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STUDY OF THE BEHAVIOR OF DIFFERENT SOWING DENSITIES OF FINGERLINGS FOR THE FATTENING OF RAINBOW TROUT

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— Abstract—

The behavior of different planting densities of fingerlings (40, 60, 80, and 100 fish/m^2) was studied for the fattening of Rainbow trout (Oncorhynchus mykiss). The fish used were 840 fingerlings of 4 months of age and with an average weight of 24.20 g; and an average size of 2.92 cm in total body length; the same ones that were distributed in a completely randomized block design with three replications per treatment, having a total of 12 experimental units. The average weights at the beginning of the research were 24.20 g and, after seven months, they were 253.75 g. While the total food consumption was 316.81 g during the seven months of evaluation. At the same time, the fish gained 229.55 grams in total. Trout were good food converters since they required between 1.11 and 1.71 kilos of balanced to convert one kilo of meat. Regarding height, there were no significant statistical differences in the treatments, starting with 12.92 cm and finally reaching a total body length of 26.95 cm in the last evaluation (the seventh month).

Keywords

Fingerlings; Rainbow trout.

Rainbow trout (Oncorhynchus mykiss) are native to the watersheds draining the Pacific in North America, ranging from Alaska to Mexico. Since 1874 it has been introduced into the waters of all continents except Antarctica for recreational purposes for sport fishing and aquaculture (FAO, 2020).

The trout is an anadromous species but also sedentary (non-migratory). In the wild, it lives in Mountain Rivers with cold water (Flores, 2018). The Republic of Ecuador has a diversity of climates that encourage productive agricultural and aquaculture activities. It is classified as an agricultural country for being a producer of bananas, flowers, and shrimp. The cultivation of rainbow trout is an option to encourage, due to the favorable conditions offered by the country. This activity has been developed in the inter-Andean region because it has water temperatures between 5ºC and 18ºC and greater water resources (Gallardo Domínguez, 2015).

Imaki (2003) indicates that starting in 1930, hatcheries and fingerling rooms were built in the provinces of Imbabura, Cotopaxi, and Azuay, respectively, with the introduction of embryonated trout eggs whose fry were used to populate the river and lake systems of the Inter-Andean region.

The province of Chimborazo presents in its geographic diversity a great potential of water resources in the different altitudinal floors, helping fish farming to develop with great productive and economic advantages. According to the Ministry of Agriculture, Livestock, Aquaculture, and Fisheries (MAGAP), this type of enterprise has increased substantially in recent years (Morales, 2019).

Trout is a demanding fish in terms of water quality and quantity; they are raised in clean, cold, and well-oxygenated waters (Calle & Calle 2017). In this context, the efficient use of feed would reduce production costs and would have an important impact on profitability, mainly in advanced and larger-scale production systems (Carpio & Tito, 2017).

This research aims to optimize the useful space for trout farming, through the use of an adequate density of fish per square meter, since it is known that in our country this parameter is not taken into account as a technical criterion.

MATERIALS AND METHODS

Location and duration of the experiment

The present investigation was carried out in the fish production program of the Nacional Técnico Autachi, Nitiluisa community, Calpi parish, Riobamba canton, Chimborazo province, Ecuador. This experiment lasted 270 days, distributed in 30 days for pond preparation and fish adaptation; 210 days for trout production, and 30 days for data tabulation, interpretation, and publication.

Experimental Units

In the present investigation, we worked with 840 fingerlings, for which 12 experimental units (ponds) of 1 m^2 by 1 m depth were used, in which the respective treatments were distributed (40, 60, 80, and 100 fingerlings/m^2).

Materials

12 ponds of 1 m^2, 840 fingerlings, balanced feed, thermometer, tape measure, rakes, desk material, pots, methylene blue, antibiotics, formaldehyde, chlorine, common salt, sodium hypochlorite, and necessary cleaning supplies.

Equipment

Precision balance, photographic camera, calculator, hygrometer, ph meter, thermometer.

Facilities

Fattening ponds.

Treatment and experiment's design

The treatments applied in this research were: T1: 40 fingerlings/m^2, T2: 60 fingerlings/m^2, T3: 80 fingerlings/m^2, T4: 100 fingerlings/m^2. They were distributed in a Completely Randomized Block Design (CRBD).

Statistical analysis

The results of the present study were subjected to the following statistical analyses: Analysis of variance (ADEVA), Separation of means test (Duncan, $\alpha \leq 0.05$), and linear regression analysis.

