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An Evaluation of Four Commercial Feeds During Chinook Salmon Rearing

Matthew M. Wipf[1*], Michael E. Barnes[2], Patrick Nero[2]

[1]Bluewater Springs State Fish Hatchery, 700 Bluewater Road, Bridger, MT 59014
[2]McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, SD 57783

***Corresponding author:** Matthew M. Wipf. Fish Hatchery Manager Bluewater Springs State Fish Hatchery, Fisheries Division, Montana Fish, Wildlife & Parks; Tel: (406) 668-7443; Email: matt.wipf@mt.gov

Abstract

There are several different commercial feeds available for use during Chinook salmon *Oncorhynchus tshawytscha* rearing. This study consisted of four separate trials evaluating the rearing performance of landlocked fall Chinook salmon receiving one of four diets, consisting of either one of three granulated feeds (Skretting Salmon Fry, Bio-Oregon Bio-Vita, Bio-Oregon Bio-Clark) or a micro-pelleted feed (Bio-Oregon Micro-Vita). The mean (± SE) weight of salmon was 0.55 ± 0.03 g at the start of the first two trials using feed sizes of #1 crumbles for the granules and 0.6 mm for Micro-Vita. The first trial used experimental-sized 100-L tanks and lasting for 28d, while the second trail used 1,415-L tanks for 41d in a production setting. In the last two trials, #2 crumbles and 0.9 mm micro-pellets were fed for 28d. In the third trial, which used 100-L tanks, initial salmon weights (mean ± SE) were 2.2 + 0.05 g. The fourth trial used 1,415-L tanks and initial weights were 3.6 + 0.1g. In the first trial, total tank weight gains were significantly lower and feed conversion ratios were significantly poorer in tanks of salmon fed Micro-Vita compared to the other three diets. In the second trial, total tank weight gains were significantly lower, and feed conversion ratios were significantly poorer, in both Bio-Clark and Micro-Vita fed fish. In the third trial, Bio-Vita produced significantly greater total tank weight gains and significantly better feed conversion ratios than the other three feeds. Ending tank weights for Bio-Clark and Micro-Vita were significantly lower than those of fish fed Bio-Vita or Salmon Fry. Based on these results, Bio-Vita or Salmon Fry are recommended to maximize growth of landlocked fall Chinook salmon during hatchery rearing.

Keywords: Chinook salmon; *Oncorhynchus tshawytscha*; feed; diet

Introduction

A wide variety of Chinook salmon *Oncorhynchus tshawytscha* feeds are commercially available, but few studies have compared their relative performance. Fletcher and Barnes[1] reported that landlocked fall Chinook salmon fed BioVita #0 starter (Bio-Oregon, Longview, Washington USA) experienced significantly less mortality than those salmon fed Silvercup soft-moist starter (Nelson and Sons, Murray, Utah USA). Similarly, Kientz et al[2] also reported that Chinook salmon fed BioVita #0 starter had significantly less mortality than those fed two other commercial feeds, and that salmon fed BioVita were also significantly larger and grew significantly faster. Twibell et al[3] observed that salmon feed Bio Vita showed significantly higher weight gain and decreased feed conversion ratios in comparison to four other commercial starter feeds. All of these studies only examined starter feeds; no evaluations have been conducted on small Chinook salmon after initial feeding.

Lake Oahe, South Dakota, USA contains a landlocked population of fall Chinook salmon that are an important recreational fishery. Because of the lack of natural reproduction, salmon must be hatchery-produced and regularly restocked into the reservoir[4]. Lake Oahe Chinook salmon present several rearing challenges[5], and dietary issues may be present[1,2,6]. With larger salmon at stocking requested by fisheries managers, and with the variety of commercially-produced Chinook salmon feeds currently

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available, research is needed to determine which feeds should be used to maximize growth.

The objective of this study was to compare the performance of four commercially available diets during the hatchery rearing of juvenile landlocked fall Chinook salmon.

