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INFLUENCE OF THE PHOTOPERIOD ON THE GROWTH OF RAINBOW TROUT FRY *(ONCORHYNCHUS MYKISS)* IN INTENSIVE CULTIVATION AT 3,658 M.S.N.M

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Abstract: In the investigation, the effect of photoperiod on the growth of rainbow trout fingerlings (*Oncorhynchus mykiss*) was evaluated in an intensive system. Three experimental photoperiod treatments were used (T1: 12 hours of natural light and 12 hours of artificial light and T2: 24 hours of artificial light) and a control treatment (T3: natural light). In T1 a transparent polyethylene cover was used and in T2 it was covered with a black polyethylene cover. The biological material used was 92,860 rainbow trout fingerlings, with an average weight of 3.0 - 3.5 gr, distributed equally and completely randomly in 9 concrete ponds, three ponds per treatment, with a density of 5.3 kg/m3. The experiment lasted 68 days, during which it was fed daily to satiety. Likewise, such as mortality and measurement of water quality parameters and biweekly biometric samplings were carried out. At the first 30 days, T1 reported the best productive values: Weight gain (GP)=5.53 g, Specific growth rate (TEC)=3.23%, Final weight (PF)=8.91 g, Relative growth factor (FCR)=0.73. After 30 days, T2 reported the best results with the exception of PF.

After the 68 days that the experiment lasted, it was concluded that the application of photoperiod in the stage of rainbow trout fingerlings exposed to photoperiod 12:12 (T1) and 24:00 (T2) were statistically better than the control group ($p<0.05$).

Keywords: Rainbow trout, photoperiod, rainbow trout fingerlings, specific growth rate and conversion factor

INTRODUCTION

The photoperiod is one of the most relevant environmental factors for the development, growth and maturation of aquatic organisms. Numerous studies have shown the positive and negative influence on the different stages of the fish (Aragón-Flores, E. et al., 2014).

Rainbow trout is a species highly valued by aquaculture, therefore, understanding how the photoperiod influences its growth is essential to improve productivity in the culture. There are different environmental factors that interrelated between them influence the growth of fish, such as temperature, light, oxygen to name a few (Blanco, 1995).

For the most part, fish need a minimum amount of light intensity for food visualization, use of energy from food, improve feed conversion, improve the immune system and others (Trippel & Neil, 2003, Monk et al., 2006, Sheng et al., 2006, Ashley, 2007, Karakatsaouli et al., 2010, Stuart & Drawbridge, 2011; Ho nryo et al., 2013, Wang et al., Alabama., 2015 cited in Aragón-Flores E. et al., 2014). Virtually not only growth is synchronized by daylight hours but by all the natural biochemical, physiological, behavioral and functional processes of the fish. The photoperiod is classified as the guiding factor that controls the growth of the fish through the levels of growth hormones (Simensen et al., 2000 cited in Yavuz Sonmez, A. et al., 2009).

Photoperiod manipulation in rainbow trout culture can have important economic benefits. Therefore, the objective of this study was to evaluate the influence of photoperiod manipulation on the growth of rainbow trout fingerlings (Oncorhynchus mykiss) in an intensive culture system under conditions of higher altitude (3658 masl) and lower oxygen pressure characteristic of the Peruvian Andes.

MATERIALS AND METHODS

The investigation was carried out in the facilities of an aquaculture company in the Junín region located at 3658 m.s.n.m. for 68 days. The experiment was established in three treatments (T1, T2 and T3) with three repetitions each 6.58 m3 (9.38 x 1.17 x 0.6 m) of useful water volume. With a total of 92,860 rainbow trout fingerlings with an initial weight of 3.0 – 3.5 gr and an initial stocking load of 5.3 kg/m3 for each pond.

For the evaluation of the effect of photoperiod manipulation, treatment 1 (T1) was defined as 12 hours of natural light and 12 hours of artificial light (12:12). Treatment 2 (T2) with 24 hours of artificial light (0:24). And treatment 3 (T3) or control group with the natural conditions of the photoperiod. The T1 and T2 ponds were conditioned. In T1, the walls and ceiling were protected with transparent polyethylene covers, in order to allow natural light to enter the interior. T2 was protected with a black polyethylene cover, in order to prevent the entry of natural light; for which a darkening structure was conditioned, which generated an environment of artificial photoperiod. The dimensions of the structure for both treatments were 10 m long, 4 m wide, and 2.5 m high.