Experimental procedure

Before the beginning of the research, the ponds were prepared and disinfected to form the experimental units of 1 m^2. The fish were distributed according to their weight in each of the blocks, and the treatments were randomly drawn or distributed. All the experimental units had the same treatment and feeding management, and the fish were fed twice during the day.

Fish weight was taken biweekly to calculate weight gain by analysis of variance, as well as feed conversion, which was calculated with feed consumption. We took data on the size at 15 days and at the end of the experiment, the cost of feed per kilogram of weight gain at the end of the fattening phase, as well as the profit/cost.

A necropsy was performed on the dead fish to determine the cause of death, and the weekly and final mortality percentages were taken. At the end of the experiment, 30% of the fish were weighed to analyze the weight gain from the beginning to the end of the fattening phase.

Sanitary program

Fifteen days before starting the experiment, the ponds were cleaned and disinfected with formalin; and three days before the fingerlings' arrival, they were disinfected with methylene blue. The fish underwent a 15-day adaptation stage before starting the experiment, for which they were placed according to the draw of the treatments (40, 60, 80, and 100 fingerlings/m^2), and initial weight and size data were taken. During the research, the study variables continued to be evaluated to determine the benefit/cost. The amount of feed supplied was calculated according to the number of fish, weight, size, and water temperature according to the recommendations of the commercial company.

The ponds were cleaned once a week. Formaldehyde and chlorine were used as disinfectants, and sodium hypochlorite was used to neutralize the chlorine.

RESULTS AND DISCUSSION

Evaluation of weight

In the evaluation at 210 days, the different treatments used did not present significant statistical differences, although the numerical weights were in the following order: 245.93 g for 40 fish/m^2; 258.68 g for 60 fish/m^2; 257.72 g for 80 fish/m^2; and 252.65 g for 100 fish/m^2 (Table 1), which finally proved that the weight variable was not affected by the density of animals per square meter.

From this analysis it was deduced that statistically, the weight was not influential in the fish densities used for the research; this is advantageous, since in most cases, traditionally in reinforced concrete ponds in the Ecuadorian highlands, densities of a maximum of 70 fish/m^2 are used, while if there is sufficient water dosage, 100 fish/m2 could be included (Blanco, 1995) and (Stevenson, 1985). Similarly, Imaki (2003) indicates that, if the water supply conditions are favorable, the ponds can deliver up to 25 kg of fish/m² of surface area, if we consider that each animal can reach 250 grams at the "plate type" we would be talking about 100 fish/m².

Table 1

Weight behavior in trout fattening using different fish densities

VARIABLE Weight	TREATMENTS				MEAN	CV (%)	
	40 fishes/m²	60 fishes/m²	80 fishes/m²	100 fishes/m²			
Initial (gr)	24,95 A	24,02 A	24,02 A	21,73 A	24.20	30.76	ns
At 30 days (g)	43,43 A	47,48 A	47,48 A	38,73 A	44,98	22.26	ns
At 60 days (g)	66,043 A	70,3 A	70,3 A	61,673 A	65,958	20.89	ns
At 90 days (g)	99,05 A	89,767 A	89,767 A	80,237 A	89,741	19.34	ns
At 120 days (g)	142,05 A	138,13 A	138,13 A	132,59 A	138,45	10.62	ns
At 150 days (g)	175,52 A	170,64 A	170,64 A	165,32 A	171,38	9.19	ns
At 180 days (g)	208,98 A	203,39 A	203,39 A	198,07 A	204,37	8.24	ns
At 210 days (g)	245,93 A	257,72 A	257,72 A	252,65 A	253,75	4.89	ns

CV: Coefficient of variation
ns: No statistically significant difference ($P > 0,05$)
Averages with equal letters do not differ statistically according to Duncan's test.

Source: Own elaboration

Evaluation of feed consumption

In the last evaluation at 210 days, the different treatments applied did not present significant statistical differences; however, the feed consumption in numerical form was staggered in the following order: 68.963 g of 40 fish/m²; 68.325 g of 60 fish/m²; 67.119 g of 80 fish/m2 and 65.362 g of 100 fish/m² (Table 2). This would experience us that until the end of the evaluation the variable feed consumption is not affected by the different treatments applied.