Methods

All experimentation occurred at McNenny State Fish Hatchery, Spearfish, South Dakota, USA using 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). Fish for this experiment were obtained from a common pool of landlocked fall Chinook salmon, which originated from spawning events in October 2012. A common pool of salmon fry received Bio-Vita starter (Bio-Oregon, Longview, Washington, USA) beginning at initial feeding and continuing for 21 days prior to the start of experimentation.

The following four commercial salmon diets and two different feed sizes were used in four separate trials:
- Salmon Fry granules (Skretting, Murray, Utah, USA), sizes #1 and #2
- Bio-vita crumbles (Bio-Oregon, Longview, Washington, USA), #1 and #2
- Bio-Clark crumbles (Bio-Oregon), #1 and #2
- Micro-Vita micro-pellets (Bio-Oregon), 0.6 mm and 0.9 mm.

Company-reported proximate analysis, feed ingredients, and vitamin and mineral premix composition is listed in Tables 1, 2, and 3.

Table 1: Proximate composition of the four commercial feeds used during the study.

	Salmon Fry	Bio-Clark	Bio-Vita	Micro-Vita
Protein (%)	52	52	52	52
Fat (%)	16	20	20	20
Fiber (%)	1.0	1.0	1.0	1.0
Phosphorus (%)	--	1.4	1.2	1.7
Ash	12.0	--	--	--

Table 2: Manufacturer-listed ingredients in label order for feeds used.

Salmon Fry	Bio-Clark	Bio-Vita	Micro-Vita
Fish Meal	Fish Meal	Fish Meal	Fish Meal
Wheat Flour	Poultry Meal	Fish Oil	Fish Oil
Feather Meal	Fish Oil	Wheat Flour	Wheat Flour
Fish Oil	Wheat Flour	Wheat Gluten	Wheat Gluten
Poultry Meal	Corn Gluten Meal	Krill Meal	Krill Meal
Krill Meal	Wheat Gluten Meal	Whey Powder	Whey Powder
Wheat Gluten	Dried Whey	Gelatin	Lecithin
Dried Whey	Krill Meal	Lecithin	Gelatin
	Lecithin		
	Gelatin		
	Lysine Hydrochloride		
	Betaine		
	DL Methionine		
	Astaxanthin		
	Ethoxyquin		

Table 3: Manufacturer-listed vitamin and mineral premix composition for feed used during the study. The itemized list appears in the exact order as the ingredient label.

Salmon Fry	Bio-Clark	Bio-Vita	Micro-Vita
Vitamin A Acetate	Vitamin B12	Vitamin D3	Vitamin A
Vitamin D3 Supplement	D-Biotin	Ascorbyl Polyphosphate C	Vitamin D3
Ascorbyl Polyphosphate C	Folic Acid	Vitamin E	Ascorbyl Polyphosphate C
Vitamin B Supplement	Ascorbyl Polyphosphate-C	Inositol	Vitamin E
Inositol	Vitamin K	Zinc Sulphate	Inositol
Zinc Sulphate	Manganese Sulphate	Nicotinic Acid	Zinc Sulphate
Nicotinic Acid	Zinc Sulphate	Calcium Pantothenate	Nicotinic Acid
Calcium Pantothenate	Calcium Iodate	Manganese Sulphate	Calcium Pantothenate
Manganese Sulphate	Copper Sulfate	Riboflavin	Manganese Sulphate
Riboflavin	Ferrous Sulphate	Pyridoxine Hydrochloride B6	Riboflavin
Pyridoxine Hydrochloroide	Sodium Selenite	Thiamine Mononitrate	Pyridoxine Hydrochloroide
Thaimine Mononitrate	Betaine	Menadione Sodium Bisulfite	Thaimine Mononitrate
Menadione Sodium Bisulfite		Copper Sulfate	Menadione Sodium Bisulfite
Sodium Bisulfite (K)		Folic Acid Calcium Iodate	Sodium Bisulfite (K)
Copper Sulphate		D-Biotin	Copper Sulphate
Folic Acid		Sodium Selenite	Foic Acid
Calcium Iodate		B12	Calcium Iodate
D-Biotin		Brewers Yeast	D-Biotin
Sodium Selenite		Vitamin E	Sodium Selenite
Vitamin B12		Astaxanthin	Vitamin B12
Brewers Yeast		Ethoxyquin	Brewers Yeast
Astaxanthin			Vitamin E
Ethoxyquin (Antioxidant)			Astaxanthin
Choline Chloride			Betane
			Ethoxyquin