In T1 and T2, STRIP5050-60 LED lights, 5m long, were used as the artificial lighting source. A green LED STRIP light was installed along the center line of the suspended pond at a height of 40 cm (0.4 m) from the water surface.

The fingerlings of the control group or treatment 3 (T3) remained in the pond with similar characteristics, exposed to the natural photoperiod. Each pond had an independent entrance and exit of water, coming from the Chacarahuanga river.

During the evaluated period, the rainbow trout fingerlings were fed satiety and balanced food was delivered daily by bowling; In addition, mortality and water quality parameters such as temperature, oxygen and pH were recorded, with the exception of the pH that was evaluated weekly. With respect to biometry, the weight (g) and size (cm) of each fish were recorded every fortnight, as well as the lighting level (lux) in each treatment.

For the statistical analysis, ANOVA was used to test the significant differences between treatments and later the Tukey test was used to compare the means of the growth rate (SGR), condition factor (K), feed conversion (FCR) and survival (S); all statistical analyzes were performed using Minitab 19 for Windows 8.

RESULTS AND DISCUSSION

Table 1 shows the results of the means and standard deviation of the productive parameters of the cultured trout in the T1 treatments: 12 hours in natural light and 12 hours in artificial light (LN/LA); T2: 24 hours exposed to artificial light (LA) and T3: 24 hours exposed to natural light (NL).

UNIT WEIGHT AND WEIGHT GAIN

Formerly it was thought that the amount of food and its composition were the main key elements for the growth of fish. However, among the factors studied, manipulation of the photoperiod also influences growth and other metabolic activities (Reynalte-Tataje et al., 2002). The effect of the different treatments on unit weight and weight gain associated with daylight hours in rainbow trout fingerlings is shown in table 1.

The final weight reached after 68 days of experimentation was decisive during the first 30 days and after that until the end of the investigation; significant differences ($P < 0.05$) were observed between the results of the treatments T1 and T3 corresponding to the final weight.

From day 30 it was observed that the final weight reached began to differ in the three treatments evaluated (figure 1), resulting in the fry subjected to treatment T1 gained more weight (8.91 g) than T2 (8.25 g) and T3 (8.05 g).

Finally, on day 68 the fish subjected to T1, T2 and T3 reached final weights of 23.94 g, 23.68 g and 22.09 g respectively. This was because the growth of the fish is regulated by various environmental factors such as

PARAMETERS	PHOTOPERIOD REGIMEN		
	LN/LA (12:12)	LA (24:00)	LN (Natural)
starting average weight (g)	3,39±0.05	3,40±0.04	3,40±0.03
final average weight (g)	23,94±0.43	23,68±0.54	22,09±0.86
Weight gain (g)	20,55±0.39	20,28±0.50	18,69±0.83
initial biomass (kg)	35,00±0.00	35,00±0.00	35,05±0.08
final biomass (kg)	240,37±4.32	239,13±2.39	216,54±5.42
biomass increase (kg)	205,37±4.32	204,13±2.39	181,49±5.34
Growth rate (SGR%)	2,88±0.01	2,86±0.01	2,75±0.04
initial length (cm)	6,71±0.03	6,71±0.02	6,71±0.02
final length (cm)	12,22±0.25	12,07±0.14	12,41±0.08
Survival percentage (%)	97,15±0.00	98,02±0.00	95,10±0.00
Conversion factor (FCR)	0,79±0.01	0,80±0.01	0,83±0.01
condition factor (k)	1,31±0.06	1,35±0.02	1,14±0.05

Table 1: Mean growth parameters of rainbow trout fingerlings (Oncorhynchus mykiss) according to treatment.

