given genre can influence it (Barcellos et al., 2009). Choosing suitable colors for growth units can be a beneficial practice in aquaculture, especially during the larval stage. Most teleost fish are visual foragers during this developmental phase. This visual behavior can lead to a decrease in feed assimilation, subsequently reducing feed conversion efficiency and increasing mortality. The appropriate color of rearing units allows for

the creation of contrast between the feed and tank walls, thereby enhancing feed intake assimilation by larvae and juvenile fish (Martin-Robichaud, 1998; Tamazouzt et al., 2000; Rotllant et al., 2003).

Popular color shades for growing units are as follows: white, yellow, green, dark/dark blue, red, and black. In the case of juvenile carp, better growth was obtained in the blue tank, but the results were insignificant, compared to the other rearing units. Another study carried out on juvenile carp (100-160 g) showed that there were no significant differences between batches of juvenile carp reared in white, black, and green tanks. Several studies have highlighted that marine fish in the larval stages show a preference for darker rearing units (Papoutsoglou et al., 2000; Naas et al., 1996).

Studies on Nile tilapia maintained in a white-rearing medium have reported color-induced metabolic effects, resulting in higher respiration rates compared to black, blue, green, yellow, and red-rearing conditions (Fanta, 1995).

The literature demonstrates that fish can adapt to different colors of the rearing environment but may change their integument color, a characteristic that could have detrimental effects on marketing (Vissio et al., 2020).

Since the introduction of American paddlefish into the Soviet Union in the 1970s, paddlefish aquaculture expanded to several European and Asian countries, with a wild population now established in the Danube River / Black Sea watershed (Naiel et al., 2021).

Some studies of paddlefish farming in Europe indicate that paddlefish aquaculture will continue to expand, although it is challenged by the suitability of the species for high-intensity production (Jarić et al., 2018). In the past, there has been significant research into paddlefish farming in Russia, Moldova, and Romania, after which farming began in commercial farms for meat production (Vedrasco et al., 2001).

Although *Polyodon spathula* (Walbaum, 1792) is a valuable fish species, there were no studies regarding its growth and adaptation to light intensity. In this context, this study aims to investigate the effects of light intensity on the growth and stress response of this species. Furthermore, our study seeks to provide knowledge on rearing this species in recirculating aquaculture.

MATERIALS AND METHODS

Fish and Experimental Design

The biological material used in the experiment was represented by juvenile *Polyodon spathula* (Walbaum,1792), provided by SCDP Nucet, Dâmbovița. A number of 78 fish aged four months, with an average individual weight of 20.9±5.5 grams, were distributed in four rearing units (two white and two green, respectively. The population of the breeding units was followed after weighing and biometric measurements to obtain an equal density and a batch with a normal distribution.

a) The growing module contains four Ewos-type units measuring 1.4 × 1.4 × 0.6 m. Each rearing unit's water column, basin shape, and water volume meets the technological requirements specific to the species *Polyodon spathula*.

b) Water quality conditioning units aim to reduce water consumption by improving water quality, keeping it within the optimum range of the main physicochemical parameters: dissolved oxygen, ammonia nitrogen concentration, solid particle concentration, pH, and carbon dioxide. Dissolved oxygen (DO) requirements of the culture species were insured by an oxygenation aeration unit, represented by a Hagen compressor with a capacity flow rate of 1.5 m^3/h. At an intermediate period of three days, the physicochemical parameters remained within the optimal range by replacing 15-20% of the water volume.

c) Throughout the experimental period, juvenile paddlefish were fed Classic Extra 1P pelleted, with a protein concentration of 45% and lipids of 12%. The total amount of feed daily was administrated manually in six equal rations and represented 2.5% of overall fish biomass.

Monitoring water quality in terms of physicochemical parameters

Monitoring of water quality was established during the whole experiment period through periodic determinations for ammonia nitrogen compounds and daily for temperature, pH, and dissolved oxygen. The monitoring of these relevant water quality parameters was made using the Hanna HI 98,186 (HANNA Instruments, Cluj-Napoca, Romania) for temperature and dissolved oxygen, while pH was measured with the pH meter WTW, 340 (Sigma-Aldrich, Darmstadt, Germany). For determination of the concentrations of nitrogen compounds, we use the Spectroquant NOVA 400 portable spectrophotometer (Merck general laboratory equipment, Enschede, Netherlands), with compatible kits from Merck (Merck laboratory equipment, Enschede, Netherlands).

The experiment evaluated the effect of growth unit color and light intensity on growth performance, biochemical composition of meat, and physiological response, for 48 days. Brightness was adjusted using translucent polycarbonate plates (6 mm). Light exposure of the growth units is based on natural photoperiodicity. Thus, the white units covered with white transparent polycarbonate light intensity have been observed with an average daily value of 105 lx and a maximum of 350 lx. In the green growing units covered with green transparent polycarbonate, the average daily value was around 30 lx, with a maximum of 80 lx. The measuring of light intensity has been measured with the Lxmeter TESTO 545 (Testo AG, Lenzkirch, Germany).

