



An Evaluation of two Commercial Feeds During the Initial Rearing of Juvenile Chinook Salmon

Jaeson Garcia, Kali A. Roduner, Analuisa Larson, Jill M. Voorhees, Michael E. Barnes*

South Dakota Department of Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, South Dakota 57783

***Corresponding Author:** Michael E. Barnes, South Dakota Department of Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, South Dakota 57783

Abstract: This study evaluated the rearing performance of juvenile landlocked Chinook salmon (*Oncorhynchus tshawytscha*) receiving one of two commercial starter diets, Bio-Oregon BioVita or Optimal AquaFeed Salmon in two consecutive trials. The first trial lasted 24 days and used #0 crumble (starter). The second trial using #1 crumble began immediately after the end of the first trial and lasted 21 days. At the end of the first trial, final tank weight and tank gain were significantly greater in tanks receiving Bio-Oregon BioVita compared to tanks receiving Optimal AquaFeed Salmon. Percent gain, feed conversion ratio (FCR), specific growth rate (SGR), percent mortality and individual fish length, weight, and condition factor were not significantly different between the diets. At the end of the second trial, tanks of fish fed Bio-Oregon BioVita were significantly heavier than those receiving the Optimal AquaFeed Salmon diet. In addition, individual fish length, weight, and condition factor were also significantly greater in fish fed BioVita. Tank gain, percent gain, FCR, percent mortality, and SGR were not significantly different between the diets. The results of this study indicate that either diet can be used during the rearing of landlocked fall Chinook salmon, although BioVita should be used to maximize growth during initial feeding or shortly thereafter.

1. INTRODUCTION

Proper nutrition is fundamental for fish development, feeding efficiencies, and survival (NRC 2011; Kandyliari et al. 2020). Nutrient requirements differ among fish species as well as within among life stages of the same species (Lall & Dumas 2015; Carter & Codabaccus 2022). Because of the relatively large number of commercially-available feeds, including those just recently introduced into the market, evaluations of their effects on fish growth and other metrics of rearing performance are essential (Carter & Codabaccus 2022).

Chinook salmon (*Oncorhynchus tshawytscha*) and other salmonid fish species are globally important in aquaculture, commercial harvest, and recreational fisheries (FAO 2020; Albrektsen et al. 2022). Although many commercial feeds exist for salmonids, relatively few studies have directly compared their rearing performance under similar conditions. Wipf et al. (2021) reported Bio-Oregon BioVita resulted in significantly greater growth compared to three other commercial feeds and suggested that it was the most appropriate feed stuff for Chinook salmon. In a study comparing Silvercup salmon starter and BioVita starter, Chinook salmon fed the BioVita diet exhibited significantly higher growth, improved feed conversion ratio, and significantly lower mortality (Kientz et al. 2012). Fletcher and Barnes (2008) reported significantly lower individual fish weight and length in fish receiving Bio-Oregon BioVita compared to those fed the Silvercup soft-moist diet. Other studies involving trout have shown significant differences in growth and weight gain among multiple diets (Kindschi et al. 2009; Martin et al. 2018; Roduner et al. 2025). However, a similar study found no differences in relative performance among three diets in rainbow trout subjected to a bacterial pathogen (Trefl et al. 2015).

In Lake Oahe, South Dakota, fall Chinook salmon have been introduced as a recreational fishery. Because this landlocked population cannot reproduce naturally in the reservoir, annual hatchery production and stocking are required to sustain the fishery (Hanten 2016; SDGFP 2016). Chinook salmon rearing poses several challenges, including possible dietary issues (Fletcher & Barnes 2008; Kientz et al. 2012). There is a relative lack of knowledge on the potential effects of different commercial feeds on juvenile landlocked Chinook salmon growth and survival, particularly during initial feeding,

Thus, the objective of this study was to compare the growth, survival, and other rearing performance metrics of Bio-Oregon BioVita and Optimal AquaFeed Salmon during the hatchery rearing of fall Chinook salmon.

2. METHODS AND MATERIALS

This experiment occurred at McNenny State Fish Hatchery, rural Spearfish, South Dakota, USA, using aerated well water at a constant temperature of 11 °C (total hardness as CaCO₃, 360 mg/L; alkalinity as CaCO₃, 210 mg/L; pH, 7.6; total dissolved solids, 390 mg/L). Two feed trials were conducted, each focused on a specific feed size, with the first trial evaluating #0 starter feeds and the second trial evaluating #1 granules.

2.1. Trial 1

Trial 1 began immediately after yolk sac absorption on 6 January 2025 and ended after 24 days on 30 January 2025. At the start of the trial, 30 individual fish were weighed to the nearest 0.01 g and measured (total length) to the nearest 0.01 mm. Similar measurements were conducted on five fish per tank each week. Approximately 200 (total weight = 0.06 kg) salmon were then placed into each of eight 190-L (160-L working volume) semi-square tanks. Flows remained similar for each tank. Feeding commenced the day after the fish were placed in the tanks. Feed amounts at or slightly above satiation were derived using the hatchery constant method (Butterbaugh & Willoughby 1967) using an anticipated feed conversion ratio of 1.1. Feeding amounts were adjusted weekly according to individual fish weights obtained as previously described.

