

THE ROLE OF ADIPOSITY IN APPETITE CONTROL IN JUVENILE CHINOOK SALMON (*Oncorhynchus tshawytscha*)

Karl Shearer
Northwest Fisheries Science Center, NWFSC, NMFS, NOAA
2725 Montlake Blvd. E., Seattle, WA 98112
(206)860-3393, FAX (206)860-3394, ksheare@sci.nwfsc.noaa.gov

Jeffrey Silverstein
School of Fisheries, University of Washington, 355100
Seattle, WA 98195
(206)685-4864, FAX (206)685-3275, jsilver@u.washington.edu

Abstract

Two sequential experiments were conducted to determine if adiposity affected feed intake in juvenile chinook salmon (*Oncorhynchus tshawytscha*) with different nutritional histories. Fry were fed high fat (23%) or low fat (3%) diets at high (satiation) and low (one half satiation) ration levels for 7 months prior to the start of the intake experiment. This pre treatment produced fish averaging 22 g with 11.3% (high fat diet) and 5.4% (low fat diet) body fat when fed to satiation or, 11 g with 8.1% (high fat diet) and 4.0% (low fat diet) body fat when fed at one-half satiation. Exp. 1 was a 2 x 2 factorial design where duplicate groups of 20 fish from the 22 g groups were fed high (20.3%) or low (2.5%) fat diets twice daily to satiation six days/week for 3 weeks. Daily feed intake was recorded. The same protocol was used in Exp. 2 on fish (40 fish/tank) from the smaller 11 g groups. Feed intakes on day one and cumulative feed intakes after 21 days were compared using Two-Way ANOVA with initial whole body fat and dietary fat as the independent variables. Effects were considered significant at $P < 0.05$. In both experiments, high body fat and low dietary fat led to significantly lower feed intake on day one. After 21 days of feeding however, only the effect of high body fat was significant, indicating that fish adjusted to the low fat diets. Our results show that in both fast and slow growing juvenile chinook salmon, adiposity plays a role in regulation of feed intake.

Introduction

Appetite in fish appears to be under multifactorial control (Peter, 1979; Vahl, 1979; Fletcher, 1984). Although the physiological control of appetite is not well understood, regulators such as stomach distention and concentration of circulating nutrients have been identified (NRC, 1987). Recently, studies designed to examine the role of adiposity (body fat level) on regulation of appetite in fish have shown a negative correlation between adiposity and voluntary food intake (Metcalf and Thorpe, 1992; Jobling and Miglavs, 1993). These studies have used starvation to produce fish differing in adiposity, thus confounding the roles of adiposity and starvation induced compensatory growth on feed intake. Our experiment was designed to determine if the level of adiposity affected feed intake in juvenile chinook salmon (*Oncorhynchus tshawytscha*) not subjected to starvation. Additionally, the effect of dietary fat level on food intake was examined.

Materials and Methods

Pretreatment

From first feeding, groups of 400 fish were reared in 750 l tanks supplied with flow through de-chlorinated municipal water. The fish were reared on natural photoperiod; water temperatures varied seasonally from 8 to 16 °C. Fish were fed diets containing 23% fat and 65% protein (high fat) or 3% fat and 85% protein (low fat) diets. Two groups were pair fed the high and low fat diets to satiation (based on intake of the group eating the least feed) and two other groups of fish were fed these diets at half this amount. This feeding regime produced four groups of fish: large fish (22 g) with 11.3±2.1% or 5.4±1.8% body fat; and small fish (11g), with 7.0±1.2% or 3.3±0.2% body fat. This phase of the experiment lasted 7 months.

Experiment 1

To test the effects of adiposity and dietary fat on food intake, we employed a 2 X 2 factorial design crossing the body fat level treatment (high or low body fat) with dietary fat level treatment (high or low) to produce four groups. Each treatment combination was replicated. In Exp. 1 we used fish with a mean weight of 22 g at the start of the experiment. The fish were moved from the flow through water system to a recirculating system one day prior to the start of the experiment. This resulted in the fish being exposed to a decrease in water temperature (13 to 11°C) and an increase in pH (6.5 to 7.8). The fish were fed twice daily, 9 AM and 1 PM, 6 d/w for 21 d. Pellets were presented a few at a time as long as fish continued to feed. After feeding ceased, uneaten pellets were removed from the tank using a siphon. These were counted and the weight of this feed was subtracted from the feed fed based on an average prefeeding pellet weight. Daily feed intake was recorded.