Growth performance assessment

Biotechnology indicators are essential to obtain information on the resulting technological performance and the efficiency of the breeding system used. The principal biotechnological parameters used to determine the growth performance of *Polyodon spathula* in the present study are described by Sîrbu et al. (2022).

Blood sampling and screening procedures

Examination of the blood profile of fish can provide insights into the physiological condition and health status of fish in aquaculture. Therefore, hematology, combined with other routine diagnostic methods, could prove valuable information in identifying and evaluating conditions that cause stress or diseases affecting production performance. At the end of the experimental period, while ensuring the integrity of the technological aspect of the experiment, approximately 2.5 ml of biological blood samples were collected from ten fish/rearing units. This sampling represented 50% of the fish population in each rearing unit and was conducted by manipulating juvenile paddlefish under strict biosecurity conditions. The blood sampling of fish was collected by caudal vein puncture along the lateral line. The hematological parameters analyzed were red blood cell count - RBCc ($x10^6$ cells/µL), hemoglobin - Hb (g/dL), and hematocrit – PVC (%). Blood analysis was performed by a method used in fish hematology described by Sîrbu et al. (2022).

The relative and absolute number of leukocytes has been performed to evaluate modifications under the influence of different light intensities in the leukocyte profile and are described by Dima et al. (2022). For the determination of total serum protein (g/dL) and glucose (mg/dL) VetTest® Chemistry Analyzer and IDEXX VetTest kits (IDEXX Laboratories, Inc., Westbrook, ME, USA) were used. To minimize the impact of diet on the results of biochemical and hematological indices, the fish were not fed on the day preceding the sampling.

Methods for determining the biochemical constituents of fish meat

The biochemical analyses of body composition (for each experimental variant, considered for the average weight of the individuals) were performed at the end of the experiment. Tissue biochemical determinations of juvenile paddlefish reared in a recirculating system were used to estimate feed retention capacity. Diet utilization and the influence of growth system environmental conditions were assessed by analysis of the main biochemical parameters: crude proteins, lipids, and ash. Proteins were determined with Gerhardt equipment by using the Kjeldahl method, fats were determined by Soxhlet solvent extraction method (petroleum ether) with Raypa extraction equipment (C. Gerhardt GmbH & Co. KG, Königswinter, Germany), the dry matter was determined by heating at a temperature of 105±2ºC using Sterilizer Esac (Systec GmbH & Co. KG, Linden, Deutschland) and ash was evaluated by calcification at temperatures of 550±20°C, in a Nabertherm furnace (Nabertherm GmbH, Bremen, Germany).

Methods of statistical data processing

Statistical analyses of the biotechnology, hematological, and biochemical indicators obtained have been processed statistically in Microsoft Office Excel 2019 and SPSS 26.0 (SPSS Inc., Chicago, IL). Statistical differences between variables were tested using a *t*-test. All the results are expressed as means ± standard deviation (SD). Results with a $p<0.05$ were considered significant.

RESULTS AND DISCUSSIONS

Several research investigations have shown that different colors of the rearing environment can influence the growth performance and health of fish (Coadă, 2012).

Assessment of dynamic water quality parameters

Temperature. The species *Polyodon spathula* tolerates a relatively large temperature range of 0-35°C, allowing it to distribute to other continents. During the experiment, the temperature variation in the two experimental variants was within the optimal tolerance range of sturgeon growth, 20.9÷25.8°C with an average of 22.8±1.76°C in the growth units of the white variant (V1), and in the green variant (V2) temperature range of 20.6÷25.2°C at an average value of 22.6±1.8°C (Figure 1), without any statistical differences (p>0.05) between the two experimental variants (Figure 1).

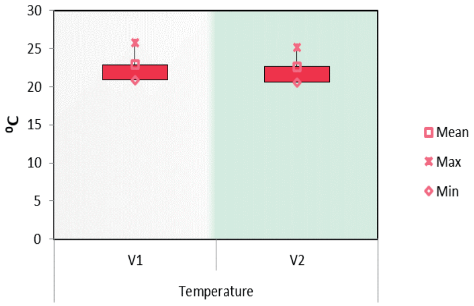

Figure 1. Temperature variation values for the two experimental variants

Dissolved oxygen. The values of DO are illustrated in Figure 2. During the analyzed period, DO values ranged from 9 to 11.87 mg/L, with an average of 10.6±1.32 mg/L in the white variant (V1). In the green variant (V2), DO values fluctuated between 8.9 and 13.9 mg/L, with an average of 11.3±2.28 mg/L. (Figure 2). No statistical differences (p>0.05) were recorded between the V1 and V2 variants.