Table 1. *Ingredient list for BioVita and AquaFeed Salmon starter (#0) feeds.*

BioVita Starter #0	AquaFeed Salmon #0
Fish meal	Animal protein products
Wheat gluten	Barley
Fish oil	Stabilized fish oil
Wheat flour	Corn protein concentrate
Krill meal	Wheat gluten
Condensed fish protein digest	Corn gluten
Dried whey	Lecithin
Monoammonium phosphate	Lysine
L-lysine	Choline chloride
Ethoxyquin	Taurine
Choline chloride	DL methionine
Vitamin E	Mono Di-calcium phosphate
DL-methionine	Calcium L-Ascorbate-2-Monosphosphate
Calcium L-ascorbyl-2-monophosphate	Threonine
Dried yeast	L-Histidine
Paracoccus pigment	Vitamin E supplement
Yeast extract	Magnesium sulfate
Roughage products	Nicotinamide
Zinc sulfate	Inositol
Ferrous sulfate	Propionic acid
Inositol	D-Calcium pantothenate
Niacin	Riboflavin supplement
Calcium pantothenate	Zinc proteinate
Manganese sulfate	Menadione sodium bisulfite complex
Riboflavin	Zinc sulfate
Mineral oil	Pyridoxine hydrochloride
Pyridoxine hydrochloride	Thiamine mononitrate
Vitamin B12	Copper proteinate
Menadione sodium bisulfite complex	Manganese proteinate
Copper sulfate	Manganese sulfate
Biotin	Folic acid
Thiamine mononitrate	Calcium iodate
Vitamin A acetate	Cobalt sulfate
Folic acid	Vitamin A supplement
Vitamin D3	Biotin

An Evaluation of two Commercial Feeds During the Initial Rearing of Juvenile Chinook Salmon

Calcium iodate	Vitamin B12 supplement
Sodium selenite	Sodium selenite
	Vitamin D supplement

Two commercially available starter diets were used. Four tanks of fish received BioVita #0 granules (Bio-Oregon, Longview, Washington, USA), and four received AquaFeed Salmon #0 granules (Optimal Fish Food LLC, Omaha, Nebraska, USA). Table 1 is the ingredient list for each feed, and Table 2 is the proximate composition. Feed was dispensed for two seconds every hour during daylight hours using 0.5-L vibratory feeders (Pentair Aquatic Ecosystems Inc., Apopka, Florida, USA). Tanks were cleaned and mortalities recorded daily. At the end of the trial, five fish from each tank were weighed to the nearest 0.01 g and measured (total length) to the nearest 0.01 mm. Total tank weights to the nearest g were also recorded.

Table 2. Proximate composition for BioVita and AquaFeed Salmon starter (#0) feeds.

	BioVita Starter #0	AquaFeed Salmon #0
Protein (%)	53	53
Fat (%)	18	18
Fiber (%)	1	1.5
Phosphorus (%)	1.2	0.9
Sodium (%)	1.1	-
Calcium (%)	2.6	-
Ash (%)	12	9

2.2. Trial 2

Trial 2 began on 31 January 2025 and lasted for 21 days, ending on 20 February 2025. After final data collection for Trial 1, fish for each treatment group were pooled (i.e. all four tanks for each diet were combined into one tank) and equally allocated back into the eight 190-L (160-L working volume) semi-square tanks. Because the fish fed BioVita diet had a greater absolute gain than those fed AquaFeed, initial tank weights were 108 g for the four BioVita-fed tanks and 94 g for the four AquaFeed-fed tanks.

Table 3. Ingredient list for BioVita and AquaFeed Salmon #1 granules.

BioVita Starter #1	AquaFeed Salmon #1
Fish meal	Animal protein products
Wheat gluten	Barley
Fish oil	Stabilized fish oil
Wheat flour	Corn protein concentrate
Krill meal	Wheat gluten
Condensed fish protein digest	Corn gluten
Dried whey	Lecithin
Monoammonium phosphate	Lysine
L-Lysine	Choline chloride
Ethoxyquin	Taurine
Choline chloride	DL methionine
Vitamin E	Mono Di-calcium phosphate
DL-methionine	Calcium L-Ascorbate-2-Monophosphate
Calcium L-ascorbyl-2-monophosphate	Threonine
Dried yeast	L-Histidine
Paracoccus pigment	Vitamin E supplement
Yeast extract	Magnesium sulfate
Roughage products	Nicotinamide
Zinc sulfate	Inositol
Ferrous sulfate	Propionic acid
Inositol	D-Calcium pantothenate
Niacin	Riboflavin supplement
Calcium pantothenate	Zinc proteinate
Manganese sulfate	Menadione sodium bisulfite complex
Riboflavin	Zinc sulfate
Mineral oil	Pyridoxine hydrochloride
Pyridoxine hydrochloride	Thiamine mononitrate
Vitamin B12	Copper proteinate
Menadione sodium bisulfite complex	Manganese proteinate

Copper sulfate	Manganese sulfate
Biotin	Folic acid
Thiamine mononitrate	Calcium iodate
Vitamin A acetate	Cobalt proteinate
Folic acid	Cobalt sulfate
Vitamin D3	Vitamin A supplement
Calcium iodate	Biotin
Sodium selenite	Vitamin B12 supplement
	Sodium selenite
	Vitamin D supplement

Feeding commenced the day after the fish were placed into tanks. Fish were fed the same brand they received in the first trial, with feed size increased to #1 granules. The ingredient list and proximate composition for each of the feeds are listed in Tables 3 and 4. Feeding rates, feed dispensing, tank cleaning, and data collection at the end of the trial were the same as in the first trial.

