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Short Communication

Short-term Feeding Cessation Prior to Harvest Does Not Affect Fillet Yield in Rainbow Trout

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Abstract

Current practice in commercial, freshwater rainbow trout operations in the USA is to feed until the day prior to harvest. However, from what is known about fish growth and metabolism during periods of starvation, this may not be the best economic practice, since growth and macronutrient deposition are affected little during short-term starvation. Therefore, cessation of feeding even a few days before harvest has the potential to produce substantial economic savings to trout growers with little or no impact on yield. To investigate this, we withheld feed from market size rainbow trout (~500 g) for 1, 2, 3, 4, and 8 days prior to harvest and evaluated the effects on body weight, fillet yield (% of whole body wet weight), and whole body proximate composition. This study was conducted in a research tank system in which 3rd use water (2 raceway passes), and commercial culture conditions were replicated as closely as possible. Weight gain, fillet yield, and proximate composition were not significantly affected (P>0.05) by short-term feeding cessation. Because feed is the primary cost in commercial trout operations, cessation of feeding 8 days prior to harvest has the potential to provide a significant reduction in feed costs for both large and small rainbow trout operations by reducing feed use 2% annually.

ABBREVIATIONS

DO: Dissolved oxygen; GPM: Gallons per minute; $NH4^+$ N: Ammonium; Sp Cond: Conductivity; TDS: Total dissolved solids

INTRODUCTION

Worldwide rainbow trout production is approximately 800,000 tons per year [1]. In the United States, the production of rainbow trout is second only to catfish in finfish aquaculture, where approximately 65 million pounds of trout are raised for commercial consumption, with several million more pounds of fish also reared for conservation stocking, pond stocking, and sport fishing. Rainbow trout have been commercially reared for over 150 years, and current freshwater production is primarily conducted in cement raceways utilizing flow-through, serially reuse water. For processing, fish are typically harvested between 0.5-1 kg (approximately 1-2 lbs), but some producers grow and harvest fish up to 2.75 kg (approximately 6 lbs) [2]. Harvesting practices vary among producers, but most commercial growers continually feed their fish, withdrawing feed only just prior to harvesting. The premise behind this practice is to maximize growth, where total animal weight is equated to fillet production. This makes sense for commercial growers that sell whole fish, but for processors whose end products are fillets; this might not be the best strategy. Under the proper conditions, rainbow trout grow exceptionally well. However, as trout approach harvestable size, growth rates decrease significantly [3,4].

A concern of salmonid producers is whether there is benefit in feeding fish to the point of harvest. When fish are removed from feed, they typically lose several grams in weight over the next several days; however, this initial weight loss is primarily due to the evacuation of the stomach and intestinal tract contents [5-8]. Since producers feed the fish several times during the day, the fish are constantly processing feed. Tissue loss, especially muscle, is thought to occur after a much greater prolongation without feed [7]. Currently, feed is the single highest cost in most aquaculture production operations, responsible for greater than 60% of production costs at some facilities [9]. Because the majority of feed costs occur during the grow-out period, which proportionately becomes greater as the fish become larger, producers have hypothesized that considerable economic savings may exist if fish are taken off of feed at some point prior to harvest instead of feeding right to harvest, without a corresponding loss in yield. For salmonids and many other species of fish, periods of reduced food intake are a normal phase in their life history [10]. Cessation of feeding studies have been conducted in the laboratory and primarily evaluated the effects of starvation in starvation-re feeding, metabolism and muscle turnover, and compensatory growth, with time off-feed lasting anywhere from 1 day to longer than 3 months [8,11,12, 13]. Other studies have shown that short-term starvation does not affect flesh quality or physiological welfare (i.e. stress) [14, 15]. However, most studies have not focused on commercial aspects specifically related to time off-feed prior to harvest and its effect on fillet yield.