The pH was kept within optimal limits for sturgeon growth, ranging from pH 8.03 (in the white variant) to pH 8.9 (in the green variant), without any statistical differences (p>0.05) between the experimental variants (Figure 3).

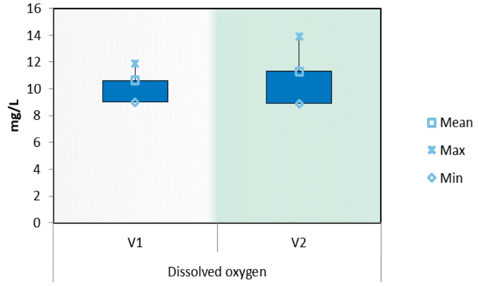

Figure 2. Dissolved oxygen variation values for the two experimental variants

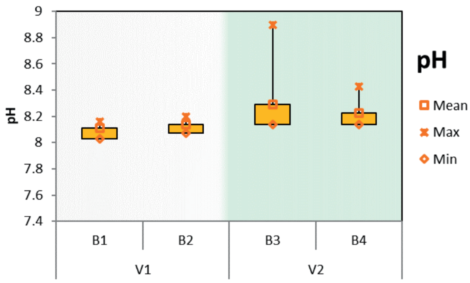

Figure 3. pH variation values for the two experimental variants

Regarding the ammonium values, the statistical analysis showed significantly higher concentrations (p>0.05) in the B4 basin (0.17 mg/L), while no significant differences (p>0.05) were recorded in the concentration registered in B1 (0.07 mg/L), B2 (0.05 mg/L) and B3 respectively (0.11 mg/L) (Figure 4).

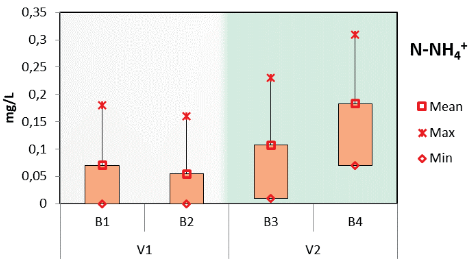

Figure 4. Ammonium ion variation values for the two experimental variants

Across the two experimental variants, the average nitrate concentration was significantly higher (p<0.05) in variant V2 (36.35±6.9 mg/L), compared to variant V1 (where an average value of 26.75±5.64 mg/L was recorded) (Figure 5).

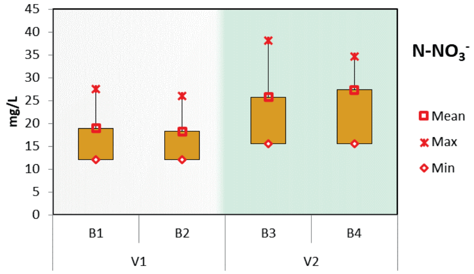

Figure 5. Nitrate variation values for the two experimental variants

During the experimental period, nitrite showed a similar growth trend as nitrate. A significantly higher valuer (p<0.05) was recorded in the case of green growth units (variant V2), (with an average value of 0.08 mg/L in B3 and 0.17 mg/L in B4), while in the white growth units (B1 and B2), significant (p<0.05) lower values were recorded (an average value of 0.04 mg/L and 0.034 mg/L) (Figure 6).

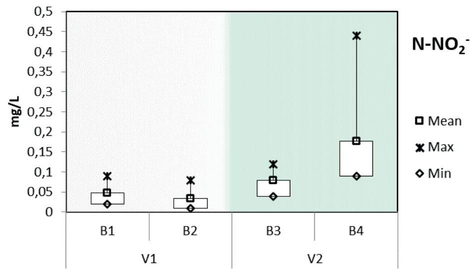

Figure 6. Nitrite variation values for the two experimental variants

Assessment of biotechnology indicators

The rearing of *Polyodon spathula* in a recirculating aquaculture system under the action of light intensity aims to obtain superior biotechnological indicators. These can be used to assess physiological conditions and growth performance. The growth rate of juvenile paddlefish in the white variant was hindered by high light intensity (V1). As a consequence, the mean individual mass, recorded at the end of the experiment, was smaller in the white-rearing units (B1 47.3 g/fish respectively B2 37.3 g/fish) compared to that registered in the green-rearing units (B3 63.2 g/fish respectively B4 61 g/fish) (Table 1).

Regarding the technological plasticity of the species, the influence of growth unit color and light intensity on the final biomass obtained in both experimental variants can be observed. As a result, in the green variant (V2), the juvenile paddlefish increased from initial biomass of 1.05 kg/m^3 to 2.95 kg/m^3, and in the white variant (V1), it grew from 1.08 kg/m^3 to 2.05 kg/m^3.