2.3. Equations

The following equations were used in this study:

$$Gain = end\ weight - start\ weight$$

$$Percent\ gain\ (\%) = \frac{gain}{start\ weight}$$

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

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

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

2.4. Statistical Analysis

The SPSS (24.0, IBM, Armonk, New York, USA) statistical program was used for data analysis. 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 subsequent statistical analysis. Percentage data were log transformed before analysis to stabilize the variances (Warton & Hui 2011).

Table 4. Proximate composition for BioVita and AquaFeed Salmon #1.

	BioVita Starter #1	AquaFeed Salmon #1
Protein (%)	52	52
Fat (%)	20	20
Fiber (%)	1	1.5
Phosphorus (%)	1.2	0.9
Sodium (%)	1.1	-
Calcium (%)	2.6	-
Ash (%)	-	9

3. RESULTS

3.1. Trial 1

At 108 g, ending total tank weight was significantly greater in BioVita-fed tanks compared to the 94 g in the AquaFeed-fed tanks (Table 5). Similarly, total tank gain was significantly greater in the BioVita group than in the AquaFeed group. Feed conversion ratio, percent mortality, specific growth rate, individual fish weight, total length, and condition factor were not significantly different between the fish receiving either feed (Table 6).

Table 5. Mean (SE) final weights, gain, feed conversion ratio (FCR¹), and mortality of tanks of Chinook salmon receiving either BioVita or AquaFeed starter diets for 24 days starting with initial feeding. Means followed by different letters are significantly different (P < 0.05; N = 4).

	BioVita	AquaFeed	P
Weight start (kg)	0.06	0.06	-

An Evaluation of two Commercial Feeds During the Initial Rearing of Juvenile Chinook Salmon

Weight end (kg)	0.108 (0.003) x	0.094 (0.004) y	0.048
Gain (kg)	0.048 (0.003) x	0.034 (0.004) y	0.048
Gain (%)	79.2 (5.5)	56.7 (7.3)	0.061
Feed fed (kg)	0.108	0.108	-
FCR ¹	2.31 (0.16)	3.36(0.49)	0.085
Mortality (%)	6.19 (1.29)	3.36 (0.49)	0.097

¹FCR = food fed/gain

Table 6. Mean (+SE) final individual fish total length, weight, specific growth rate (SGR)¹, and condition factor (K)² of Chinook salmon receiving either BioVita or AquaFeed starter diets for 24 days starting with initial feeding. Means followed by different letters are significantly different ($P < 0.05$; $N = 4$).

	BioVita	AquaFeed	P
Length start (mm)	33.87	33.87	-
Length end (mm)	42.35 (0.57)	40.21(0.68)	0.052
Weight start (g)	0.30	0.30	-
Weight end (g)	0.54 (0.04)	0.46 (0.02)	0.111
SGR ¹	2.42 (0.29)	1.74 (0.22)	0.111
K ²	0.71 (0.02)	0.70 (0.03)	0.910

¹Specific Growth Rate (SGR) = $100 * (\ln(\text{end weight}) - \ln(\text{start weight})) / (\text{number of days})$

²Condition Factor (K) = $105 * (\text{fish weight}) / (\text{fish length})^3$

3.2. Trial 2

Gain, percent gain, feed conversion ratio, and percent mortality were not significantly different between the treatment groups (Table 7). Individual fish weight and total length were significantly greater in fish fed BioVita, at 55.81 mm and 1.47 g, respectively, compared to the fish fed AquaFeed that had a mean total length of 49.99 mm and weight of 1.03 g (Table 8). Specific growth rate and condition factor were not significantly different in fish fed either of the feeds.

Table 7. Mean (SE) final weight, gain, feed conversion ratio (FCR¹), and mortality of tanks of Chinook salmon receiving either BioVita or AquaFeed #1 granule diets from 24 to 45 days after initial feeding. Means followed by different letters are significantly different ($P < 0.05$; $N = 4$).

	BioVita	AquaFeed	P
Weight start (kg)	0.11 (0.00) x	0.09 (0.00) y	0.021
Weight end (kg)	0.25 (0.01) x	0.20 (0.02) y	0.021
Gain (kg)	0.14 (0.01)	0.11 (0.02)	0.060
Gain (%)	133.88 (4.83)	111.44 (16.86)	0.226
Feed fed (g)	0.108	0.108	-
FCR ¹	1.46 (0.05)	1.83 (0.29)	0.264
Mortality (%)	2.50 (0.81)	2.91 (1.91)	0.883

¹FCR = food fed/gain

Table 8. Mean (SE) individual fish total length, weight, specific growth rate (SGR)¹ and condition factor (K)² of Chinook salmon receiving either BioVita or AquaFeed #1 granule diets for 24 to 45 days after initial feeding. Means followed by different letters are significantly different ($P < 0.05$; $N = 4$).