In commercial production, water is often used multiple times for growing fish. First-use water is used in hatching eggs and rearing fry, as these fish are the most sensitive and susceptible to health issues when reared under reduced water quality. The water that flows from the earlier rearing stages is then gravity passed multiple times through downstream raceways where increasingly larger fish are reared. The serial reuse of water from one raceway to another allows the water to be used multiple times but can have adverse effects on fish. Prior experience shows that fish in first-use water cannot be directly transferred to fifth-use or further removed water stages without a significant loss in growth and high mortality with fish <100 g suffering the biggest impact. As fish within the production facility get larger, they are progressively moved into lower quality water and in so doing gain a tolerance to poorer water conditions. Because our research focuses on implementing basic science determined in the laboratory and employing it in an applicable manner, testing was done in tanks receiving flow-through water that had previously been passed through two commercial raceways (3rduse). Our primary goal was to determine if short-term withholding of feed from rainbow trout would produce fillet yields similar to the industry standard of feeding until the day prior to harvest.

MATERIALS AND METHODS

Experimental Tank System and Fish Stocking

This study was conducted in outdoor tanks capable of receiving water from production raceways at Snake River Farm, Clear Springs Foods, Inc., Buhl, ID. This system has thirty-six 400 L tanks arranged in three banks of 12 tanks in which the experimental tanks can receive the same water as the production trout raised in serial reuse water. Two banks of 12 tanks were supplied with 3rduse water (passed through 2 production scale raceways of fish) for the study. A total of 20 tanks were used in the study: five feeding cessation treatments randomly allocated to four tanks each so that 2 tanks for each treatment were represented in each bank of tanks. Juvenile rainbow trout were netted from an adjacent raceway at Snake River Farm, anesthetized with tricaine methanesulfonate (MS-222; 50 mg/L), and hauled in a fish transport tank that received supplemental oxygen. Trout were then sorted and weighed, and 15 fish were randomly stocked in each experimental tank (4 tanks/treatment). After a two week acclimation period, fish were counted and group-weighed (475.8 ± 37.8 g), and the study initiated. Tank conditions were regulated to approximate conditions in the raceways at Snake River Farm with an initial stocking density of 21.6 kg/m^3 and approximately 4 water turnovers per hour (6 GPM). Water quality in tanks was monitored with eight 6920 V2 water quality sondes/data loggers containing temperature, conductivity (SpCond), dissolved oxygen (DO), ammonium (NH_4^+ N), pH, total dissolved solids (TDS), and turbidity sensors (YSI, Inc., Yellow Springs, OH). Sondes were randomly allocated to one tank per experimental treatment, and water quality data were recorded for 24 h in each tank and then reallocated again until all tanks were monitored. Values were averaged for each 24 h period in each tank. Water quality parameters within treatments (time off-feed) did not vary significantly, so values were averaged and were well within tolerable limits for rainbow trout under culture conditions (temperature 13.6 C; SpCond686.67 uS/cm;TDS460.07 mg/L; pH7.72; $NH4^+$ N0.03 mg/L; turbidity1.07NTU; DO 5.92 mg/L).

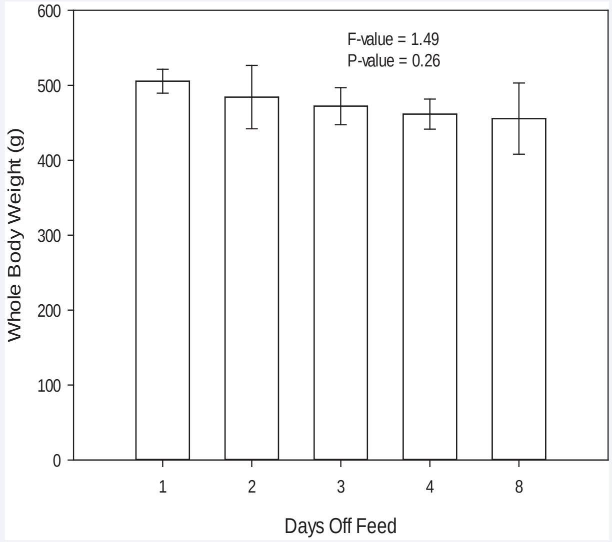

Figure 1 Whole body wet weight of rainbow trout after feeding cessation of 1, 2, 3, 4, and 8 days prior to harvest. Each bar represents 48 fish pooled from four tanks per treatment.