To identify any significant differences in total growth gain within and between experimental variants, the Pairwise Comparisons Test was applied (Table 2).

In this study, light intensity played a significant role (p<0.05) in the growth of juvenile paddlefish. The results obtained in the present study showed that light intensity significantly affected the growth of paddlefish, and the highest performance resulted in the 30lx light intensity green variant - V2. Differences in morphology and behavior, such as the presence of rostrum and the digestive and filtering mechanism of paddlefish compared to sturgeon, mean that the response to foraging is different, which also complicates nutritional issues therefore, adequate light intensity could improve feeding efficiency.

Table 1. Performance indicators show the evolution of growth gain in both experimental variants

Indicators	Experimental Phase	Variant V1 B1	B2	Mean	Variant V2 Mean	B3	B4
Total biomass [g]	Initial	429.6	436.5	433.05	421.4	421.9	420.8
	Final	897.04	746.7	821.87	1179.1	1200.06	1158.2
Total biomass [kg/m^3]	Initial	1.07	1.09	1.08	1.1	1.06	1.05
	Final	2.24	1.87	2.05	2.95	3.0	2.9
Biomass gain [g]		467.44	310.2	388.82	757.8	778.16	737.4
Fish number	Initial	20	20	20	19	19	19
	Final	19	20	19.5	19	19	19
Survival [%]		95	100	97.5	100	100	100
Mean weight [g/fish]	Initial	21.48	21.83	21.65	22.16	22.18	22.15
	Final	47.2	37.3	42.3	62.1	63.2	61.0
Experimental time		48	48	48	48	48	48

Table 2. The estimation of the marginal population means using the Pairwise Comparisons test

Pairwise Comparisons

Dependent Variable: Final_weight

Variant	**(I) Unit**	**(J) Units**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[d]	**95% Confidence Interval for Difference**[d]	
						Lower Bound	**Upper Bound**
V1	B1f	B2f	9.878[a,b]	8.806	1.000	-14.013	33.768
		B3f	-19.457[a,b]	9.041	.208	-43.986	5.071
		B4f	-13.745[a,b]	8.918	.766	-37.940	10.450
	B2f	B1f	-9.878[a,b]	8.806	1.000	-33.768	14.013
		B3f	-29.335[a,b,*]	8.930	.009	-53.563	-5.107
		B4f	-23.623[a,b]	8.806	.054	-47.513	.268
V2	B3f	B1f	19.457[a,b]	9.041	.208	-5.071	43.986
		B2f	29.335[a,b,*]	8.930	.009	5.107	53.563
		B4f	5.712[a,b]	9.041	1.000	-18.816	30.241
	B4f	B1f	13.745[a,b]	8.918	.766	-10.450	37.940
		B2f	23.623[a,b]	8.806	.054	-.268	47.513
		B3f	-5.712[a,b]	9.041	1.000	-30.241	18.816

Based on estimated marginal means
*The mean difference is significant at the 0.05 level.
[a]An estimate of the modified population marginal mean (I).
[b]An estimate of the modified population marginal mean (J).
[d]Adjustment for multiple comparisons: Bonferroni.

The results of our experiment are similar to those of the previous study, from which it has found that low light intensity (V2 - with a daily mean luminous intensity of 30 lx) induces an increase in body weight in juvenile paddlefish. The two different intensities of luminosity used in the experiment significantly influenced growth performance parameters (FCR, SGR), a result confirmed by some previous studies in other species (Karakatsouli et al., 2007; Karakatsouli et al., 2008).

Based on the values obtained for SGR and FCR, it is suggested that the daily light intensity of 30 lx (V2) was favorable for food conversion and retention.

In the present study, the SGR (2.18 g%/day in green variant) and FCR (0.78 g/g) of juvenile paddlefish have been significantly influenced by different light intensities. The results obtained on the effect of light intensity on the growth performance of juvenile paddlefish are also similar to other studies that reported that blue and green light can facilitate the growth of *Verasper moseri* (Yamanome et al., 2009), *Scophthalmus maximus* (Wu et al., 2021), *Macrobrachium rosenbergii* (Wei et al., 2021), *Penaeus vannamei* (Fei et al., 2020a; Fei et al., 2020b) and *Strongylocentrotus intermedius* (Yang et al., 2020). Also, larvae of Atlantic cod (*Gadus morhua*) are exposed to increased somatic growth when exposed to blue or green light spectra (Sierra-Flores et al., 2016). The green-light spectrum is beneficial for barfin flounder (*Verasper moseri*) to achieve higher growth rates, while the red-light spectrum harms its growth. Optimal light intensities vary among different fish species.

Figure 7 demonstrates the inversely proportional correlation relationship between SGR and FCR evolution.