	BioVita	AquaFeed	P
Length start (mm)	42.35 (0.00)	40.21 (0.00)	-
Length end (mm)	55.81 (0.40) x	49.99 (1.19) y	0.004
Weight start (g)	0.54 (0.00)	0.46 (0.00)	-
Weight end (g)	1.47 (0.03) x	1.03 (0.09) y	0.021
SGR ¹	4.77 (0.09)	3.78 (0.40)	0.053
K ²	0.85 (0.00) x	0.82 (0.01) y	0.046

¹ Specific Growth Rate (SGR) = $100 * (\ln(\text{end weight}) - \ln(\text{start weight})) / (\text{number of days})$

²Condition Factor (K) = $105 * (\text{fish weight}) / (\text{fish length})^3$

4. DISCUSSION

The results of this experiment indicate improved growth in juvenile Chinook salmon fed BioVita at initial feeding compared to those fed the AquaFeed Salmon diet. However, after the fish were switched from #0 (starter) to #1, the results are much more ambiguous. It is difficult to isolate the possible reason

or reasons for any differences between the diets because of the number of differences in ingredients between the two feeds. For example, the primary ingredient in the BioVita feeds is fish meal, whereas the primary ingredient in the AquaFeed feeds is animal protein products. Krill meal, shrimp meal, blood meal, varieties of insect meal, fish silage, hydrolyzed feather meal, and poultry by-product meal have been used as animal protein products in fish diets (El-Sayed 1998; Nwana et al. 2004; Turker et al. 2005; Arunlertaree & Moolthongnoi 2008; Mohd Din et al. 2012; Alegbeleye et al. 2012; Chor et al. 2013; Adewole & Olaleye 2014; Hernandez et al. 2014; Sing et al. 2014; Madage et al. 2015; Yones & Metwalli 2015; Yu et al. 2015; Gong et al. 2016; Srour et al. 2016; Rapatsa & Moyo 2017; Mohd Taufek et al. 2018; Belghit et al. 2019). Many of these animal protein products vary in nutritional value and lack some of the essential amino acids required for fish (Tran et al. 2015; Rapatsa & Moyo 2017; Luthada-Raswiswi et al. 2021).

BioVita Starter and AquaFeed Salmon feeds have similar proximate analysis. Specifically, the crude protein levels for BioVita and AquaFeed were exactly the same. Both protein percentages sufficiently meet nutrient requirements for Pacific salmon (*Oncorhynchus* spp.) as suggested by the National Research Council (2011). The protein sources may have affected the results of these trials. Fish meal is an excellent protein for salmon; it is highly digestible and contains all essential amino acids in the proportions that fish require (Lall & Dumas 2015; Barrows et al. 2023). The BioVita diets also contain krill meal, krill-based additives (e.g., Paracoccus pigment), and fish protein hydrolysate which enhance palatability, provides pigments and nutrients, and may support immunity (Barnes et al. 2006; Gong et al. 2016; Mahdy et al. 2022). In Chinook salmon, partial replacement of fish meal by animal protein products did not result in impaired growth, however, higher replacement percentages resulted in decreased growth (Fowler 1991) and digestibility (Hajen et al. 1993). Consistent results have been observed in other *Oncorhynchus* species (Bransden et al. 2016; Lee et al. 2001; Yanik et al. 2003; Burr et al. 2012; Hajen et al. 1993; Gunathilaka et al. 2025). Similarly, decreased growth rates have been observed in high percentages of fish meal replacement by plant-protein sources in Chinook salmon (Higgs et al. 1982; Bureau et al. 1998; Fowler 2011) and other salmonids (Collins et al. 2013; Pierce et al. 2008; Egerton et al. 2020). Animal protein products may be suitable for fish meal replacement, however, due to the high variability of nutritional content, it's considered unreliable as a primary protein source in fish diets (NRC 2011; Hardy 1996). Thus, the differences in protein sources and other ingredients may provide a possible explanation for the performance differences observed.

Yeast ingredients may have also influenced significant growth differences in this study. BioVita feeds contained dried yeast and yeast extract, whereas Aquafeed salmon feeds did not. Yeast is considered a valuable component of aquaculture feeds due to its beneficial effects on both nutrition and immune function (NRC 2011; Barnes & Durben 2010; Mahdy et al. 2022). When included as a feed additive, yeast has improved growth and reduced mortality in Chinook salmon (Barnes et al. 2006) as well as other fish species (Barnes & Durben 2010; Mahdy et al. 2022; Barnes et al. 2006; Staykov et al. 2007; Lara-Flores et al. 2010; Cook et al., 2003; Li & Gatlin 2003; Li & Gatlin 2003; Ghosh et al. 2005). Yeast also has immunostimulatory properties (Staykov et al. 2007; Li & Gatlin 2004; Pooramini et al. 2009).

The results from this study may have been influenced by uneven feed dispersal. The AquaFeed feed appeared to have an excessive oil topcoat, often clumped, and frequently interfered with the automatic feeders. This uneven distribution may have reduced consumption and increased waste. BioVita did not clump and visibly appeared to have less waste in the tank. The consistently lower feed conversion ratio observed with BioVita suggests improved palatability and feed utilization (NRC 2011; Lall & Dumas 2015).

The two trials in this study had a relatively short duration at only 24 and 21 days. The National Research Council (2011) recommended feed trials be a minimum of 56 days. However, Weatherup and McCracken (1999) stated that trials must only endure long enough for significant differences to be observed.

Lastly, commercial feed formulations are proprietary and subject to change. Thus, these results may only be applicable to feeds used during this study. However, the results from this experiment suggest that Bio-Oregon BioVita should be used during initial feeding of juvenile landlocked Chinook salmon to maximize growth. After switching to #1, either feed may be appropriate.

