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A comparison between elevated and submerged horizontal spray bars

Abstract

Horizontal spray bars are one type of water inlet used in circular rearing tanks. While typically elevated above the water surface, they can also be submerged to change flow dynamics and potentially influence fish behavior. This study compared the growth of juvenile rainbow trout (*Oncorhynchus mykiss*) reared with a single submerged horizontal spray bar versus a single elevated horizontal spray bar. In the first experiment Kamloop strain rainbow trout were reared for 120 days in tanks with elevated or submerged spray bars. No significant differences in gain, percent gain, feed conversion ratio, specific growth rate, and individual fish length, weight, and condition factor were observed between the treatments. Similar results were observed in a second 97-day experiment using Shasta strain rainbow trout. These results indicate that growth is similar with either elevated or submerged spray bars. The use of either spray bar location can thus be based on other factors.

Keywords: submerged spray bar, rainbow trout, *Oncorhynchus mykiss,* gain

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Introduction

Water can enter fish rearing units via a number of different structures. Spray bars are a type of water inlet consisting of a pipe with various numbers of holes. Spray bars can provide aeration, as well as be adjusted to influence water velocities within tanks. Such adjustments are particularly important to obtain hydraulic self-cleaning in circular tanks.[1-3]

Spray bars can be orientated horizontally, vertically, or horizontally and vertically combined. In addition, they can be elevated above the water surface or submerged below it. While elevated spray bars are typically used, the use of submerged spray bars in conjunction with circular tanks has also been used in recirculating aquaculture systems.[4]

While considerable research has evaluated how submerged spray bars affect in-tank water velocities,[1-6] hydrodynamics,[7-9] and fish behavior,[10,11] few studies have evaluated fish growth when reared with submerged spray bars. Ross et al.[12] reported that rainbow trout (*Oncorhynchus mykiss*) grew slower in circular tanks with submerged spray bars compared to cross-flow and plug-flow tanks. Similarly, Ross and Watten[13] found that higher densities of lake trout (*Salvelinus namaycush*) reared in circular tanks with submerged spray bars had reduced growth compared to cross-flow and plug-flow tanks. However, neither of these studies directly compared submerged spray bars to the more commonly-used elevated spray bars in circular tanks.

This study was undertaken because of the relative lack of information of submerged spray bars on fish growth. The objective of this study was to evaluate the effect of a single horizontal elevated spray bar compared to a single horizontal submerged spray bar on the growth of juvenile rainbow trout reared in circular tanks.

Methods

Two separate experiments were conducted at McNenny State Fish Hatchery, Spearfish, South Dakota, USA using degassed and aerated well water at a constant temperature of 11° C (total hardness as $CaCO_3$, 360 mg L^{-1}; alkalinity as $CaCO_3$, 210 mg L^{-1}; pH, 7.6; total dissolved solids, 390 mg L^{-1}). Oxygen levels were at full saturation in water after aeration. The experimental units for both studies were 2,000-L circular tanks (1.8 m diameter, 0.8 m deep, 0.6 m operating depth). In the first experiment, approximately 1,600 (4.73 kg $tank^{-1}$) juvenile Kamloop strain rainbow trout (initial mean ± SE; total length 60.9 ± 1.1 mm, weight 3.0 ± 0.1 g; N = 40) were placed into fourteen tanks on December 21, 2021. This experiment lasted 120 days, ending on April 19, 2022. In the second experiment, approximately 2,300 (8.52 kg $tank^{-1}$) juvenile Shasta strain rainbow trout (initial mean ± SE; total length 70.0 ± 0.0 mm, weight 4.0 ± 0.0 g; N = 50) were placed into fourteen tanks on May 20, 2022. This experiment lasted 97 days, ending on August 25, 2022.

In both experiments, seven tanks had an elevated spray bar (Figure 1) and seven had submerged spray bars (Figure 2). All tanks were covered by a sheet of corrugated plastic with a small opening for feed delivery as described by Walker et al.[14] Tanks also contained four aluminum angles as vertically-suspended environmental enrichment as described by Krebs et al.[15] The cover and environmental enrichment are illustrated in Figure 3.