Light is a vital environmental factor that influences the growth and survival of teleosts. The survival rates obtained in this study indicated that the lower 30 lx light intensity was safe for juvenile paddlefish. The light might affect fish feeding and other issues, such as improved appetite, increased ratio consumption, and high food conversion efficiency, which influence the early stages of fish and have commonly been reported to be responsible for faster teleost growth under continuous light conditions (Villamizaret et al., 2011). Light influences the development of aquatic animals from early life stages to adult reproductive stages.

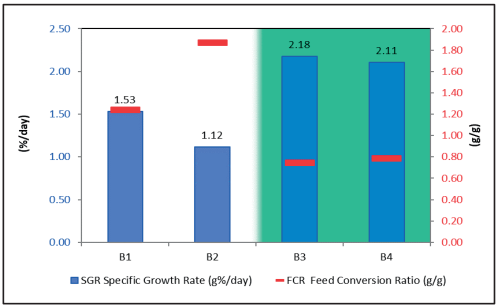

Figure 7. Relationship between FCR (feed conversion rate) and SGR (specific growth gain)

Investigation of the possible influence of light intensity on the blood profile of *Polyodon spathula* (Walbaum, 1792) juveniles

To assess the effect of light intensity on the hematological profile of juvenile paddlefish, the variation in the values of hematological indices, erythrocyte constants, and different types of leukocytes at the end of the experimental period in the two variants have been analyzed. To investigate the influence of light intensity on the physiological condition of juvenile paddlefish reared in a recirculating system, hematological indicators such as hematocrit (PVC, %), hemoglobin concentration (Hb, g/dL), and red blood cell count, RBCc (×10^6 cells/µL) were assessed. Furthermore, erythrocyte constants derived as mean corpuscular volume MCV (fL), mean corpuscular hemoglobin MCH (pg), and mean corpuscular hemoglobin concentration MCHC (g/dL) have been calculated.

The results of the hematological indices are presented in Table 3. At the end of the experimental period, RBCc, PVC, and Hb showed insignificant differences ($p>0.05$), the values of the white variant (V1) being similar to the values of the green variant (V2).

The skin of juvenile paddlefish in the white rearing units (V1 - variant with a daily average luminous intensity of 105 lx) underwent a slight depigmentation compared to the green variant (V2 - with a daily mean luminous intensity of 30 lx) and acquired a darker shade of skin, a phenomenon also observed in juvenile carp. Indeed, some studies have reported that skin coloration in teleost fish is under the multiparametric control of both external and internal (physical, nutritional, genetic, and neurohormonal) factors (Papoutsoglou et al., 2000; Karakatsouli al., 2010).

Table 3. Hematological indices of paddlefish in the two experimental variants.

Hematological parameters	White color (V1)	Green color (V2)	*p-value*
RBCc (×10^6 cells/µL)	0.98±0.06	0.96±0.06	0.73
PVC (%)	34.54±1.56	32.09±1.54	0.27
Hb (g/dL)	6.53±0.24	6.35±0.22	0.58
MCV (fL)	356.60±18.99	351.70±31.80	0.89
MCH (pg)	68.46±4.73	68.90±4.89	0.94
MCHC (g/dL)	19.34±1.29	20.04±0.84	0.65

RBCc - red blood cell count, PVC – hematocrit, Hb – hemoglobin, MCV - mean corpuscular volume, MCH - mean corpuscular hemoglobin, MCHC - mean corpuscular hemoglobin concentration. Results are presented as duplicate means ± standard error.

Hematological indices have been measured to evaluate general health status and nutritional and environmental conditions affecting the fish (Hoseinifar et al., 2011).

Circulating blood erythrocyte numbers of juvenile paddlefish were kept constant in both variants. In the experimental green variant V2 the mean was 0.96±0.06×10^6cells/µL, while in variant V1 the mean was 0.98±0.06×10^6 cells/µL. In the present experiment, the obtained values were lower than those obtained in adult paddlefish reared in open systems, where the range is between 1.04-1.36×10^6/µL (Bucur et al., 2009). Circulating blood hemoglobin and hematocrit of juvenile paddlefish showed no significant difference between V1 (105 lx - mean daily light intensity) and V2 (30 lx - mean daily light intensity). This indicator aligns with values reported by other studies conducted for the species *Polyodon spathula*, where hemoglobin levels fell within the range of 6.2-9.6 g/dL (Bucur et al., 2009; Coadă et al., 2012). Therefore, a possible explanation for the observed increase of hematocrit could be the heightened erythropoiesis in response to the potentially stressful impact of light (Valenzuela et al., 2006). However, this situation was not found in our experiment, with the number of

erythrocytes, hemoglobin, and hematocrit recorded at the end of the experiment being similar.
According to our results, high (V1 – white variant with a daily average luminous intensity of 105 lx) and low (V2 – green with a daily mean luminous intensity of 30 lx) light intensity had no significant effect on these parameters. Similar results have been previously reported for *Huso huso* (Musavi et al., 2022) and other species (Adeoye et al., 2016; Zamini et al., 2014).
The mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) showed no significant differences (p>0.05), the values of the high light intensity variant (V1) being approximately similar to those of the low light intensity variant (V2). Standard reference intervals of blood parameters are relevant for assessing and observing fish welfare. In the past, numerous normal reference ranges for hematological indices of farmed and wild fish have been established (Bocioc et al., 2015; Fazio et al., 2019).