ACKNOWLEDGEMENTS

Isaac Pollock and Connor Bennett assisted with fish rearing and data collection during this study.

- [1] Adewole, H.A., Olaleye, V.F. 2014. Growth performance in *Clarias gariepinus* Burchell fingerlings fed blood meal–bovine rumen digesta blend diets. *Ife Journal of Science* 16, 495–503. <https://doi.org/10.4314/ij.s.v16i3>
- [2] Albrektsen, S., Kortet, R., Skov, P.V., Ytteborg, E., Gitlesen, S., Kleinegris, D., Mydland, L.-T., Hansen, J.Ø., Lock, E.-J., Mørkøre, T., James, P., Wang, X., Whitaker, R.D., Vang, B., Hatlen, B., Daneshvar, E., Bhatnagar, A., Jensen, L.B., Øverland, M. 2022. Future feed resources in sustainable salmonid production: A review. *Reviews in Aquaculture* 14, 1790–1812. <https://doi.org/10.1111/raq.12673>
- [3] Alegbeleye, W.O., Obasa, S.O., Olude, O.O., Otubu, K., Jimoh, W. 2012. Preliminary evaluation of the nutritive value of the variegated grasshopper (*Zonocerus variegatus* L.) for African catfish *Clarias gariepinus* (Burchell. 1822) fingerlings. *Aquaculture Research* 43, 412–420. <https://doi.org/10.1111/j.1365-2109.2011.02844.x>
- [4] Arunlertaree, C., Moolthongnoi, C. 2008. The use of fermented feather meal for replacement fish meal in the diet of oreochromis niloticus. *Environment and Natural Resources Journal* 6, 13–24.
- [5] Barnes, M.E., Durben, D.J. 2010. An evaluation of DVAqua®, a fully-fermented yeast culture, during long-term hatchery rearing of McConaughy strain rainbow trout. *Aquaculture Nutrition* 16, 299–304. <https://doi.org/10.1111/j.1365-2095.2009.00665.x>
- [6] Barnes, M.E., Durben, D.J., Reeves, S.G., Sanders, R. 2006. Dietary yeast culture supplementation improves initial rearing of McConaughy strain rainbow trout. *Aquaculture Nutrition* 12, 388–394. <https://doi.org/10.1111/j.1365-2095.2006.00439.x>
- [7] Belghit, I., Liland, N.S., Gjesdal, P., Biancarosa, I., Menchetti, E., Li, Y., Waagbø, R., Krogdahl, Å., Lock, E.-J. 2019. Black soldier fly larvae meal can replace fish meal in diets of sea-water phase Atlantic salmon (*Salmo salar*). *Aquaculture* 503, 609–619. <https://doi.org/10.1016/j.aquaculture.2018.12.032>
- [8] Bransden, M.P., Carter, C.G., Nowak, B.F. 2001. Effects of dietary protein source on growth, immune function, blood chemistry and disease resistance of Atlantic salmon (*Salmo salar* L.) parr. *Animal Science* 73, 105–113. <https://doi.org/10.1017/S1357729800058100>
- [9] Bureau, D.P., Harris, A.M., Cho, C.Y. 1998. The effects of purified alcohol extracts from soy products on feed intake and growth of Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*). *Aquaculture* 161, 27–43. [https://doi.org/10.1016/S0044-8486\(97\)00254-8](https://doi.org/10.1016/S0044-8486(97)00254-8)
- [10] Burr, G.S., Wolters, W.R., Barrows, F.T., Hardy, R.W. 2012. Replacing fishmeal with blends of alternative proteins on growth performance of rainbow trout (*Oncorhynchus mykiss*), and early or late stage juvenile Atlantic salmon (*Salmo salar*). *Aquaculture* 334–337, 110–116. <https://doi.org/10.1016/j.aquaculture.2011.12.044>
- [11] Butterbaugh, G.L., Willoughby, H.A. 1967. Feeding guide for brook, brown, and rainbow trout. *Progressive Fish-Culturist* 29, 210–215. [https://doi.org/10.1577/1548-8640\(1967\)29\[210:AFGFBB\]2.0.CO;2](https://doi.org/10.1577/1548-8640(1967)29[210:AFGFBB]2.0.CO;2)
- [12] Carter, C.G., Codabaccus, M.B. 2022. Feeding in hatcheries. In: Davis, D.A. (ed.), *Feed and feeding practices in aquaculture* (2nd ed.). Woodhead Publishing Series in Food Science, Technology and Nutrition. Woodhead Publishing, Oxford, pp. 355–398. <https://doi.org/10.1016/B978-0-12-821598-2.00013-8>
- [13] Chor, W.-K., Lim, L.-S., Shapawi, R. 2013. Evaluation of feather meal as a dietary protein source for African catfish fry, *Clarias gariepinus*. *Journal of Fisheries and Aquatic Science* 8, 697–705. <https://doi.org/10.3923/jfas.2013.697.705>
- [14] Collins, S.A., Øverland, M., Skrede, A., Drew, M.D. 2013. Effect of plant protein sources on growth rate in salmonids: Meta-analysis of dietary inclusion of soybean, pea and canola/rapeseed meals and protein concentrates. *Aquaculture* 400–401, 85–100. <https://doi.org/10.1016/j.aquaculture.2013.03.006>
- [15] Cook, M.T., Hayball, P.J., Hutchinson, W., Nowak, B.F., Hayball, J.D. 2003. Administration of a commercial immunostimulant preparation, EcoActiva™ as a feed supplement enhances macrophage respiratory burst and the growth rate of snapper (*Pagrus auratus*, Sparidae (Bloch and Schneider)) in winter. *Fish & Shellfish Immunology* 14, 333–345. <https://doi.org/10.1006/fsim.2002.0441>
- [16] Egerton, S., Wan, A., Murphy, K., Collins, F., Ahern, G., Sugrue, I., Busca, K., Egan, F., Muller, N., Whooley, J., McGinnity, P., Culloty, S., Ross, R.P., Stanton, C. 2020. Replacing fishmeal with plant protein in Atlantic salmon (*Salmo salar*) diets by supplementation with fish protein hydrolysate. *Scientific Reports* 10, 4194. <https://doi.org/10.1038/s41598-020-60325-7>
- [17] El-sayed, A. 1998. Total replacement of fish meal with animal protein sources in Nile tilapia, *Oreochromis niloticus* (L.), feeds. *Aquaculture Research* 29, 275–280. <https://doi.org/10.1046/j.1365-2109.1998.00199.x>