Feeding amounts were calculated using the hatchery constant method at an HC of 5.60[7] based on prior experience with landlocked salmon at McNenny hatchery. Mortalities were removed and recorded daily. At the end of each trial, five fish per tank were weighed to the nearest 0.1 g and measured to the nearest 0.1 mm (Tritan Digital Caliper, Minneapolis, Minnesota, USA). Total tank weights were collected to the nearest 0.1 g.

The following equations were used:

Total weight gain = (end weight)/(start weight)

Feed conversion ratio (FCR) = (food fed to tank)/(Total weight gain)

Condition Factor (K) = 10^{5*} (fish weight)/fish length^3

Trial 1
From the initial common pool, approximately 320 salmon (173g) were placed into each of 12, 100-L circular tanks. Flows in each tank were 9 L/minute. Mean (+ SE) initial individual fish weights and lengths were 0.6 + 0.1 g and 40.1 + 0.6 mm, respectively. The four feeds, at a crumble size of #1 or micropellet size of 0.6 mm, were randomly assigned to each tank (N = 3). Feed was weighed daily to the nearest 0.1 g and administered via automatic feeders (Sweeney Enterprises, Inc., Boerne, Texas, USA) hourly from 08:00 to 16:00. This trial lasted 28 days.

Trial 2
From the initial common pool, approximately 2,595 salmon (1.28 Kg) were placed into each of 12, 1,415-L circular tanks (1.8m diameter; 0.8m depth). Flows in each tank were approximately 57 L/minute. Mean (+ SE) initial individual salmon weights and lengths were 0.6 + 0.1 g and 40.1 + 0.6 mm, respectively. The four feeds, at a crumble size of #1 or micropellet size of 0.6 mm, were randomly assigned to each tank (N = 3). Feed was weighed daily to the nearest gram and administered via automatic feeders (EWOS Aquaculture, Norco-Plast, AB, Sweden) hourly from 08:00 to 16:00. This trial lasted 41d.

Trial 3
At the end of the first trial, all fish were placed into a common pool. From this pool, 267 fish (587 g) were placed into each of 12, 100-L circular tanks. Tank flows were set at 9 L/minute. Mean (+ SE) initial individual salmon weights and lengths were 2.2 + 0.1 g and 60.9 + 0.4 mm, respectively. The four feeds, at a crumble size of #2 or micropellet size of 0.9 mm, were randomly assigned to each tank (N = 3). This trial lasted 28 days.

Trial 4
At the end of the second trial, all of the fish were put into a common pool. From this pool, 1,964 fish (7,010 g) were placed into each of 12, 1,415-L circular tanks. Flows were set at 57 L/minute. Mean (+ SE) initial individual salmon weights and lengths were 3.6 + 0.1 g and 71.2 + 0.5 mm, respectively. The four feeds, at a crumble size of #2 or micropellet size of 0.9 mm, were randomly assigned to each tank (N = 3). This trial lasted 28 days.

Data Analysis
To prevent pseudo-replication, individual weights and lengths from each tank were averaged within treatment groups, and the mean values were used during subsequent data analysis. Percent survival data was arcsine square root transformed[8] prior to statistical analysis. Statistical analysis was conducted using the SPSS computer program (Version 9.0; Chicago, Illinois, USA). All data was analyzed using ANOVA with Tukey post-hoc means testing. Significance was predetermined at $P < 0.05$.

Results

Trial 1
Final weights and gain and were significantly lower, and feed conversion ratio was significantly higher, in tanks fed Micro-Vita compared those fed Salmon Fry, Bio-Clark, or Bio-Vita. Mortality was minimal and was not significantly different among the dietary treatments. There was also no significant difference in individual length, weight, or condition factor among the diets.