Assessment of leukocyte reactions
The analysis of blood smears from quantitative and qualitative aspects can offer valuable information to study innate/native immunity. To determine the influence of different light intensities on the hematological profile, the leukocyte profile of juvenile paddlefish subjects from the two experimental variants was also studied, which included the determination of a relative number of leukocytes and the absolute number of leukocytes (Figures 8 and 9).
Lymphocytes (%). Concerning small lymphocytes between experimental white and green variants, no significant differences (p>0.05) were observed, but the highest value was recorded in the green variant (71%). The relative number of large lymphocytes was not significantly different between the experimental variants (p>0.05), however, compared to the value obtained between variants there was a 6% increase in the white variant (V1).
Monocytes (%) identified at the end of the experiment showed no significant difference (p>0.05) in the relative number in both experimental variants.
Neutrophil granulocytes (%) from leukogram showed that there was an insignificant increase (p>0.05) in the white experimental variant (14%) compared to the green experimental variant (6%). Basophilic and eosinophilic granulocytes were absent.

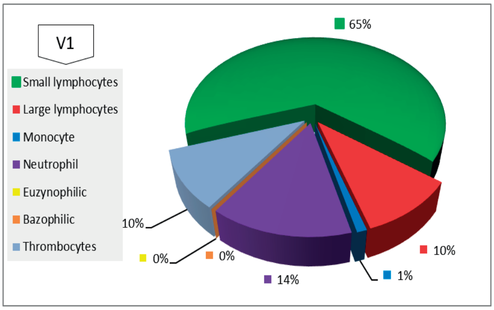

Figure 8. Variation in the relative number of leukocytes in the white variant - V1

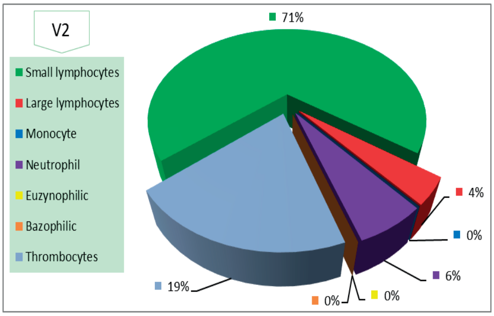

Figure 9. Variation in the relative number of leukocytes in the green variant – V2

The *relative number of thrombocytes* showed an insignificant increase (p>0.05) in the 9% green variant compared to the white variant.
Analysis of blood smears from a quantitative and qualitative aspect can provide the necessary information to study innate/native immunity. The modifications of the various types of cells that form the leukocytic complex are presented in Figures 10 and 11.

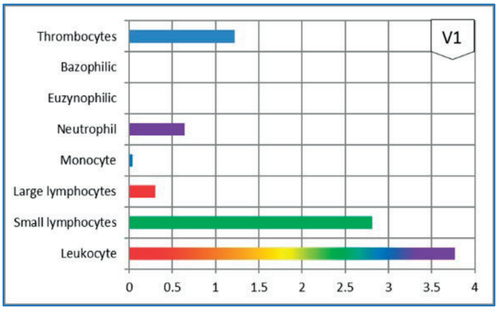

Figure 10. The variation of the absolute number of leukocytes in the white variant (V1)

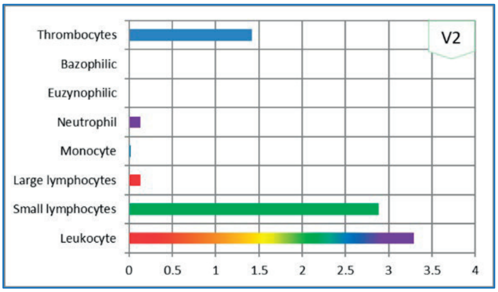

Figure 11. The variation of the absolute number of leukocytes in the green variant (V2)

At the end of the experimental period, no significant differences were observed between the experimental variants on the leukocyte complex ($p>0.05$). The absolute number of small lymphocytes was dominant in the total leukocytes and showed approximately the same tendency as in the number of leukocytes.