- [18] FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action, The State of World Fisheries and Aquaculture (SOFIA). FAO, Rome, Italy. <https://doi.org/10.4060/ca9229en>
- [19] Fletcher, B., Barnes, M. E. 2008. Performance of two starter diets during landlocked fall Chinook salmon initial feeding. *Proceedings of the South Dakota Academy of Science* 87, 179–184.
- [20] Fowler, L.G. 1991. Poultry by-product meal as a dietary protein source in fall Chinook salmon diets. *Aquaculture* 99, 309–321. [https://doi.org/10.1016/0044-8486\(91\)90251-2](https://doi.org/10.1016/0044-8486(91)90251-2)
- [21] Fowler, L.G. 1980. Substitution of soybean and cottonseed products for fish meal in diets fed to Chinook and coho salmon. *The Progressive Fish-Culturist* 42, 87–91. [https://doi.org/10.1577/1548-8659\(1980\)42\[87:SOSACP\]2.0.CO;2](https://doi.org/10.1577/1548-8659(1980)42[87:SOSACP]2.0.CO;2)
- [22] Ghosh, K., Sen, S.K., Ray, A.K. 2005. Feed utilization efficiency and growth performance in Rohu, Labeo Rohita (Hamilton, 1822), fingerlings fed yeast extract powder supplemented diets. *Acta Ichthyologica Et Piscatoria* 35, 111–117. <https://doi.org/10.3750/AIP2005.35.2.07>
- [23] Gong, Y., Huang, Y., Gao, L., Lu, J., Huang, H., Xia, Y. 2016. Substitution of krill meal for fish meal in feed for Russian sturgeon, *Acipenser gueldenstaedtii*. *Israeli Journal of Aquaculture - Bamidgheh* 68. <https://doi.org/10.46989/001c.20797>
- [24] Gunathilaka, B.E., Kim, G.-U., Lee, S.-M. 2025. Fish meal replacement in chum salmon (*Oncorhynchus keta*) diet with alternative protein sources. *Aquaculture Nutrition* 2025, 4630480. <https://doi.org/10.1155/anu/4630480>
- [25] Hajen, W.E., Higgs, D.A., Beames, R.M. and Dosanjh, B.S. 1993. Digestibility of various feedstuffs by post-juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in sea water. 2. Measurement of digestibility. *Aquaculture* 112, 333-348. [https://doi.org/10.1016/0044-8486\(93\)90394-E](https://doi.org/10.1016/0044-8486(93)90394-E)
- [26] Hanten, R., Fincel, M.J., Meyer, H.A., Potter, K. & Smith, M.J. 2016. Annual fish population and angler use, harvest, and preference surveys on Lake Sharpe, South Dakota, 2015. South Dakota Department of Game, Fish and Parks, Annual Report 16-05, Pierre.
- [27] Hardy, R.W. 1996. Alternate protein sources for salmon and trout diets. *Animal Feed Science and Technology*, N. American Nutrition Conferences III 59, 71–80. [https://doi.org/10.1016/0377-8401\(95\)00888-8](https://doi.org/10.1016/0377-8401(95)00888-8)
- [28] Hernandez, C., Osuna-Osuna, L., Benitez-Hernandez, A., Sanchez-Gutierrez, J., González-Rodríguez, B., Dominguez-Jimenez, P. 2014. Replacement of fish meal with poultry by-product meal feed grade in diet for juvenile of spotted rose snapper *Lutjanus guttatus*. *Latin American Journal of Aquatic Research* 42, 111–120. <https://doi.org/10.3856/vol42-issue1-fulltext-8>
- [29] Higgs, D.A., McBride, J.R., Markert, J.R., Dosanjh, B.S., Plotnikoff, M.D., Clarke, W.C. 1982. Evaluation of Tower and Candle rapeseed (canola) meal and Bronowski rapeseed protein concentrate as protein supplements in practical dry diets for juvenile Chinook salmon (*Oncorhynchus tshawytscha*). *Aquaculture* 29, 1–31. [https://doi.org/10.1016/0044-8486\(82\)90030-8](https://doi.org/10.1016/0044-8486(82)90030-8)
- [30] Kandylari, A., Mallouchos, A., Papandroulakis, N., Golla, J.P., Lam, T.T., Sakellari, A., Karavoltsos, S., Vasiliou, V., Kapsokfalou, M. 2020. Nutrient composition and fatty acid and protein profiles of selected fish by-products. *Foods* 9, 190. <https://doi.org/10.3390/foods9020190>
- [31] Kindschi, G.A., Myrick, C.A., Barrows, F.T., Toner, M., Fraser, W.C., Ilgen, J., Beck, L. 2009. Performance of Yellowstone and Snake River cutthroat trout fry fed seven different diets. *North American Journal of Aquaculture* 71, 325–329. <https://doi.org/10.1577/A08-026.1>
- [32] Lall, S.P., Dumas, A. 2015. 3 - Nutritional requirements of cultured fish: Formulating nutritionally adequate feeds. In: Davis, D.A. (ed.), *Feed and feeding practices in aquaculture* (2nd ed.). Woodhead Publishing Series in Food Science, Technology and Nutrition. Woodhead Publishing, Oxford, pp. 53–109. <https://doi.org/10.1016/B978-0-08-100506-4.00003-9>
- [33] Lara-Flores, M., Olivera-Castillo, L., Olvera-Novoa, M.A. 2010. Effect of the inclusion of a bacterial mix (*Streptococcus faecium* and *Lactobacillus acidophilus*), and the yeast (*Saccharomyces cerevisiae*) on growth, feed utilization and intestinal enzymatic activity of Nile tilapia (*Oreochromis niloticus*). *International Journal of Fish Aquaculture* 2, 93–101.
- [34] Lee, K., Dabrowski, K., Blom, J.H., Bai, S.C. 2001. Replacement of fish meal by a mixture of animal by-products in juvenile rainbow trout diets. *North American Journal of Aquaculture* 63, 109–117. [https://doi.org/10.1577/1548-8454\(2001\)063<0109:ROFMBA>2.0.CO;2](https://doi.org/10.1577/1548-8454(2001)063<0109:ROFMBA>2.0.CO;2)
- [35] Li, P., Gatlin, D.M. 2004. Dietary brewers yeast and the prebiotic Grobionic™AE influence growth performance, immune responses and resistance of hybrid striped bass (*Morone chrysops* × *M. saxatilis*) to *Streptococcus iniae* infection. *Aquaculture* 231, 445–456. <https://doi.org/10.1016/j.aquaculture.2003.08.021>