Table 2
Feed consumption in trout fattening using different fish densities

VARIABLE Feed consumption (g)	TREATMENT 40 fishes/m²	60 fishes/m²	80 fishes/m²	100 fishes/m²	MEAN	CV (%)	
At 30 days (g)	26,946 A	28,188 A	25,942 A	23,472 A	26,137	30.77	ns
At 60 days (g)	25,727 A	25,645 A	29,959 A	24,976 A	26,576	22.02	ns
At 90 days (g)	42,882 A	33,567 A	35,853 A	30,477 A	35,695	17.87	ns
At 120 days (g)	48,204 A	57,172 A	54,134 A	57,134 A	54,161	14.86	ns
At 150 days (g)	49,258 A	46,544 A	58,894 A	46,277 A	50,243	26.70	ns
At 180 days (g)	57,921 A	57,435 A	56,312 A	54,557 A	56,556	9.19	ns
At 210 days (g)	68,963 A	68,325 A	67,119 A	65,362 A	67,442	8.24	ns
Total	319,9 A	316,88 A	328,21 A	302,25 A	316,81	9.48	ns

CV: Coefficient of variation
ns: No statistically significant ($P > 0,05$)
Averages with equal letters do not differ statistically according to Duncan's test.

Source: Own elaboration

According to the statistical analysis, it was determined that the density of fish per square meter is not influential in the fattening of rainbow trout, i.e. consumption is relatively normal with or without overcrowding, so that sustained management of the trout pond is possible, as long as the flow rates are accurate. According to FAO (2014), the amount of feed to be supplied to each group of trout depends on the type of feed, water quality, temperature, condition, and size of the fish. Similarly, Gómez (2017) mentions that feed should be distributed spreading it to the air, according to the daily ratio that corresponds to each of the ponds, to ensure uniform growth.

Evaluation of weight gain

At 210 days after the last evaluation, the different treatments applied showed no significant statistical differences, therefore the weight gain parameter was scaled as follows: 54.583 g of 100 fish/m²; 54.327 g of 80 fish/m²; 51.637 g of 60 fish/m² and 36.953 g of 40 fish/m² (Table 3). This shows that until the last evaluation, the weight gain variable was not statistically significant due to the treatments.

Table 3
Weight gain in trout fattening using different fish densities

VARIABLE Weight gain (g)	TREATMENT 40 fishes/m²	60 fishes/m²	80 fishes/m²	100 fishes/m²	MEAN	CV (%)	
At 30 days	18,483 A	24,183 A	23,463 A	17 A	20,783	15.87	ns
At 60 days	22,61 A	15,533 A	22,817 A	22,94 A	20,975	28.37	ns
At 90 days	33,007 A	24,093 A	19,467 A	18,563 A	23,783	30.81	ns
At 120 days	43,00 A	51,133 A	48,367 A	52,35 A	48,713	14.77	ns
At 150 days	33,467 A	33,003 A	32,51 A	32,737 A	32,929	4.15	ns
At 180 days	33,463 A	33,00 A	32,747 A	32,743 A	32,988	4.08	ns
At 210 days	36,953 AB	51,637 AB	54,327 A	54,583 A	49,375	13.30	*
Total	220,98 A	232,58 A	233,7 A	230,92 A	229,55	2.89	ns

CV: Coefficient of variation
ns: No statistically significant difference ($P > 0,05$)
*: Statistically different ($P \leq 0,05$)
Averages with equal letters do not differ statistically according to Duncan's test.

Source: Own elaboration

The present research shows that the weight gain in each evaluation, and even in the total period, had no statistical influence on the management of the different fish densities. In this regard, Blanco (1995) and Imaki (2003) mention that as long as there are an acceptable flow rate and complete prophylaxis, it is possible to keep up to 100 fish of 250 g/m² or 25 kilos of plate trout/m² of the pond, without interfering with weight gain.

Evaluation of feed conversion

At the end of the evaluation at 210 days, the four treatments used did not show significant statistical differences, however, the intakes were in the following order: 2.08 of conversion in the experimental unit containing 40 fish/m²; 1.33 of feed conversion for the 60 fish/m² of surface area; 1.24 grams of feed used to gain one gram of meat by the animals, supporting a density of 80 fish/m² and 1.2 of conversion in fish included at the rate of 100 fish/m² (Table 4). This indicated that until the end of the experiment, feed conversion was not affected by animal density under the detailed treatments.