Table 4: Mean (+ SE) final tank weights, gain, feed conversion ratio (FCR*), and mortality from tanks of Chinook salmon receiving one of four different diets. Means followed by different letters in a row are significantly different ($P < 0.05$; N=3).

	Salmon Fry	Bio-Clark	Bio-Vita	Micro-Vita
Trial 1				
Feed size	#1	#1	#1	0.6mm
Tank size	100-L	100-L	100-L	100-L
Days	28	28	28	28
Final weight (g)	659 +6.4^A	639 + 9.9^A	667 + 7.4^A	550 + 9.8^B
Gain (g)	486 +6.4^A	467 + 9.9^A	494 + 7.3^A	378 + 9.8^B
Food fed (g)	450.7	450.7	450.7	450.7
FCR	0.93 + 0.54^A	0.97 +0.56^A	0.91 +0.65^A	1.20 + 0.69^B
Mortality (%)	1.3 + 0.1	1.6 + 0.1	0.3+0.3	0.3 + 0.1
Trial 2				
Feed size	#1	#1	#1	0.6mm
Tank size	1,415-L	1,415-L	1,415-L	1,415-L
Days	41	41	41	41
Final weight (g)	7,790 + 25^A	6,780 +19^B	7,530 + 23^{AB}	6,180 + 15^C
Gain (g)	6,510 + 25^A	5,500 + 19^B	6,250 + 2^{3AB}	4,900 + 15^C
Food fed (g)	5,560	5,560	5,560	5,560
FCR	0.89 + 0.03^A	1.1 + 0.04^B	0.93 + 0.04^{AB}	1.2 + 0.04^C
Mortality (%)	1.4 + 0.1	2.1 + 0.1	1.7 + 0.1	2.2 +0.1
Trial 3				
Feed size	#2	#2	#2	0.9mm
Tank size	100-L	100-L	100-L	100-L
Days	28	28	28	28
Final weight (g)	1,300 + 37^B	1,310 + 29^B	1,400 + 26^A	1,280 + 4^B
Gain (g)	713 + 37^B	723 + 29^B	813 + 26^A	693 + 4^B
Food fed (g)	749.9	749.9	749.9	749.9
FCR	1.05 + 0.05^B	1.04 + 0.04^B	0.92 + 0.03^A	1.08 + 0.01^B
Mortality (%)	0.7+ 0.1	0.2 + 0.1	0.02 + 0.1	0.4 + 0.1
Trial 4				
Feed size	#2	#2	#2	0.9mm
Tank size	1,415-L	1,415-L	1,415-L	1,415-L

Days	28	28	28	28
Final weight (kg)	$14.9+0.2^{A}$	$13.5 + 0.1^{B}$	$15.0 +0.3^{A}$	$12.7 + 0.4^{B}$
Gain (kg)	$7.9 +0.2^{A}$	$6.5 + 0.1^{B}$	$8.0 +0.3^{A}$	$5.7 + 0.4^{B}$
Food fed (kg)	8.1	8.1	8.1	8.1
FCR	$1.03 + 0.01^{A}$	$1.25 + 0.02^{B}$	$1.01 + 0.02^{A}$	$1.42 + 0.01^{B}$
Mortality (%)	0.0 + 0.0	0.1 + 0.1	0.2 + 0.1	0.1+0.1

*FCR = food fed/gain

Table 5: Mean (+ SE) final individual fish total length, weight, and condition factor (K*) of Chinook salmon receiving one of four different diets. Means followed by different letters in a row are significantly different ($P< 0.05$; N=3).