- [36] Li, P., Gatlin, D.M. 2003. Evaluation of brewers yeast (*Saccharomyces cerevisiae*) as a feed supplement for hybrid striped bass (*Morone chrysops*×*M. saxatilis*). *Aquaculture* 219, 681–692. [https://doi.org/10.1016/S0044-8486\(02\)00653-1](https://doi.org/10.1016/S0044-8486(02)00653-1)
- [37] Luthada-Raswiswi, R., Mukaratirwa, S., O'Brien, G. 2021. Animal protein sources as a substitute for fishmeal in aquaculture diets: A systematic review and meta-analysis. *Applied Sciences* 11, 3854. <https://doi.org/10.3390/app11093854>
- [38] Madage, S.S.K., Medis, W.U.D., Sultanbawa, Y. 2015. Fish silage as replacement of fishmeal in red tilapia feeds. *Journal of Applied Aquaculture* 27, 95–106. <https://doi.org/10.1080/10454438.2015.1005483>
- [39] Mahdy, M.A., Jamal, M.T., Al-Harb, M., Al-Mur, B.A., Haque, M.F. 2022. Use of yeasts in aquaculture nutrition and immunostimulation: A review. *Journal of Applied Biology & Biotechnology* 10, 59–65. <https://doi.org/10.7324/JABB.2022.100507>
- [40] Martin, T.J., Voorhees, J.M., Treft, C.E., Fletcher, B., Barnes, M.E. 2018. Effects of four commercial diets on rainbow trout *Oncorhynchus mykiss* growth, feeding efficiency, and mortality at a production hatchery with endemic bacterial coldwater disease. *Insights in Aquaculture and Biotechnology* 2, 10.
- [41] Mohd Din, A.R.J., Abdul Razak, S., Sabaratnam, V. 2012. Nutritive potential and utilization of super worm (*Zophobas morio*) meal in the diet of Nile tilapia (*Oreochromis niloticus*) juvenile. *African Journal of Biotechnology* 11. <https://doi.org/10.5897/AJB11.1084>
- [42] Mohd Taufek, N., Muin, H., Raji, A., Yusof, H., Alias, Z., Abdul Razak, S. 2017. Potential of field crickets meal (*Gryllus bimaculatus*) in the diet of African catfish (*Clarias gariepinus*). *Journal of Applied Animal Research* 46, 1–6. <https://doi.org/10.1080/09712119.2017.1357560>
- [43] National Research Council (NRC). 2011. *Nutrient Requirements of Fish and Shrimp*. Washington, DC: National Academies Press. <https://doi.org/10.17226/13039>
- [44] Nwanna, L., Ajenifuja, A., Enujiugha, V. 2004. Replacement of fish meal with chemically preserved shrimp head in the diets of African catfish, *Clarias gariepinus*. *Food, Agriculture, Environment* 2, 79–83.
- [45] Pierce, L.R., Palti, Y., Silverstein, J.T., Barrows, F.T., Hallerman, E.M., Parsons, J.E. 2008. Family growth response to fishmeal and plant-based diets shows genotype×diet interaction in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture* 278, 37–42. <https://doi.org/10.1016/j.aquaculture.2008.03.017>
- [46] Pooramini, M., Kamali, A., Hajimoradloo, A., Alizadeh, M., Ghorbani, R. 2009. Effect of using yeast (*Saccharomyces cerevisiae*) as probiotic on growth parameters, survival and carcass quality in rainbow trout *Oncorhynchus mykiss* fry. *International Aquatic Research* 1, 39–44.
- [47] Rapatsa, M.M., Moyo, N.A.G. 2017. Evaluation of *Imbrasia belina* meal as a fishmeal substitute in *Oreochromis mossambicus* diets: Growth performance, histological analysis and enzyme activity. *Aquaculture Reports* 5, 18–26. <https://doi.org/10.1016/j.aqrep.2016.11.004>
- [48] Roduner, K.A., Voorhees, J.M., Barnes, M.E. 2025. An evaluation of two commercial feeds during rainbow trout initial rearing. *Journal of Aquaculture and Marine Biology* 14, 75-81. <https://doi.org/10.15406/jamb.2025.14.00418>
- [49] Sing, K.-W., Kamarudin, M.S., Wilson, J.-J., Azirun, M.S. 2014. Evaluation of blowfly (*Chrysomya megacephala*) maggot meal as an effective, sustainable replacement for fishmeal in the diet of farmed juvenile red tilapia (*Oreochromis* sp.). *Pakistan Veterinary Journal* 34, 288–292.
- [50] Srour, T.M., Essa, M., Abdel-Rahim, M.M., Mansour, M.A. 2016. Replacement of fish meal with poultry by-product meal (PBM) and its effects on the survival, growth, feed utilization, and microbial load of European seabass, *Dicentrarchus labrax* fry. *Global Advanced Research Journal of Agricultural Science* 5, 2315–5094.
- [51] Staykov, Y., Spring, P., Denev, S., Sweetman, J. 2007. Effect of a mannan oligosaccharide on the growth performance and immune status of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture International* 15, 153–161. <https://doi.org/10.1007/s10499-007-9096-z>
- [52] Tran, G., Heuzé, V., Makkar, H.P.S. 2015. Insects in fish diets. *Animal Frontiers* 5, 37–44. <https://doi.org/10.2527/af.2015-0018>
- [53] Treft, C.E., Barnes, M.E., Voorhees, J.M., Martin, T.J., Fletcher, B.L. 2017. Impacts of feeding three commercial trout starter diets to rainbow trout on bacterial coldwater disease-induced mortality. *Journal of Marine Biology and Aquaculture* 3, 1–5. <https://doi.org/10.15436/2381-0750.17.1501>
- [54] Turker, A., Yiğit, M., Ergün, S., Karaali, B., Erteken, A. 2005. Potential of poultry by-product meal as a substitute for fishmeal in diets for black sea turbot *Scophthalmus maeoticus*: growth and nutrient utilization in winter. *Israeli Journal of Aquaculture - Bamidgah* 57, 49–61. <https://doi.org/10.46989/001c.20392>