Feeding Regimen

Fish were fed a proprietary diet formulation developed and manufactured by Clear Springs Foods, Inc., containing approximately 20% fat and 48% protein. Feed rates (approximately 2.0% body weight/day) were calculated for each tank, based on feeding charts developed at Snake River Farm, using average fish weight and total tank biomass. Trout were fed using automatic, clockwork belt feeders (Dynamic Aqua-Supply, Ltd., Surrey, British Columbia, Canada) providing feed to the fish from 0900 until 1700 h. After acclimation, feed was withheld from rainbow trout 1 to 8 days prior to harvest and commercial processing to evaluate the effects on yield (total body weight and fillet yield) and proximate composition. Trout were weighed, then the fish on the 8-days off-feed treatment were taken off feed for the reminder of the trial, followed by-fish in the 4 , 3, 2, and 1 days off-feed treatments, which had feed withheld 4, 5, 6, and 7 days after this point, respectively. All treatments were harvested

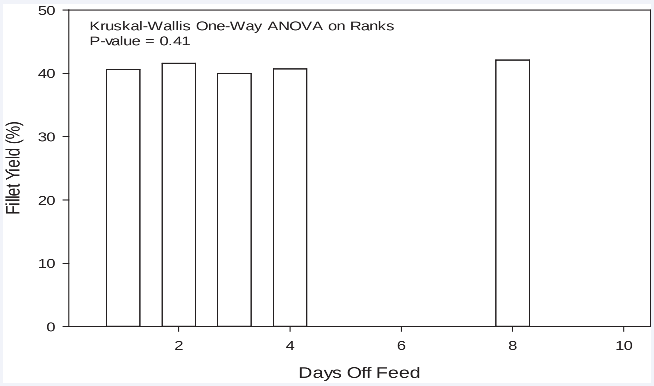

Figure 2 Fillet yield (% of whole body wet weight) of rainbow trout after feeding cessation of 1, 2, 3, 4, and 8 days prior to harvest. Error measurement was not possible for fillet yield, since rainbow trout from each treatment (days off feed) were pooled (n=3 tanks).

All tanks were harvested on the same day. Trout in tanks were group weighed prior to collection, and after the weight was recorded, twelve fish from each tank for an individual feeding cessation treatment were netted and pooled into a 50 gal plastic container(4 tanks and 48 fish total in each container) filled 1/3 full of crushed ice. Fish were then immediately transported (within 15 minutes) to the processing facility and weighed prior to processing. Trout were filleted, and fillet weights were recorded.

Three remaining fish in each tank were euthanized in 200 mg/L MS-222 and frozen for proximate analysis as described below. Ten sub-samples (10 g) of feed were also collected, frozen, and then analyzed for proximate composition. Trout whole body were processed into a puree using a Robot Coupe food processor (Robot Coupe R-2, Ridgefield, MS,USA) and sub sampled in duplicate for proximate analysis. Feed and fish samples were dried and analyzed using AOAC [16] methods for proximate composition with the exception of crude protein and crude lipid. Dried samples were finely ground by mortar and pestle and analyzed for crude protein (total nitrogen x 6.25) using a LECO nitrogen analyzer (TruSpec N,LECO Corporation, St. Joseph, MI, USA) and AOAC [16] approved methods for meat (992.15) and feed (990.03). Crude fat was analyzed using an Ankom HCl Hydrolysis system (Ankom,Inc., Macedon, NY, USA), and ash was measured by incineration at 550 °C in a muffle furnace. Gross energy content of the samples was determined using a Parr bomb calorimeter (Parr Instrument Co., Moline, IL, USA).