The absolute number of neutrophils recorded at the end of the experiment showed slightly higher values in the experimental variant with light intensity of 105 lx (V1) compared to V2 (light intensity of 30 lx). For the absolute number of platelets, a tendency of reduction was observed, but it was not statistically ($p>0.05$) in the 105 lx light intensity variant (V1).

The present study found that juvenile paddlefish exposed to 30 lx showed relatively more leukocyte counts, probably suggesting enhanced immunity with low light intensity in this species. At the same time, leukocytes are also known to play an essential role in innate immunity, and their number could be considered an indicator of fish health status (Alcorn et al., 2003). The relative number of leukocytes registered in our study is sensitively equal under the conditions of its growth influenced by a light intensity of 105 and 30 lx, a similar observation was reported by other authors at a light intensity between 7-600 lx (Ruchin et al., 2006). Basophilic and eosinophilic granulocytes were absent, and this finding was also observed by other authors (Buchtíková et al., 2011).

The most numerous cells of the total granulocyte leukocytes are the neutrophils, which play a role in antimicrobial defense due to their specific properties. At the end of the experiment, the number of neutrophilic granulocytes has the same tendency to increase as the other leukocytes (lymphocytes, monocytes). Thus, the relative number of neutrophils increases by 14% in the white light variant, compared to 6% in the green variant. In contrast, platelets showed an insignificant increase of 19% in the green variant compared to the white variant (10%). In the study on the effect of photoperiod on the growth of juvenile Siberian sturgeon (*Acipenser baerii*), hematological indices were reported to be within normal limits under optimal photoperiod conditions. In contrast, pronounced neutrophilia and leukopenia were observed for this species. After statistical evaluation of the absolute number of leukocytes (lymphocytes, monocytes) at the end of the experiment, no statistically significant differences were obtained for the two colors of light, white and green. This implies that the juvenile paddlefish's body was adapted and remained unaffected by light intensity.

Since most previous studies examining these effects of light have tended to investigate the influence of single colors of light or white light (full spectrum) on fish growth and immunity, there is presently limited information available on the effects of light color variation on fish physiological ecology (Xueweijie et al., 2022).

Investigation of serum biochemical parameters. At the end of the experimental period, the results of serum biochemical parameters indicate normal blood glucose and total protein levels in the sturgeon. In both experimental variants, glycemia recorded an average value between 84.03±1.08 mg/dL in the white variant (V1) and 81.19±1.22 mg/dL in the green variant (V2), with no significant differences ($p>0.05$) between the experimental variants (Figure 12).

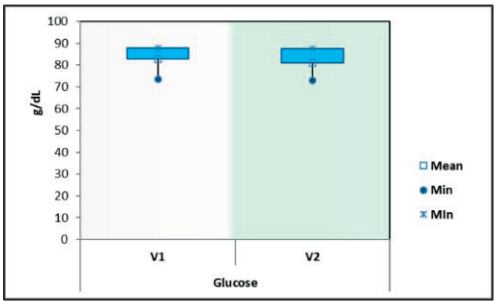

Figure 12. Analytical values of glucose concentration in the serum blood of juvenile paddlefish were determined at the end of the experimental period

In the case of the total proteins, the results showed no significant differences ($p>0.05$)

between the experimental variants, with an average of 3.92±0.09 mg/dL in the white variant (V1) and 3.88±0.10 mg/dL in the green variant (V2) (Figure 13).

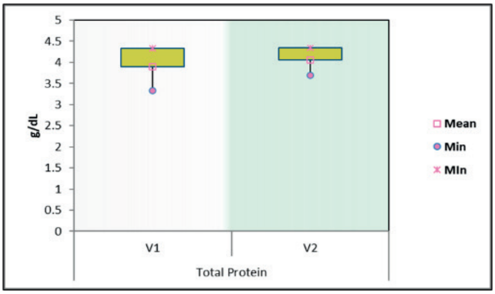

Figure 13. Analytical values of total protein in the serum blood of juvenile paddlefish were determined at the end of the experimental period

Determination of serum glucose in fish is the most efficient and rapid method of assessing stress. A high-value marker for stress is the serum glucose level, while the serum total protein level is primarily a synthetic indicator of stress, the state of nutrition of the body. There are significant influences on serum biochemical concentrations by the following factors: age, gender, environmental conditions, and nutritional diet (Banan et al., 2013). In our study, serum glucose and serum total protein showed no significant differences between the variants with different light intensities, the values obtained being within the normal range for these parameters. Usually, blood contains 40-90 mg of glucose per 100 mL of blood. According to some authors, blood glucose in some freshwater fish species ranges from 25-200 mg/dL. Normal blood contains 3.5- 5.5 mg of total protein per 100 ml of blood (Misaila et al., 2009). Usually, animal husbandry, including fish farming, involves a high density of animals in a limited space. The results obtained in the present experiment were observed at the species of *Acipenser stellatus*, and the blood normally contains 30-75 mg/dL (Patriche et al., 2011).
According to some studies, there are reports that light conditions may influence blood glucose and lactate levels, Baekelandt et al., 2019 reported that pike (*Sander lucioperca*) exposed to red light had higher blood glucose levels compared to fish exposed to white light. Concerning total protein and glucose levels, there were no significant differences between the different light intensities in terms of serum parameters of swordfish. The results for total protein are similar to that of tilapia (Wang et al., 2023) and red porgy, with no significant differences in total protein and globulin levels between different photoperiod groups (Biswas et al., 2006).

