FEEDING TECHNIQUE DOES NOT IMPACT THE GROWTH OF RAINBOW TROUT RECEIVING SUB-SATIATION RATIONS

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ABSTRACT

Three feeding techniques were evaluated during the rearing of domesticated rainbow trout (*Oncorhynchus mykiss*) in production raceways. Eight-hour continuous-feeding belt feeders, once-a-day hand feeding, and demand feeders were used to dispense feed at a projected growth rate of 0.060 cm/day, approximately 75% of satiation feeding-levels. The experiment lasted for 164 days, during which individual trout weight increased from 33 to 180 g. No significant differences in total raceway weight gain, food conversion ratio, individual fish length or weight, percent fin length, or survival was observed among the three feeding techniques. However, there was significantly greater variation in individual fish weight in the fish from raceways fed by demand feeders compared to the other feeding techniques. Once-a-day hand feeding is recommended for juvenile domesticated rainbow trout at less-than-satiation feeding levels to maximize the efficient use of hatchery labor and to reduce costs associated with unnecessary equipment and maintenance.

Keywords

Rainbow Trout, *Oncorhynchus mykiss*, Feeding, Demand Feeder, Belt Feeder

INTRODUCTION

Feeding fish is one of the most basic and important components of aquaculture (De Silva and Anderson 1995), and feeding methods must be economical and efficient (Barrows and Hardy 2001). Successful feeding techniques are those that deliver the necessary nutrients to the fish, but also minimize waste (Noble et al. 2007). Inefficient feeding can cause inadequate or unknown growth, poor water quality, and increased production costs (Guillaume et al 1999).

Feeding techniques can be categorized as either hand feeding or automatic (mechanical) feeding (Barrows and Hardy 2001; Carter 2015). Hand feeding is the most primitive technique, and may be the most widely used

(Piper et al. 1982; Carter 2015). Hand feeding can occur multiple times each day, and has the benefit of allowing for timely observations of fish health and rearing conditions (Barrows and Hardy 2001; Graig and Helfrich 2009). However, hand feeding requires a large input of labor (Carter 2015). Although requiring an initial input of capital, automatic feeding using mechanical devices has lower labor requirements (Piper et al. 1982; Aloisi 1994). In addition, they can efficiently feed either continuously or multiple times per day, and may improve fish growth and rearing efficiencies (Carter 2015).

Belt feeders and demand feeders are two types of mechanical feeders frequently used during rainbow trout (*Oncorhynchus mykiss*) rearing (FAO 2016). Neither of these feeders require electricity to operate. Belt feeders are powered by wind-up springs and dispense feed continually throughout a several hour time period (Graig and Helfrich 2009). They must be refilled daily. Demand feeders are suspended over rearing units and have a trigger that the fish activate to release food, thereby feeding on demand (Piper et al. 1982; Graig and Helfrich 2009). In contrast to belt feeders, demand feeders do not necessarily have to be refilled daily if fish are allowed to feed to satiation, depending on the size of the hopper. No published studies have evaluated the use of belt feeders, but several have compared the use of demand feeders in comparison to hand feeding. Aloisi (1994) indicated that demand feeders saved labor and were a cost-effective alternative to hand feeding during the rearing of lake trout (*Salvelinus namaycush*), while Suzuki et al. (2008) observed increased growth and feed consumption in rainbow trout fed with demand feeders. In comparison to hand-feeding to satiation, the use of demand feeders has led to improved feed conversion ratios, improved water quality, and improved dress-out weights (Boydstun and Patterson 1982; Tipping et al. 1986; Suzuki et al. 2008). However, if fish are fed to less-than-satiation, demand feeders must be refilled daily because rations must be restricted; the amount of feed the fish receive each day must be regulated.

In contrast with commercial aquaculture where fish are typically fed to satiation to maximize growth (Meade 1989; Carter 2015), hatcheries producing fish for recreation or conservation may restrict feed rations to produce fish at specific sizes on specific dates to maximize post-stocking survival or angler satisfaction (Flagg and Nash 1999; Lorenzen 2000). The feeding methods used to grow fish as quickly as possible may not be the most efficient when fish are fed to less than satiation.

Several feeding methodologies have yet to be evaluated. There have been no prior evaluations of belt feeder use during the feeding of salmonids in comparison to other feeding techniques, there have been no prior evaluations of demand-feeder use at less-than-satiation levels, and there have been no studies comparing hand-feeding with mechanical feeders at feeding levels below satiation. The objective of this study was to compare the use of belt feeders, demand feeders, and once-a-day hand feeding on the rearing performance of rainbow trout fed at a level well below satiation.