Figure 1 Image of a circular tank with an elevated horizontal spray bar.

Figure 2 Image of circular tank with submerged horizontal spray bar.

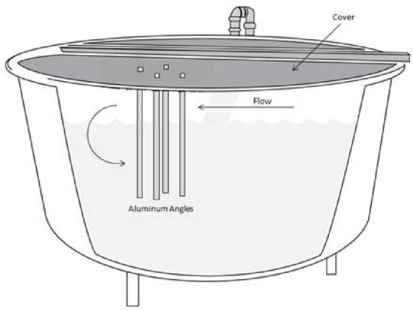

Figure 3 Diagram of a circular tank showing the cover and vertically-suspended environmental enrichment (aluminum angles).

Fish in both experiments were fed 1.5mm extruded trout diet (Pro-tec, Skretting, Tooele, Utah, USA) every 15-min during daylight hours using automatic feeders. Feeding rates were determined by the hatchery constant method,[16] with an expected feed conversion ratio of 1.1 and a projected growth rate of 0.75cm d^{-1}, which was slightly above satiation.

At the end of both of the experiments, final tank weights were obtained by weighing all of the fish in each tank to the nearest 0.1 kg. In addition, ten fish per tank were individually measured (total length), to the nearest 1.0 mm, and weighed to the nearest 0.1 g. Gain, percent gain, feed conversion ratio (FCR), specific growth rate (SGR), and condition factor (K) were calculated using the following formulas:

$$Gain = ending\ tank\ weight - starting\ tank\ weight$$

$$Gain\% = 100 * \frac{gain}{starting\ tank\ weight}$$

$$Feed\ conversion\ ratio\ (FCR) = \frac{food\ fed}{gain}$$

$$Specific\ Growth\ Rate\ (SGR) = 100 * \frac{\ln(end\ weight) - \ln(start\ weight)}{number\ of\ days}$$

$$Condition\ Factor\ (K) = 10^5 * \frac{fish\ weight}{fish\ lenght^3}$$

Data were analyzed using the SPSS 24.0 software (IBM, Armonk, New York, USA), with significance predetermined at $P < 0.05$. T-tests were used for comparisons between treatments. Because the tanks, and not individual fish, were the experimental unit, the mean of individual fish data for each tank was used for statistical analysis (N = 7). Percentage data were log transformed before analysis to stabilize the variances.[17]

Results

In the first experiment with Kamloop strain rainbow trout, there were no significant differences in gain, percent gain, feed conversion ratio, and percent mortality between tanks of fish reared with elevated or submerged spray bars (Table 1). Individual fish length, weight, condition factor, and specific growth rate were also not significantly different between treatments (Table 2).

Table 1 Mean (± SE) final total tank weight, gain, percent gain, feed conversion ratio (FCR[1]), and percent mortality of Kamloop strain rainbow trout reared in circular tanks with either an elevated or submerged spray bar (N=7)

	Elevated	Submerged	*P*
Tank weight (kg)	114.6 ± 3.4	116.4 ± 3.5	0.72
Gain (kg)	109.9 ± 3.4	111.7 ± 3.5	0.72
Gain (%)	2,339 ± 73	2,376 ± 74	0.72
FCR	0.87 ± 0.03	0.86 ± 0.03	0.73
Mortality (%)	1.3 ± 0.3	1.8 ± 0.4	0.34

[1]FCR = food fed/gain

Table 2 Mean (± SE) final individual fish total length, weight, specific growth rate (SGR[1]), and condition factor (K^2) for Kamloop strain rainbow trout reared in circular tanks with either an elevated or submerged spray bar (N=7)

	Elevated	Submerged	P
Length (mm)	182 ± 2.2	181 ± 3.1	0.81
Weight (g)	75.4 ± 3.1	74.2 ± 3.6	0.82
SGR	2.7 ± 0.03	2.7 ± 0.04	0.79
K	1.3 ± 0.01	1.3 ± 0.01	0.97

[1]SGR = 100 x [(ln(end weight) – ln(start weight)) / number of days]

[2]K = [weight / ($length^3$)] x 10^5

The results from the second experiment with Shasta strain rainbow trout were similar to the first. Gain, percent gain, feed conversion ratio, and percent mortality were not significantly different between tanks of fish reared with elevated or submerged spray bars (Table 3). There were also no significant differences in individual fish length, weight, condition factor, and specific growth rate between the treatments (Table 4).