Statistical Analysis

Day's off-feed was the fixed effect in this study. Average whole body wet weight (g) and whole body proximate composition was analyzed by one-way analysis of variance (ANOVA). Fish collected to determine fillet yield (% of whole body wet weight) were pooled by treatment (day's off-feed) rather than by experimental tank due to limitations of the commercial processing facility, values were analyzed by Kruskal-Wallis one-way ANOVA on ranks [17]. Measured values from individual fish were averaged for each tank (experimental unit) for use in statistical analyses, except for fillet yield, as mentioned. Data were subjected to the Levene test for equal variances and the Shapiro-Wilk test for normality. A significance level of $\alpha = 0.05$ was used for all statistical analyses. Statistical analyses were performed with the SAS System for Windows Version 8 (SAS Institute, Inc., Cary, NC, USA). Omnibus F-tests were not statistically significant between treatments for any measured parameters; therefore, pairwise comparisons between means for main effects were not conducted.

RESULTS AND DISCUSSION

The goal of this study was to determine the effect of short-term feeding cessation prior to harvest on fish weight and fillet yield in rainbow trout. Feed is the primary economic cost in commercial rainbow trout farming. The standard procedure at most commercial trout farms is to feed fish until the day prior to harvest in order to maximize yield, and this practice is common in the rainbow trout industry in the Magic Valley region of Southern Idaho, where the majority, >70%, of rainbow trout within the U.S. are grown. However, studies with salmonids have shown that growth and yield are affected little during short-term starvation [8, 18]. Reducing the amount of feed fed, even at a small proportion of the total yearly feed expenditure, could reap substantial cost savings on large farms annually or over a protracted period of time on smaller farms. This is especially true prior to harvest when the fish are largest and feed levels are highest.

In the present study, we withheld feed for 1, 2, 4, and 8 days prior to harvest of marketable size rainbow trout (approximately 500 g) in our research tanks system at Snake River Farm (Clear Springs Foods, Inc.). There were no significant differences

Table 1: Feed (% dry matter basis) and whole body (% wet weight basis) proximate composition and gross energy content (calories) of rainbow trout after feeding cessation of 1, 2, 3, 4, and 8 days prior to harvest[1,2].

Days off feed	% protein		%Fat		%Ash		%Moisture		Energy	
	Average	Std.Dev	Average	Std.Dev	Average	Std.Dev	Average	Std.Dev	Average	Std.Dev
1	17.6	2.3	11.42	2.6	2.04	0.61	68.7	0.5	6459.1	147.3
2	17.6	2.6	9.5	2.7	2.49	0.92	70.6	1.6	6300.3	119.2
3	17.4	2.1	10.6	1.8	2.47	0.53	69.6	0.1	6396.2	52.7
4	17.6	3.5	11.2	4	2.51	0.73	69	1.8	6499.8	178.1
8	17.8	1.7	11.8	2	2.32	0.77	68.2	0.8	6548.5	13.2
Feed	48.6	0.01	21	0.13	6.77	0.06	7.21	0.38	5643.4	3.8

[1]Each value is the mean of triplicate samples for rainbow trout whole body and ten sub-samples of feed.
[2]No statistically significant differences were found between proximate compositions and energy contents among the days off feed treatments for trout whole body.