- [55] Warton D.I., Hui, F.K.C. 2001. The arcsine is asinine: the analysis of proportions in ecology. *Ecology* 92, 3-10. <https://doi.org/10.1890/10-0340.1>
- [56] Weatherup, R.N., McCracken, K.J. 1999. Changes in rainbow trout, *Oncorhynchus mykiss* (Walbaum), body composition with weight. *Aquaculture Research* 30, 305–307. <https://doi.org/10.1046/j.1365-2109.1999.00320.x>
- [57] Wipf, M.M., Barnes, M.E., Nero, P. 2021. An evaluation of four commercial feeds during Chinook salmon rearing. *Journal of Marine Biology and Aquaculture* 7, 1–5. <https://doi.org/10.15436/2381-0750.21.3002>
- [58] Yanik, T., Bai, S.C., Dabrowski, K. 2003. Replacing fish meal in rainbow trout (*Oncorhynchus mykiss*) diets. *Israeli Journal of Aquaculture - Bamidgeh* 55, 179–186. <https://doi.org/10.46989/001c.20355>
- [59] Yones, A.M.M., Metwalli, A.A. 2015. Effects of fish meal substitution with poultry by-product meal on growth performance, nutrients utilization and blood contents of juvenile Nile tilapia (*Oreochromis niloticus*). *Journal of Aquaculture Research & Development* 7, 389–395. <https://doi.org/10.4172/2155-9546.1000389>
- [60] Yu, H., Zhang, Q., Cao, H., Tong, T., Huang, G., Li, W. 2015. Replacement of fish meal by meat and bone meal in diets for juvenile snakehead *Ophiocephalus argus*. *Fisheries Science* 81, 723–729. <https://doi.org/10.1007/s12562-015-0871-x>

Citation: Michael E. Barnes et al. “An Evaluation of two Commercial Feeds During the Initial Rearing of Juvenile Chinook Salmon”. *International Journal of Innovative Studies in Aquatic Biology and Fisheries*. 2025; 10 (1):22-31. DOI: <https://doi.org/10.20431/24547670.1001004>.

Copyright: © 2025 Authors. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.