	Salmon Fry	Bio-Clark	Bio-Vita	Micro-Vita
Trial 1				
Length (mm)	60.9 + 0.1	62.1 +0.7	60.5 + 1.1	60.1 + 0.9
Weight (g)	2.2 + 0.1	2.2 + 0.1	2.3 + 0.1	2.1 + 0.1
K	1.00 + 0.04	0.95 + 0.03	0.91 + 0.01	0.97 + 0.02
Trial 2				
Length (mm)	$73.5 + 0.7^{A}$	$71.0 + 0.9^{AB}$	$71.8 + 1.1^{AB}$	$68.7 + 1.0^{B}$
Weight (g)	$4.0 + 0.2^{A}$	$3.5 + 0.2^{AB}$	$3.7 + 0.2^{AB}$	$3.2 + 0.2^{B}$
K*	0.99 + 0.02	0.97 +0.03	0.98 + 0.03	0.97+0.01
Trial 3				
Length (mm)	76.9 + 1.7	78.1 + 1.9	80.7 + 0.7	77.3 + 1.3
Weight (g)	4.5 + 0.3	4.8 + 0.4	5.3 + 0.2	4.4 + 0.3
K*	0.98 + 0.01	1.01 + 0.01	1.00 + 0.01	0.95+0.02
Trial 4				
Length (mm)	90.4+1.8	91.3 + 1.3	90.6 + 0.3	86.2 + 1.1
Weight (g)	7.8 + 0.4	8.0 + 0.6	7.4 + 0.2	6.7 + 0.4
K*	1.04 + 0.01	1.04 + 0.04	0.99 + 0.02	1.03 + 0.03

*K = ([Weight / Length^3] x 10^5)

Trial 2

Similar to the first trial, final weights and gain and were significantly lower, and feed conversion ratio was significantly higher, in tanks fed Micro-Vita compared those fed Salmon Fry, Bio-Clark, or Bio-Vita. Final weights, gain, and feed conversion ratio were also significantly worse in the tanks fed Bio-Clark compared to those fed Salmon Fry. Mortality was minimal and was not significantly different among the dietary treatments. Salmon receiving Micro-Vita were significantly shorter and weighed significantly less than those fish fed the other three diets.

Trial 3

Final weights and gain were significantly higher in the tanks of salmon receiving Bio-Vita compared to the tanks receiving any of the other diets. Feed conversion ratio was also significantly lower in the Bio-Vita tanks. Mortality was minimal and was not significantly different among the dietary treatments. There was also no significant difference in individual length, weight, or condition factor among the diets.

Trial 4

Final weights and gain were significantly higher in the tanks receiving Salmon Fry or Bio-Vita compared to those tanks receiving either Bio-Clark or Micro-Vita. Feed conversion ratio was also significantly lower in the Salmon Fry and Bio-Vita treatments. Mortality was minimal and was not significantly different among the dietary treatments. There was also no significant difference in individual length, weight, or condition factor among the diets

Discussion

If only one feed is used during the rearing of juvenile landlocked fall Chinook salmon, then the results of this study indicate that Bio-Vita would be the most appropriate choice. Fish fed either Bio-Vita or Salmon Fry performed similarly in three of the trials, but Bio-Vita fed salmon outperformed Salmon Fry fed salmon in one trial. Kientz et al[2] also recommended the use of Bio-Vita starter during the initial rearing of Chinook salmon and reported improvements in growth compared to other commercially available diets similar to that noted by Twibell et al[3]. Without knowing the exact dietary formulations, it is difficult to determine what ingredients, and what concentrations of ingredients, may be causing the differences in salmon growth observed in this study. The nutritive value and digestibility of rendered animal proteins is extremely variable[9,10]. Bio-Clark was the only feed that used poultry meal and corn gluten meal as secondary protein sources, which may have contributed to its relatively poor performance. Poultry meal proximate composition varies from manufacturer to manufacture[11].

The proximate composition and ingredients listed were similar between the Bio-Vita and Micro-Vita feeds, indicating that the reduced growth of salmon fed Micro-Vita may not have been nutritionally induced. As a microparticulate feed, Micro-Vita likely had an accelerated sink rate in the water column[12], making it less available to the fish. Holt et al[12] also noted that the texture of micro-pelleted diets may also be a reason for rejection of micro-pelleted feeds, such as Micro-Vita. Similarly, Kientz et al[2] also observed reduced Chinook salmon growth in a micro-pellet feed compared to crumbles during initial feeding.