LN/LA: T1, LA: T2, LN: T3

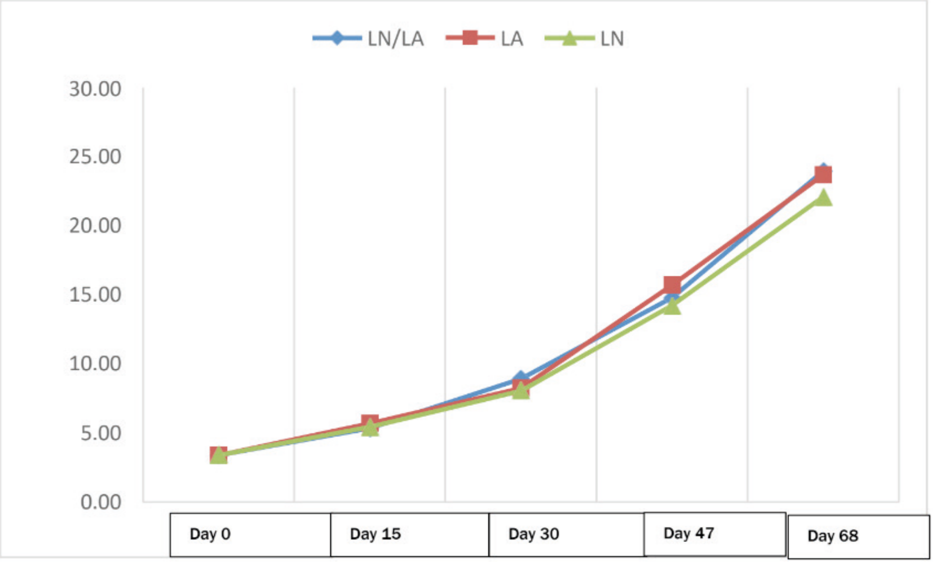

Figure 1: Growth curve (g) of the treatments studied during the experimental period

photoperiod, temperature, sex, genotype, as well as the nutritional status of the fish (Bocuf and Falcón, 2001).

The weight gain at 68 days or the end of the experimental period according to the ANOVA analysis showed significant differences (P< 0.05) between the fish subjected to the treatments T1 and T2 with T3. Treatment T1 presented a numerically higher weight gain (20.55 g) than treatment T2 (20.28 g) and T3 (18.69 g). According to Volkoff et al., (2005) changes in food intake, digestion and specific behaviors are regulated by light. Therefore; the weight gain of rainbow trout fingerlings subjected to artificial photoperiod could mean that fish grown under these conditions have shown better feed efficiency due to the improvement in the digestion process. Yavuz Sonmez et al. (2009) in their studies observed that periods of light hours: darkness of 16:08 obtained the greatest weight gain. These results are similar to those of the present investigation, since the treatments subjected to artificial photoperiod presented the best results of weight gain.

GROWTH RATE

When evaluating the results of the growth rate for each treatment, the influence of the photoperiod was demonstrated, since, according to the ANOVA analysis, there are significant differences (P< 0.05) between the fish subjected to the treatments T1 and T2 with T3. The average SGR values for treatments T1, T2 and T3 were 2.88%, 2.86% and 2.75% respectively. According to Taylor et al (2006) rainbow trout fingerlings (*Oncorhynchus mykiss*) exposed to long photoperiods (18 hours light: 6 hours darkness) were found to directly affect growth. Regarding similar achievements, in works carried out with photoperiods of 16 L: 08 O and 24 L: 00 O, they have shown a positive effect on the growth of larvae of some fish such as: *Oncorhynchus mykiss* "trucha", *Lates calcarifer* "barramundi", *Sparus aurata* "golden", due to increased activity and better visualization of food in fish (Puvanendran & Brown, 2002; Ginés et al., 2004; Biswas et al., 2005).

CONDITION FACTOR

For the rainbow trout species in an average unit weight range of 4 to 23 grams, the expected K values are 0.95 - 1.3 (Morales and Quiroz, 2007). Numerically, at the end of the experimentation, the K values obtained for the treatments T1, T2 and T3 were within the indicated range, so that the rainbow trout fingerlings at the end of the experimental period were found to be in good condition. According to Porter and Col., (1999), keeping fish exposed to artificial light improves performance in terms of growth. The analysis of variance at the end of the experimental period (68 days) showed significant differences (P< 0.05) between treatments T1 and T2 with treatment T3.

FEED CONVERSION

Feed conversion at the end of the experimental period showed a significant difference (P< 0.05) between treatment T1 and T3. Although statistically significant differences were not observed with the average FCR of the T2 treatment; the T2 treatment numerically presented an average FCR better than the treatment exposed to 24 hours exposed to natural light (T3).