Table 4

Weight conversion in trout fattening using different fish densities

VARIABLE Weight conversion	TREATMENT				MEAN	CV (%)	
	40 fishes/m²	60 fishes/m²	80 fishes/m²	100 fishes/m²			
At 30 days	1,41 A	1,16 A	1,11 A	1,40 A	1,27	25,23	ns
At 60 days	1,15 B	1,73 A	1,32 AB	1,09 B	1,32	12,50	**
At 90 days	1,36 A	1,39 A	1,98 A	1,71 A	1,61	25,47	ns
At 120 days	1,12 A	1,12 A	1,12 A	1,09 A	1,11	1,76	ns
At 150 days	1,47 A	1,41 A	1,80 A	1,41 A	1,52	25,54	ns
At 180 days	1,72 A	1,74 A	1,72 A	1,67 A	1,71	6,39	ns
At 210 days	2,09 A	1,33 A	1,24 A	1,20 A	1,46	37.39	ns
Total	1,44 A	1,36 A	1,40 A	1,31 A	1,38	7.82	ns

CV: Coefficient of variation
ns: No statistically significant difference ($P > 0,05$)
**: Highly statistically different ($P \leq 0,01$)
Averages with equal letters do not differ statistically according to Duncan's test.

Source: Own elaboration

This analysis indicates that all experimental units had the same attitude to convert feed, so the increase in fish density was not influential in the fattening of rainbow trout, which may indicate that in the climatic conditions of the province of Chimborazo, Ecuador, up to 100 fish/m2 or more could be maintained depending on the ponds, without altering the consumption, weights and feed conversions, of course maintaining optimal water conditions (quantity and quality) and adequate environmental temperature.

Colque (2020) mentions that up to 19.62 kg/m² can be maintained, equivalent to 80 fish per m² of surface area; widely surpassed to that stated by Calle & Calle (2017) where they indicate that in the production process of rainbow trout produced based on natural food (organic cereals and fishmeal) 25 to 30 trout/m² can be kept.

Similarly, Morales (2004) in his research on the growth and feed efficiency of rainbow trout in cages, states that the optimal daily ratio found corresponded to 2.9% of body weight.

Size evaluation

At the end of the research, at 210 days the length variable, the four treatments used did not show significant statistical differences, although these lengths numerically were shown in the following order of treatments: 27.35 cm by the 60 fish stabled in one square meter; 27.28 cm length of the fish that supported a density of 80 per unit area; 26.93 cm total body length of the fish that resisted an animal load of 100 per unit area, and 26.25 centimeters the trout with a stocking density of 80 per square meter (Table 5). This evaluation indicates that, until the end, the size is not differentiated by the treatments used.

Table 5

Length behavior in trout fattening with different fish densities

VARIABLE Length	TREATMENT				MEAN	CV (%)	
	40 fishes/m²	60 fishes/m²	80 fishes/m²	100 fishes/m²			
Initial (cm)	12,97 A	13,42 A	13,17 A	12,15 A	12,93	14,28	ns
At 30 days (cm)	15,42 A	15,87 A	14,77 A	14,30 A	15,09	10,12	ns
At 60 days (cm)	16,82 A	17,05 A	16,65 A	16,44 A	16,74	8,45	ns
At 90 days (cm)	18,49 A	18,55 A	17,85 A	18,06 A	18,24	8,42	ns
At 120 days (cm)	20,54 A	21,00 A	20,52 A	20,42 A	20,62	6,43	ns
At 150 days (cm)	22,37 A	22,89 A	22,51 A	22,51 A	22,57	5,53	ns
At 180 days (cm)	24,21 A	24,79 A	24,49 A	24,60 A	24,52	4,82	ns
At 210 days (cm	26,25 A	27,35 A	27,28 A	26,93 A	26,95	4,03	ns

CV: Coefficient of variation
ns: No statistically significant difference (P > 0,05)
Averages with equal letters do not differ statistically according to Duncan's test.

Source: Own elaboration

This research shows that size is not influential on the fish density and growth of rainbow trout. According to Bustamante, Araníbar, Huanca, & Rodriguez (2016), and FAO (2014) the most important factor that regulates fish growth is water temperature since fish do not have their capacity to regulate their body temperature. The higher the water temperature, the higher the metabolic rate.