METHODS

The experiment was conducted from 20 September 2007 to 1 March 2008 at McNenny State Fish Hatchery, rural Spearfish, South Dakota, using degassed and aerated well water at a constant temperature of 11°C (total hardness as $CaCO_3$, 360 mg/L; alkalinity as $CaCO_3$, 210 mg/L; pH, 7.6; total dissolved solids, 390 mg/L). Three feeding methods were used in this experiment: once-a-day hand feeding, belt feeders, and demand feeders. Three thousand "shasta strain" rainbow trout (mean initial length and weight of 139 mm and 33 g), were placed in nine separate covered raceways (30.5 m long, 2.4 m wide, 0.76 m deep). Three raceways were fed once-a-day by hand at approximately 08:30 a.m. Three raceways were each fed by two belt feeders (Pentair Aquatic Eco-Systems, Cary, North Carolina) which were filled each day at 08:30 a.m. and dispensed food continuously for approximately 12 hours. Three raceways were each fed by two demand feeders (Babington Enterprises Inc., Hagerman, Idaho) which were filled at 08:30 a.m. each day. All units from each treatment received the same amount of feed each day throughout the trial, with 469 kg fed to each raceway during the duration of the experiment. Feeding levels were based on a hatchery constant of 6.6, with a planned feed conversion of 1.1 (Buterbaugh & Willoughby 1967).

At both the start and end of the 164 day experiment, 30 fish from each raceway were weighed individually to the nearest 1.0 g and measured to the nearest 0.1 mm. Dorsal, pectoral, and pelvic fins were also measured to the nearest 0.1 mm, with fin length standardized using the Kindschi (1987) formula: Fin length (%) = ([fin length (mm) / standard length (mm)] × 100). Total weights were also recorded for each raceway unit at the start and end of the experiment, with weight gain calculated by subtracting the initial weight from the ending weight. The amount of food fed and mortalities were recorded daily. Feed conversion ratio (FCR) was calculated by the formula: FCR = [food fed (kg) / weight gain (kg)].

Levene's test was used to compare the variances in the data among the treatments (Kuehl 2000). Because the variances were significantly different in one of the variables, the nonparametric Kruskal-Wallis H test (one-way analysis of variance on ranks) was used for further data analysis (Ott 1984). Significance was predetermined at $P < 0.05$.

RESULTS

There was no significant difference in weight gain or feed conversion ratio among the three treatments (Table 1). Mean weight gain was very similar among the raceway units, ranging from 422.3 to 437.9 kg in those raceways fed by hand, from 430.0 to 437.9 kg in those raceways fed using belt feeders and from 431.6 to 445.9 kg in the raceways fed with demand feeders. Feed conversion among all of the raceways was very similar, ranging from 1.05 to 1.11. Mortality in all units was negligible, with no significant differences among treatments.

No significant differences were observed in individual fish weights or lengths among the treatments (Table 2). However, variability in weight of fish fed by demand feeders was significantly higher (P = 0.024) than fish fed by hand or by belt feeders. There were no significant differences in percent dorsal, pectoral, and pelvic fin length among all of the treatments.

Table 1. Mean (SE) tank weights, weight gain, feed conversion ratio, and mortality of Shasta strain rainbow trout fed either by hand, belt feeders, or demand feeders.

	Feeding Technique		
	Hand	**Belt Feeders**	**Demand Feeders**
Start weight (kg)	99.8 (0.0)	99.8 (0.0)	99.8 (0.0)
End weight (kg)	530.4 (4.5)	534.1 (2.8)	538.7 (4.1)
Gain (kg)	430.6 (4.5)	434.3 (2.8)	438.9 (4.1)
Feed conversion ratio	1.09 (0.01)	1.08 (0.01)	1.07(0.01)
Mortality (%)	0.12 (0.01)	0.11 (0.01)	0.10 (0.01)

Table 2. Mean (SE) weight, length, and percent dorsal, pectoral, and pelvic fin length from Shasta strain rainbow trout fed either by hand, belt feeders, or demand feeders.

	Feeding Technique		
	Hand	**Belt Feeders**	**Demand Feeders**
Weight (g)	183 (6)	181 (1)	176 (14)
Length (mm)	265 (4)	263 (3)	262 (4)
Dorsal fin (%)	10.0 (0.4)	10.3 (0.3)	11.0 (0.5)
Pectoral fin (%)	11.8 (0.0)	11.4 (0.1)	11.4 (0.2)
Pelvic fin (%)	11.7 (0.9)	10.6 (0.3)	10.9 (0.3)

DISCUSSION

This is the first study to compare feeding by hand, demand feeders, and belt feeders under a less-than-satiation feeding regime. It is also the first study to include any evaluation of belt feeders directly. In a study comparing demand feeders with continuous feeding, which would be analogous to using beltfeeders, Valente et al. (2001) observed improved growth rates and feed conversion ratios in demand-fed rainbow trout. In contrast to the approximately 1.0% of body weight used in this study, the relatively higher rate of 2.5% body weight used by Valente et al. (2001) makes it difficult to compare the results between the two studies. The results of this study are similar to that of Paspatis et al. (1999), who reported no significant difference in sea bass (*Dicentrarchus labrax*) fed by hand or continuously.