Experiment 2

The protocol for experiment 2 was the same as for experiment 1, except small high and low fat fish (11 g) were used. These fish had been acclimated to the recirculation system for 30 days prior to the start of the experiment. Water quality remained stable (11 °C and pH 7.0).

The diets fed in the feed intake study (Table 1) were high or low in lipids (16 and 4%) and the low lipid diet contained 12% alpha cellulose to produce diets containing equal amounts of protein (65%).

Table 1. Composition of the experimental diets fed to juvenile chinook salmon to examine the effect of body fat and dietary fat on short term feed intake.

Ingredient	Low fat	High fat
	% dry weight	
Fish meal ¹	628	628
Gelatin	100	100
Wheat gluten	50	50
Fish oil	40	160
Vitamin C	1	1
Choline Chloride	10	10
CaH ₂ PO ₄	10	10
Trace minerals	1	1
Vitamin mix	15	15
MgO	5	5
Alpha-cellulose	120	0

¹ Fish muscle meal, 95% protein, 1% fat, 4% ash.

Analysis

Initial fat determinations on fish were performed on 10 individual fish from each of the four pretreatment groups. Final fat determinations were performed on pooled samples of five fish from each tank. Fish were dried to constant weight at 105 °C, ground and extracted using a

Soxhlet extractor with dimethylchloride as the solvent. Feed intakes on day one and cumulative feed intakes after 21 days were compared using Two-Way ANOVA (Statview™, Abacus Concepts, Berkeley, CA, 1992) with initial whole body fat (high or low) and dietary fat (high or low) as the independent variables. Effects were considered significant at P<0.05.

Results

Experiment 1

Feed consumption in experiment 1 was lower than expected based on normal intake observed for juvenile chinook salmon in previous experiments using flow-through municipal water. This was attributed to the fish being subjected to a change in water quality. No mortality occurred during the experiment. Comparison of feed intakes on day 1 (Table 2) indicated that feed intake was significantly influenced by fish body fat. Although the effect of dietary fat was not significant, both high and low body fat fish ate considerably less of the low fat diet. After 21 d of feeding, the low body fat fish had consumed significantly more of both the high and low fat diets than the high body fat fish (Table 2).

Table 2. Initial and final weights and body fat, feed intake on day 1, total feed intake and feed efficiency of juvenile chinook salmon fed high (20.3%) and low (2.5%) fat diets for 21 days (Experiment 1). For all descriptive statistics, n=2.

Body Fat	Diet Fat	Initial Weight ¹ (g)	Final Weight ¹ (g)	Initial Fat ² (%)	Final Fat ³ (%)
High	High	22.7±0.1	21.4±2.5	11.3±2.1	12.0±0.1
High	Low	22.5±0.3	21.4±0.4	11.3±2.1	12.9±1.0
Low	High	22.6±0.1	24.4±0.2	5.4±1.8	6.9±0.2
Low	Low	22.7±0.1	22.7±0.2	5.4±1.8	6.1±0.1
<u>Probability</u>	<u>df</u>				
Body Fat	1		0.08		0.0001
Dietary Fat	1		0.38		0.85
Interaction	1		0.36		0.07

Body Fat	Diet Fat	Feed Eaten Day 1 ⁴ (g)	Feed Eaten Total ⁴ (g)	Gain/Feed x100
High	High	1.7±1.1	25.3±23.3	NC ⁵
High	Low	1.4±0.3	11.1±6.6	NC ⁵
Low	High	9.3±0.4	50.2±3.9	66±10
Low	Low	6.0±1.5	37.2±4.3	0±5
<u>Probability</u>	<u>df</u>			
Body Fat	1	0.0009	0.04	0.20
Dietary Fat	1	0.06	0.20	0.90
Interaction	1	0.08	0.95	0.89

¹ Total weight of fish in tank/number of fish.