(P>0.05) in wet, whole body weights of rainbow trout between the feeding cessation groups (Figure 1). The small decrease in total body weight observed from 1 to 8 days off-feed was likely due to the evacuation of food from the stomach and elimination of fecal matter from the intestine as the number of days without feed increased and not to a loss of body mass. Gut emptying rather than muscle or fat loss has been implicated in initial weight loss of Atlantic salmon [19] and rainbow trout [20] during the early stages of starvation. The time required for gastric and gastrointestinal clearing during starvation can vary considerably due fish size, ration size, and environmental temperature [5]. Einen et al. [8] reported that weight loss after the first 3 days was dominated by gut emptying in harvestable Atlantic salmon (average weight = 4.87 kg) in 6 °C water. Grove et al. [6] estimated that the majority of gastric emptying takes between 50-75 h for 500 g rainbow trout at approximately 14 °C, similar to the conditions in this study, which supports the small decline in total body weight we observed as the number of days off-feed increased. Presumably, it would take more time for digest to completely leave the gastrointestinal tract (intestinal clearance) [6].

Fillet yield, which was approximately 40% of body weight, was the same for all groups (P>0.05) (Figure 2). Although total body weight declined as the number of days off-feed increased, this did not affect fillet yield, which showed a small, non-significant increase after 8 days off-feed. However, research on muscle protein synthesis and degradation suggests time off-feed longer than 1 week could have a negative effect on yield. Loughna and Goldspink [7] showed that between 7 and 14 days of time off-feed caused serious declines in protein synthesis in red and white muscle, RNA activity, and DNA-P and RNA-P concentrations in rainbow trout, suggesting that starvation longer than 7 days may have a negative impact on growth. The authors propose in the days immediately following feeding cessation that protein degradation rates and decline in specific growth rate are likely exaggerated due to loss of gut contents, but past this time frame, significant reductions in growth and yield may be observed. Yet, long-term starvation in salmonids shows that these short-term changes in growth and protein synthesis ultimately do not affect yield over the short- or long-term. In Atlantic salmon, fillet yield is unaffected until after 30 days of withholding feed [8,18]. After 30 days, the reduced fillet yield is explained by a lower proportion of muscle mass compared to bones, fins, and head [8]. In rainbow trout, starvation for longer periods, such as 3 and 16 weeks, causes significant reductions in growth of 13.5% and 32.5%, respectively, compared to fed fish [21]. The authors suggest the major decrease in percentage dry weight of whole rainbow trout during starvation occurs only after 45 days. Our data suggest that feeding cessation 1 week prior to harvest will not affect whole body weight, and more importantly, fillet yield of market size rainbow trout. However, it should be noted that while the fish are not losing weight during prolonged feed cessation of 15 days or greater, there can be no corresponding increase in wet and fillet weight as would have been seen if the fish had remained on feed during this time [8]. Further study is needed to determine if longer periods of feeding cessation can be used without affecting fillet yield with the fish population used in this study. The length of time feed was withheld from rainbow trout did not affect whole body proximate composition either (Table 1). Einen et al. [8] observed similar results in Atlantic salmon subjected to starvation prior to harvest. Salmon were starved for 0, 3, 7, 14, 30, 58, and 86 days prior to slaughter. Unlike this study, the authors looked at liver, fillet, and viscera instead of whole body proximate composition. They found that protein and fat content of these tissues declined only after 58 days of starvation for fat and 86 days for protein (liver only). According to this data, it takes a relatively long time (at least 58 days) for starvation to affect proximate composition in well-fed salmonids, although the length of time may vary depending on existing energy reserves, size of fish, physical activity, and water temperature [22]. We did not see any changes in whole body proximate composition of rainbow trout, which was expected with such short time periods of feeding cessation.

In conclusion, current practice in the commercial, freshwater rainbow trout industry is to feed until the day prior to harvest. However, in the present study, we have shown that if feed is withheld from rainbow trout from 1 to 8 days prior to harvest, whole body weight and fillet yield are not affected. Because feed is the primary economic cost in commercial trout operations, cessation of feeding 8 days prior to harvest will produce significant savings in both large and small rainbow trout operations by reducing feed use 2% annually without negatively impacting yield . Furthermore, taking fish off-feed several days prior to harvest will eliminate fecal matter from the intestine and reduce the chance of fecal contamination of fillets during processing.

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