There is considerably more published research on the use of demand feeders than belt, or other continuous, feeders. Shima et al. (2001) observed that rainbow trout using demand feeders had improved feed conversion ratios compared to those fed with automatic feeders. However, they used much higher feeding rates, with fish on automatic feeders fed at a rate of 2.87% or 2.84% body weight, whereas demand-fed fish consumed rations at a rate of 3.05% body weight. Bailey and Alanärä (2006) reported similar findings for Atlantic salmon (*Salmo salar*). Suzuki et al. (2008) reported a higher specific growth rate in rainbow trout fed using demand feeders compared to hand-fed trout, but also noted increased feed consumption. However, several studies reported different results, similar to the lack of differences between demand-fed and hand-fed trout in this reduced-ration study. Wagner et al. (1996) found no differences in growth or food conversion ratio in rainbow trout fed at rates of approximately 4% body weight by hand or to satiation by demand feeders. Yamamoto et al. (2002) also found no difference in rainbow trout rearing performance when they were fed to satiation by hand or demand feeders, and Aloisi (1994) reported similar results comparing demand and hand-feeding in lake trout. Differences in feeding rates among the studies, as well as different demand feeder spacing (Wagner et al. 1996), likely explain the differences in the observed results. Genetics may also play a role. Valente et al. (2001) compared two feeding techniques with two strains of rainbow trout, and observed dissimilar responses from each strain. The Shasta strain used in this study is extremely domesticated (Needham and Behnke 1962), and other, more-wild strains may not respond similarly to feeding techniques when fed a reduced ration.

Growth and feed conversion ratios from rainbow trout fed a reduced ration were not significantly influenced by any of the feeding methods used in this study. Similarly, Noble et al. (2007) also observed no differences in growth or feed conversion ratio among fish getting one large meal, three smaller meals, or unlimited access. This may be explained by rainbow trout consuming almost 100% of the feed pellets irrespective of feeding method (Brännäs and Alanärä 1992). At the less-than-satiation rations used in this study, portion size was likely not an issue. Bailey and Alanärä (2006) reported that trout receiving a single large portion size had poorer feed conversion ratios than trout fed numerous smaller portions. This may be occurring because, with only one large feeding, the fish consume more feed than needed to cover their daily metabolic requirements (Bres 1986). Linnér and Brännäs (2001) showed that reducing the number of daily feeding events from 32 to 8 significantly improved rainbow trout growth. However, Johansen and Jobling (1998) and Juell et al. (1994) reported no effect of feeding frequency on the growth rate of Atlantic salmon. Cho (1992) recommended feeding rainbow trout one to four times daily based on body size and temperature.

The increase in size variability in the demand-fed fish in this study is similar to that reported by Kindschi (1984) and Aloisi (1994). In addition, Johansen and Jobling (1998) observed that Atlantic salmon fed automatically multiple times during the day had increased size variability compared to those fed fewer times. However, Shima et al. (2001) reported lower size variation in rainbow trout fed by demand feeders than in fish fed continually for 12 or 24 hours a day, and Paspatis et al. (1999) observed that, when fed to satiation, juvenile Atlantic salmon grew more homogenously when using self-feeders compared to continuous feeders. Wagner et al. (1996) also reported no differences in size variability among rainbow trout fed at high rates either by hand or by demand feeders. The increased size variability in the demand-fed fish in this study may be due to more aggressive fish dominating the immediate area around the trigger (Brännäs and Alanärä 1993) in combination with limited feed supplies. The dominant fish could eat at their leisure to satiation throughout the day, while subordinate fish would likely receive much less feed. However, hand-feeding once-a-day would likely spread the feed out to more of the population, making it more difficult for aggressive individuals to eat substantially more food than other fish.

The lack of any effect of feeding type on fin condition observed in this study is supported by others. Wagner et al. (1996) also observed no differences in fin condition between demand-fed and hand-fed rainbow trout. Noble et al. (2007) also reported no effect of feeding frequency on rainbow trout fin condition. However, Suzuki et al. (2008) reported that fewer demand-fed rainbow trout experienced dorsal fin damage, in comparison to those fed by hand.

In conclusion, the lack of differences on rainbow trout growth, feed conversion, and fin condition among the three feeding techniques used in this study indicates that once-a-day hand-feeding is preferable when rainbow trout are fed at rates substantially below satiation. Demand feeders require occasional cleaning and tuning of actuation, along with customized mounting hardware. Belt feeders also require mounting hardware, occasional cleaning, lubing of metallic parts, and repair or replacement of the clockwork mechanisms. Because of the simplicity of hand feeding once a day, this method is recommended as the most efficient way to deliver feed to rainbow trout being fed a restricted diet.

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