The four trials in this study all had relatively short durations, running from 21 to 41 days, making the significant differences in salmon growth observed among the diets are particularly noteworthy. The National Research Council[13] recommends minimal feed trial durations of 56 days, and in one example, significant differences between diets was not observed until after 84 days[14]. However, Weatherup and McCracken[15] state that studies must only run long enough for significant differences to be observed.

The results of this study may be limited to landlocked fall Chinook salmon. In addition, because commercial feed formulations are proprietary and subject to change, these results may only be applicable to the feeds available at the time of the study. The same branded feeds used today may very well be different.

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References

1. Fletcher, B., Barnes, M.E. Performance of two starter diets during landlocked fall Chinook salmon initial feeding. (2008) Proc S DakAcadSci 87:179-184.
PubMed | CrossRef | Others
2. Kientz, J., Barnes, M.E., Durben, D.J. Performance of commercial starter diets during first-feeding of landlocked fall Chinook salmon. (2012) Proc SD AcadSci91:101-106.
PubMed | CrossRef | Others
3. Twibell, R.G., Gannam, A.L., Ostrand, S.L., et al. Evaluation of commercial diets for first-feeding spring Chinook salmon. (2009) NAmJAquac71(2):116-121.
PubMed | CrossRef | Others
4. Marrone, G.M., Stout, D.A. Whitlocks Bay Spawning Station Annual Report. (1997) SD Dept of Game, Fish and Parks Annual Report Number 97-19. Pierre.
PubMed | CrossRef | Others
5. Barnes, M.E., Hanten, R.P., Cordes, R.J., et al. Reproductive performance of inland fall Chinook salmon. (2000) N Am J Aqua 62(3):203211.
PubMed | CrossRef | Others
6. Barnes, M.E., Sayler, W.A., Cordes, R.J. Initiation of feeding during hatchery rearing of landlocked fall Chinook salmon fry. (2002) Proc SD Acad S i 81:137141.
PubMed | CrossRef | Others
7. Butterbaugh, G.L., Willoughby, H.A. A feeding guide for brook, brown, and rainbow trout. (1967) Prog Fish-Cult 29(4):210-214.
PubMed | CrossRef | Others
8. Zar, J. H. Biostatistical Analysis Fourth Edition. (1999) Prentice-Hall, Inc. New Jersey.
PubMed | CrossRef | Others
9. Bureau, D.P., Harris, A.M., Cho, C.Y. Apparent digestibility of rendered animal protein ingredients for rainbow trout (*Oncorhynchus mykiss*). (1999) Aquaculture 180(3/4):345-358.
PubMed | CrossRef | Others
10. Bureau, D.P., Harris, A.M., Bevan, D.J., et al. Feather meals and meat and bone meals from different origins as protein sources in rainbow trout (*Oncorhynchus mykiss*) diets. (2000) Aquaculture 181(3/4):281-291.
PubMed | CrossRef | Others
11. Dong, F.M., Hardy, R.W., Haard, N.F., et al. Chemical composition and protein digestibility of poultry by-product meals for salmonid diets. (1993) Aquaculture 116(2/3):149-158.
PubMed | CrossRef | Others
12. Holt, G. J., Webb K. A., Rust, M. B. Microparticulate diets: testing and evaluating success. Pages 353-372 in G. J. Holt editor. Larval Fish Nutrition. Wiley Blackwell. 2011. Oxford, UK.
PubMed | CrossRef | Others
13. Malcolm. J. National Research Council. Nutrient requirements of fish and shrimp. (2011) National Academies Press 20: 601-602.
PubMed | CrossRef | Others
14. de Francesco, M., Parisi, G., Médale, F., et al. Effect of long-term feeding with a plant protein mixture based diet on growth and body/fillet quality traits of large rainbow trout (*Oncorhynchus mykiss*). (2004) Aquaculture 236(1-4):413-429.
PubMed | CrossRef | Others
15. Weatherup, R.N., McCracken, K.J. Changes in rainbow trout, *Oncorhynchus mykiss* (Walbaum), body composition with weight. (1999) Aquaculture Res 30:305307.
PubMed | CrossRef | Others