Biochemical composition analysis of the muscle tissue of juvenile Polyodon spathula (Walbaum, 1792)

The results recorded in the present study related to the effect of light intensity on the meat biochemical composition of juvenile paddlefish, reared in a recirculating aquaculture system have been compared to those reported by other authors. Biochemical analyses of muscle tissue were performed at the end of the experimental period.
The results obtained from determining the biochemical composition of the muscle tissue of juvenile paddlefish are illustrated in Figures 14 and 15.

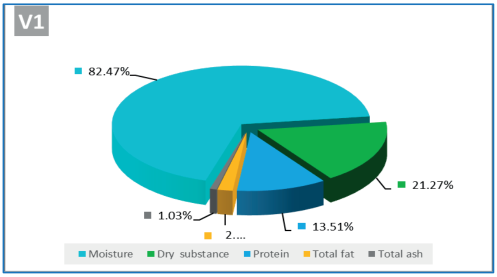

Figure 14. The biochemical composition of the muscle tissue of juvenile paddlefish in the white variant at the end of the experimental period

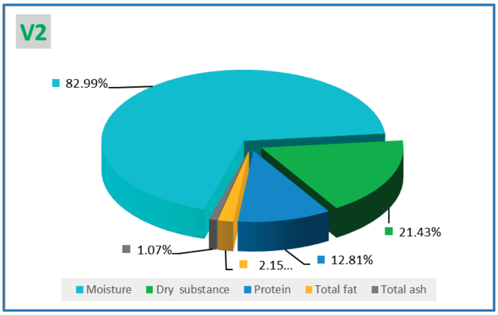

Figure 15.The biochemical composition of the muscle tissue of juvenile paddlefish in the green variant at the end of the experimental period

The muscle tissue biochemical composition analysis revealed no statistically significant differences ($p > 0.05$) in proteins, lipids, ash, and moisture levels between juvenile paddlefish reared in high and low light-intensity conditions. The evaluation of the composition of the muscle tissue of the juvenile paddlefish showed no significant differences between proteins, lipids, ash, and moisture of paddlefish reared in high and low light intensity. These results indicate a lower percentage of protein compared to other sturgeon species, where the protein content of the oarfish muscle tissue is 14% (Bucur et al., 2009) or even 16-19% (Simeanu et al., 2012). Regarding the fat content in the muscle tissue of juvenile paddlefish, low values were recorded in both experimental variants. Based on these data, the species *Polyodon spathula* is placed in the category of fish with a relatively low lipid content (2.45-3.96%), which is confirmed by other authors (Simeanu et al., 2012). Also, in the study on proximate chemical composition analysis of sturgeon *Polyodon spathula* meat aged two and three summers, it was observed that between the two ages, there was no significant difference in the chemical composition of the fillets (Simeanu et al., 2022). Sturgeon as a meat product is a relatively new, albeit burgeoning field, with a protein and fat profile similar to salmonids (Gao et al., 2020; Pelic et al., 2019).

CONCLUSIONS

Light intensity significantly influenced the growth of juvenile paddlefish in RAS. Fish exposed to light at 30 lx showed the highest growth performance of all treatment groups. This information provides a starting point for the rearing of paddlefish in RAS. In this study, in which we examined the responses of paddlefish juveniles to different light intensities to exposure, it was concluded that low light intensity (green color) simulated growth performance compared to high light intensity (white color), which can simultaneously improve growth and not affected of the immune response of the species without stressing paddlefish juveniles. Our results indicate the paddlefish juveniles can adapt to various light intensities and grow favorably under low light conditions in a recirculating aquaculture system. Furthermore, we recommend conducting additional research to enhance the lighting regime to augment both fish production and welfare. Investigating optimal light conditions, such as intensity, duration, and color spectrum, can provide valuable insights into how these factors influence the physiological well-being and growth of fish. This research could contribute to refining aquaculture practices, ensuring not only increased productivity but also the overall health and quality of the fish population. Additionally, a thorough examination of behavioral responses to different lighting conditions can aid in designing environments that promote the natural behaviors of the fish, ultimately contributing to improved welfare and sustainable aquaculture practices.

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