The species can withstand wide ranges of temperature variation (0-27 °C), but spawning and growth occur in a narrower range (9-14 °C). The optimum water temperature for rainbow trout (Oncorhynchus mykiss) breeding is below 21 °C (FAO, 2020). Thus, in the present investigation, with an average water temperature of 10-11 ºC, plate type trout (250 g) were fattened in 7 months (from fingerling to commercial size); while in waters with an average of 16ºC, fish of the same productive condition would be obtained in 3 or 4 months; therefore, it is convenient to continue investigating the effect of water temperature and climatic conditions on the development of trout, since fish are poikilothermic animals and depend on environmental temperature for their metabolism.

Mortality

Table 6 shows the mortality parameters that could occur in the fattening of rainbow trout under different stocking densities.

Table 6
Mortality of fish reared at different densities

Treatment	Mortality	
	Nº	%
40 Fishes / m²	1	0,12
60 Fishes / m²	1	0,12
80 Fishes / m²	5	0,60
100 Fishes / m²	7	0,83
Total	14	1,67

Source: Own elaboration

It can be seen that the total mortality was 14 specimens out of 840, i.e. 1.67%, of which the experimental units where 100 trout/m² were housed were the ones with the highest rate (0.83%); however, Zapata (2015) states that the low mortality is because there was no excess stress on the fish and the ponds were kept clean and protected from predators.

Similarly, Zambrano (2013) mentions that the percentage of mortality during the entire growth process has been calculated by phases: 6.50% in the fingerling stage, 3.60% in the rearing stage, and 5.40% in the fattening stage, a total of 15.50% during nine months in concrete ponds, a parameter that is higher than our data. With this particular data, it is very advantageous to have a good technological alternative to undertake fish farming in the Ecuadorian highlands.

Economic evaluation

According to this analysis, we can indicate that as the density of fish in the ponds increases, the net income also rises from 0.75 dollars with 40 fish/m²; 3.62 dollars with 60 fish/m²; 5.11 dollars with 80 fish/m²; up to 8.68 dollars in trout that were kept at a rate of 100/m² (Table 7).

Likewise, the Profit/Cost, although positive in all treatments, always the highest density (100 fish/m²) obtained the most optimal indicator, since, for each monetary unit invested, 16 cents of profit or 16% of profitability is obtained in seven months of productive-economic exercise.

Table 7
Economic analysis of trout raised at different densities

DETAIL	Unit.	Amo.	UV	TREATMENTS (TROUTS / M²)			
				40	60	80	100
Ponds (depreciation)	m²	1	2,33	2,33	2,33	2,33	2,33
Divisions (mesh) - deprec.	u	1	0,23	0,23	0,23	0,23	0,23
Supplies	u	1	-	0,20	0,30	0,40	0,50
Medicines	u	1	-	0,10	0,15	0,20	0,25
Food (according to consumption)	kg	-	0,72	9,21	13,69	18,90	21,76
Labor (3 Days/month)	day	-	4	11,76	18,48	24,36	29,4
TOTAL EXPENSES				**23,84**	**35,19**	**46,43**	**54,48**
Average Weight	Kg/fish			0,25	0,26	0,26	0,25
Weight / Experimental Unit	Kg			9,84	15,52	20,62	25,27
TOTAL GROSS INCOME	**$**	**1**	**2,5 / Kg**	**24,59**	**38,80**	**51,54**	**63,16**
NET INCOME				**0,75**	**3,62**	**5,11**	**8,68**
PROFIT / COST				**1,03**	**1,10**	**1,11**	**1,16**

Am: Amount
VU: Unit value

Source: Own elaboration

CONCLUSIONS AND RECOMMENDATIONS

Throughout the research, no significant statistical difference was found in the different variables, which means that it is convenient to raise to 100 fish/m², as long as there are optimal water conditions (quantity and quality) and adequate environmental temperature.

Trout weights averaged 44.98, 65.95, 89.74, 138.45, 171.38, 204.37, and 253.75 grams from the first to the seventh month of evaluation, respectively. The trout were good feed converters since they required between 1.11 and 1.71 kilos of feed to convert one kilo of meat.

In the size aspect, there were no statistical differences between treatments, although the general averages were: 15.09 cm in the first month, 16.74 cm in the second month, 18.24 cm in the third month, 20.62 cm in the fourth evaluation, 22.57 cm in the fifth month, 24.52 cm in the sixth month and finally 26.95 cm in the last evaluation (the seventh month).

According to the economic analysis, it is possible to recommend the management of up to 100 fish per square meter of pond surface for the breeding of rainbow trout in the Ecuadorian highlands, depending on the availability of water (flow) and its quality, since in this particular case space and the investment are optimized.

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