² Estimated from 10 individual analysis from a common pool of high or low fat fish.

³ Based on tank means, 5 individual analysis/tank.

⁴ Dry weight basis, intake /tank.

⁵ Fish lost weight.

Experiment 2

Feed consumption in experiment 2 (~1% body weight/d) was considerably higher than in experiment 1 (Table 3). We attribute this to the fish being acclimated to the recirculation system. No mortality occurred during the experiment. On day one the low body fat fish consumed significantly more feed than the high body fat fish and both groups consumed significantly more of the high fat diet. After 21 days low body fat fish had consumed

significantly more feed than the high body fat fish (Fig 1). The highest cumulative feed consumption occurred in the low body fat fish fed the low fat diet. Mean fish weight increased in all treatments, and body fat levels increased in all groups except the high body fat fish fed the low fat diet. Feed efficiency (gain/feed) was significantly higher on the high fat diet but was not affected by the level of body fat.

Table 3. Initial and final weights and body fat, feed intake on day 1, total feed intake and feed efficiency of juvenile chinook salmon fed high (20.3%) and low (2.5%) fat diets for 21 days (Experiment 2). For all descriptive statistics, n=2.

Body Fat	Diet Fat	Initial Weight ¹ (g)	Final Weight ¹ (g)	Initial Fat ² (%)	Final Fat ³ (%)
High	High	10.6±0.1	11.7±0.2	7.0±1.2	9.2±0.6
High	Low	10.5±0.3	11.0±0.3	7.0±1.2	7.1±0.2
Low	High	10.5±0.1	12.0±0.1	3.3±0.2	5.0±0.8
Low	Low	10.6±0.3	11.6±0.4	3.3±0.2	4.2±0.4
<u>Probability</u>	<u>df</u>				
Body Fat	1		0.06		0.0008
Dietary Fat	1		0.04		0.02
Interaction	1		0.38		0.16

Body Fat	Diet Fat	Feed Eaten Day 1 ⁴ (g)	Feed Eaten Total ⁴ (g)	Gain/Feed x100
High	High	10.9±0.1	63.6±4.6	85.7±9.4
High	Low	8.8±1.8	47.0±2.7	42.7±8.8
Low	High	20.7±3.0	81.8±1.6	88.1±22.5
Low	Low	15.4±1.1	89.7±4.9	53.1±3.6
<u>Probability</u>	<u>df</u>			
Body Fat	1	0.003	0.003	0.50
Dietary Fat	1	0.05	0.17	0.01
Interaction	1	0.30	0.01	0.72

¹ Total weight of fish in tank/number of fish.

² Estimated from 10 individual analysis from a common pool of high or low fat fish.

³ Based on tank means, 5 individual analysis/tank.

⁴ Dry weight basis, intake /tank.

Discussion

During the pretreatment portion of the experiment the amount of feed fed to all the groups was determined by the group fed to satiation and eating the least amount of feed. Our observation was that the high fat fish had the least appetite, and that low fat fish would have consumed additional feed. This was expected since numerous reports have shown that fish will eat more of a less energy dense diet up to the limits of their stomach capacity (Lee and Putnam, 1973; Bromley and Adkins, 1984; Hilton, et al., 1983). Metcalfe and Thorpe (1992) and Jobling and Miglavs, (1993) reported that in juvenile Atlantic salmon (*Salmo salar*) and Arctic charr (*Salvelinus alpinus*) fatter fish had reduced appetite compared to starved lean fish. Jobling and Miglavs (1993) reported that feed intake in 6.5% body fat fish was about 50% of that of fish previously starved 4% body fat fish. The results of both our experiments clearly show that even without a starvation period, adiposity affects appetite in juvenile chinook salmon.

The effect of dietary fat level on feed intake was less clear. Initially, high fat diets were consumed in greater quantities, but some adjustment to the low energy density diet was observed in experiment 2 (Fig. 1).