Table 3 Mean (± SE) final total tank weight, gain, percent gain, feed conversion ratio (FCR[1]), and percent mortality of Shasta strain rainbow trout reared in circular tanks with either an elevated or submerged spray bar (N = 7)

	Elevated	Submerged	P
Tank weight (kg)	86.6 ± 1.0	85.5 ± 1.2	0.48
Gain (kg)	78.1 ± 1.0	77.0 ± 1.2	0.48
Gain (%)	919 ± 11.7	906 ± 14.4	0.48
FCR	0.90 ± 0.01	0.90 ± 0.01	0.47
Mortality (%)	0.22 ± 0.04	0.18 ± 0.04	0.49

[1]FCR = food fed/gain

Table 4 Mean (± SE) final individual fish total length, weight, specific growth rate (SGR[1]), and condition factor (K^2) for Shasta strain rainbow trout reared in circular tanks with either an elevated or submerged spray bar (N = 7)

	Elevated	Submerged	P
Length (mm)	148 ± 2	146 ± 2	0.53
Weight (g)	38.8 ± 1.7	35.9 ± 2.4	0.34
SGR	2.4 ± 0.05	2.4 ± 0.07	0.32
K	1.2 ± 0.01	1.1 ± 0.04	0.27

[1]SGR = 100 x [(ln(end weight) – ln(start weight)) / number of days]

[2]K = [weight / ($length^3$)] x 10^5

Discussion

This is the first study to directly compare elevated and submerged horizontal spray bars in circular tanks. The results from both

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experiments clearly indicate no impacts of spray bar location on the growth and hatchery rearing performance of juvenile rainbow trout. Two prior studies appeared to indicate slower growth of rainbow and lake trout in circular tanks with submerged spray bars.[12,13] However, these prior studies did not directly control for spray bar location, focusing instead on cross-flow and plug-flow tanks. Specifically, Ross et al.[12] observed slower rainbow trout growth rates in circular tanks with submerged spray bars compared to cross-flow and plug-flow tanks. Similarly, Ross and Watten[13] observed reduced growth in lake trout reared in circular tanks with submerged spray bars, again compared to cross-flow and plug-flow tanks.

Numerous studies have documented that submerged spray bars can influence in-tank water velocities and tank hydrodynamics.[1-9]. In addition, submerged spray bars may potentially impact fish behavior.[10,11] Because this study indicates that spray bar location does not impact rainbow trout growth, decisions on which location to use can be based on tank hydraulics, fish behavior, or other factors.

Different strains of rainbow trout may exhibit varying responses to identical treatments, which could make the results of this study specific to both the species and strains used.[18,19] In addition, the results of this study may have been impacted by the use of overhead cover and vertically-suspended environmental enrichment. While tank covers and environmental enrichment have been shown to positively impact fish growth and feed conversion ratio,[22-28] any potential interactions among spray bar location, amount of overhead cover, and vertically-suspended environmental enrichment is unknown.

The impact of submerged spray bars on in-tank noise levels was not measured in this study, although it is possible that in-tank noise levels may decrease when spray bars are submerged. Elevated noise levels can exacerbate abnormal otolith formation in hatchery-reared fish, causing permanent hearing impairment and potentially reducing survival rates when fish are release into natural waters.[29] Thus, the potential impact of spray bar location on in-tank noise levels may have important implications for conservation fish hatcheries.[30,31]

In conclusion, horizontal spray bar may be located either above or below the water surface of circular tanks without affecting the growth, survival, and rearing efficiency of juvenile rainbow trout. Future studies should examine the effects of spray bar location on the growth of other strains of rainbow trout and fish species. Additionally, research exploring the potential impacts of spray bar location on otolith formation and post-stocking survival should be conducted.

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Conflicts of interest

We declare that there is no conflict of interest of any kind.

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