According to Webster et al. (2001) the use of photoperiod causes an increase in food consumption in fish and a seasonal boost to their growth. This increase in food intake occurs to maintain the need for energy maintenance, since, for the fish, daylight hours increase, therefore, their activity increases.

On the other hand, Yavuz Sonmez et al. (2009) evidenced in their investigations that rainbow trout fingerlings of 2 g of initial weight exposed to long photoperiods (light:darkness) 12:12, 16:8 and 24:0, statistically presented better feed conversion rates compared to short photoperiods. The results obtained in the present investigation would reaffirm what was described by the author, since the FCR obtained in long photoperiod were better than the natural or control photoperiod.

Although the FCR is influenced by several factors such as density, strain, food and photoperiod; another author states that the FCR is directly influenced by the brand of balanced feed supplied (Uysal and Alpbaz, 2002). In the present investigation, it must be noted that the planting density, strain and balanced food used were the same for all treatments, the only differential being exposure to daylight hours.

SURVIVAL

The average survival of rainbow trout fingerlings at the end of the experimental period for the three treatments were: 97.15% (T1), 98.02% (T2) and 95.10% (T3). At the end of the investigation, there were significant differences ($P< 0.05$) between treatments T1 and T2 with T3. These results are consistent with those obtained by Ergun et al. (2003), who alludes to a better survival rate for rainbow trout (O. mykiss) subjected to a 24-hour photoperiod. Just as some authors point out the positive effect of photoperiod on survival, Villamizar et al., (2009) point out that photoperiod manipulation does not always cause benefits in fish survival, probably as a result of stress caused by excess light.

PHYSICAL AND CHEMICAL PARAMETERS OF WATER QUALITY DURING THE EXPERIMENTAL STAGE

The average values of temperature, oxygen and pH during the experimentation period were found in the optimal range for the growth of rainbow trout (*Oncorhynchus mykiss*); obtaining non-significant differences ($p>0.05$) in all treatments during the experimental phase. In addition, there were no oscillations due to seasonality (began at the end of spring and ended at the beginning of summer). These parameters are among the determining factors in trout production, since the quantity and quality of water will guarantee the optimum growth and development of the fish.

During the experimental period, the temperature values remained between the values considered by Aquino (2009), who points out that the temperature must be between 9 and 17 °C; the average temperature in treatments T1, T2 and T3 were 10.32 °C, 10.26 °C and 10.23 °C respectively.

According to FONDEPES (2014) the oxygen level in the water for fish must not be less than 5.5 mg/l to guarantee survival and a good feed conversion rate, since lower levels can cause stress in the fish and cause death. It is important to mention that the concentration of dissolved oxygen in water is influenced by the variation in temperature, atmospheric pressure and dissolved salts contained in the water, there being an inversely proportional relationship between temperature, atmospheric pressure and dissolved oxygen (FONDEPES, 2014). Rainbow trout being cold water fish require higher levels of oxygen; however, at 3,658 m.s.n.m. the amount of oxygen available in the present investigation was not influenced by pressure. The average dissolved oxygen values in treatments T1, T2 and T3 were 6.82 mg/l, 6.98 mg/l and 6.91 mg/l respectively.

Regarding the pH values obtained after 68 days in the T1, T2 and T3 treatments, they were 7.72, 7.76 and 7.73 respectively. The pH record indicates that the values were in the range of allowable values as stated by Woynarovich et al. (2011), who mentions pH values from 6.5 to 8.0 when they are embryos and fingerlings, which is why it is considered a factor that did not influence the productive parameters evaluated.

LIGHT LEVEL MEASUREMENT

The results of the average lighting level evaluated in the treatments: 12 hours of natural light and 12 hours of artificial light (LN/LA), 24 hours of artificial light (LA) and natural light (LN) were 415 LUX, 403 LUX and >2500 LUX respectively. These results were close to those obtained by Taylor J. F. (2006) in his research with rainbow trout with an average initial weight of 5.1 g, recording a light intensity on the surface of the ponds of 212 ± 129 LUX.

Gilles Boeuf and Pierre-Yves Le Bail (1998) indicate that fish have a specific threshold of light intensity, and that above this it seems that light intensity is not a determining factor in the regulation of fish growth.

CONCLUSION

This study concludes, under the field conditions in which it has been carried out, that the growth of rainbow trout fingerlings was significantly affected ($P< 0.05$) by the photoperiod during the experimental period.

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