In our experiments differences in appetite were of a similar magnitude between large (22g) fish with 11.3 and 5.4%, and small fish with 7.0 and 3.3% body fat despite different rates of growth (fast vs.slow). Therefore, adiposity was a major factor regulating feed intake. This

suggests that growth may actually be retarded if a feeding regime or diet results in high body fat levels in juvenile salmonids.

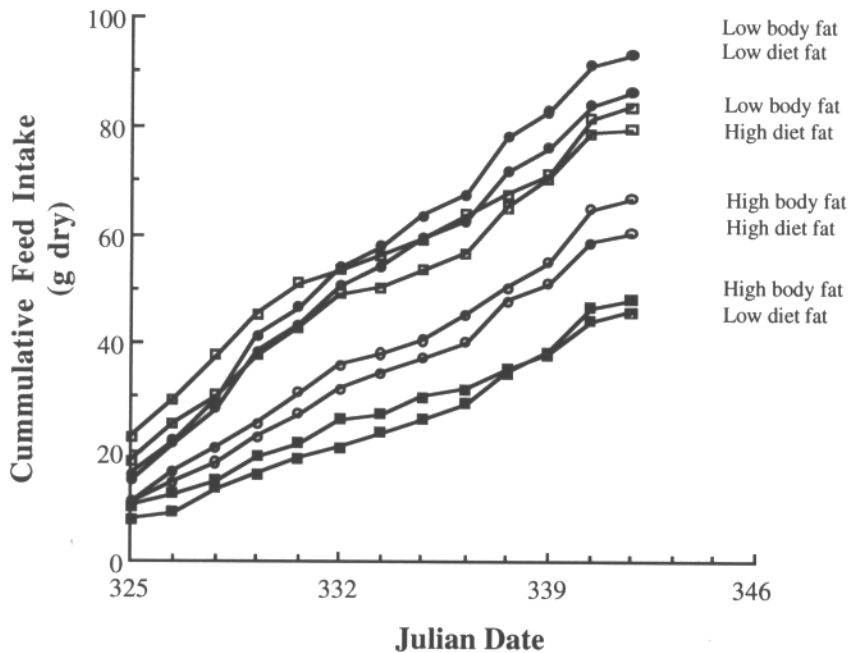


Figure 1. Experiment 2, cumulative feed intake of juvenile chinook salmon (11 g) with high (7.0%) or low (3.3%) body fat, fed high (20.3%) or low (2.5%) fat diets.

References

- Bromley, P. J. and Adkins, T. C. 1984. The influence of cellulose filler on feeding, growth and utilization of protein and energy on rainbow trout, *Salmo gairdneri* Richardson. *J. Fish. Biol.*, 24: 235-244.
- Fletcher, D. J. 1984. The physiological control of appetite in fish. *Comp. Biochem. Physiol.*, 78A: 617-628.
- Hilton, J. W., Atkinson, J. I. and Slinger, S. J. 1983. Effect of increasing dietary fiber on growth of rainbow trout (*Salmo gairdneri*) *Can. J. Fish. Aquat. Sci.*, 40:81-85.
- Jobling, M. and Miglavs, I. 1993. The size of lipid deposits-a factor contributing to the control of food intake in Arctic charr, *Salvelinus alpinus*. *J. Fish. Biol.*, 43: 487-489.
- Lee, D. J. and Putnam, G. B. 1973. The response of rainbow trout to varying protein/energy ratios in a test diet. *J. Nutr.*, 103: 916-922.
- Metcalf, N. B., Thorpe, J. E. 1992. Anorexia and defended energy levels in over-wintering juvenile salmon. *J. Anim. Ecol.*, 61: 175-181
- NRC 1987. Predicting feed intake of food-producing Animals. 85 pp.
- Peter, R. E. 1979. The brain and feeding behavior. In: *Fish Physiology*. Vol VIII. Bioenergetics and growth. (Hoar, W. S., Randall, D. J. and Brett, J. R. eds) 121-159.
- Vahl, O. 1979. An hypothesis on the control of food intake in fish. *Aquaculture*, 17: 221-229.

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