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University of Hawaii Aquaculture Program in association with
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http://www.aquaculturehub.org

ISSN 0792 - 156X

PUBLISHER:
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL
Phone: + 972 52 3965809
http://siamb.org.il

REPLACING FISH MEAL IN RAINBOW TROUT *(ONCORHYNCHUS MYKISS)* DIETS

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(Received 21.11.02, Accepted 11.5.03)

Key words: blood meal, bone and meat meal, fish meal replacement, *Oncorhynchus mykiss*, poultry by-products

Abstract

The effects of Ohio State University (OSU) meal (a mixture of blood meal, meat and bone meal, poultry by-products and feather meal), as partial or total replacement of fish meal was investigated. Thirty-two fish tanks, each containing 30 rainbow trout (initial mean weight 1.93 g), were fed one of 10 diets (the control had only two replicates) containing a different quantity of OSU meal for 14 weeks. The trout fed the diets containing 20% or 40% OSU meal grew similarly to the trout fed the fish meal based diet. Total replacement of the fish meal caused a significant reduction in growth ($p<0.05$) only at the 47% protein level and not at the 36%. The results of this study suggest that diets containing up to 75% OSU meal and 25% fish meal are sufficient for good growth in rainbow trout fry.

Introduction

Trout and salmon farming is a rapidly expanding industry throughout the world. Domestic products can successfully compete with imported salmon and other fish species. Public acceptance of salmon and trout is excellent and the increasing market demand can be filled by salmonids raised in aquaculture. Feed is the largest single cost (40-60%)

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in trout production and fish meal is a major component of most aquaculture feeds. Substantially higher quality feeds are needed in aquaculture than in other livestock husbandry owing to the high required protein level (40%). In addition, the diet must be attractive to the fish and readily consumed to avoid water pollution. Quality feeds come from quality ingredients, suggesting that only specialized manufacturing and processing can produce ingredients that can replace digestible fish meals (Smith et al, 1988; Dabrowski, 1993).

Salmonid aquaculture will require high protein ingredients as alternative sources of high-quality fish meal if the optimistic projection for 2-3 fold growth of the world's aquaculture industry by the next decade comes true. These ingredients must be tested, identified as suitable and standardized before they can be used to replace fish meal in salmonid diets. Alternative protein sources for salmonid diets may be by-products produced by the inedible rendering industry, such as blood, meat and bone meal, hydrolyzed hair and feather meals and many others.

Lack of the necessary quantity and quality of commercially available fish meals, and their high retail prices, have prompted many investigators to examine ways to replace fish meal with animal or plant proteins in diets for rainbow trout and other aquatic animals. The present study was undertaken to determine if fish meal protein could be partially or totally replaced by the Ohio State University (OSU) fish meal analog (a combination of feather meal, blood meal, meat and bone meal and poultry by-product meal) in rainbow trout diets.

Materials and Methods

Experimental design. Rainbow trout were produced at the Piketon Research and Extension Center of the Ohio State University. Thirty-two fish tanks were stocked with 30 rainbow trout fry (average weight 1.9 g), each, for a total weight per tank of 57±1 g. The fry were fed one of 10 diets for 14 weeks; there were three replicates of each treatment plus two controls. The fish in each tank were weighed collectively (to 0.1 g) twice a month and the quantity of feed was adjusted weekly (Yanik and Aras, 1998).

The 40 l flow-through tanks received well water at a rate of 500 ml/min. Supplemental aeration was provided to maintain dissolved oxygen near air saturation. The water temperature was maintained at 10±1°C and light was regulated at 12 hours light:12 hours dark.

Fish and animal by-products were purchased from a commercial source (H.J. Baker and Bro., Inc.). A single lot representative of the commodity was obtained, namely Canadian herring white fish meal, menhaden fish meal, blood meal, meat and bone meal, poultry by-product meal and feather meal. The alternate protein ingredients and reference herring meal were subjected to proximate analysis (Dabrowski et al., 1989) and included in diets based on modifications of the formula MNR-89G (economical grower diet for fingerlings and yearlings) of Guelph University (Cho, 1990). The only modification from the original MNR-89G formula was the replacement of blood meal by brewer's yeast. The ingredients and chemical composition of the diets are presented in Tables 1 and 2.

Five of the diets (1-5) were formulated to contain 36% crude protein and 3800 kcal/kg diet and five of the diets (6-10) were formulated to contain 47% crude protein and 4200 kcal/kg diet. Diets 1-10 contained the OSU fish meal analog; the control diet (47% protein, 4100 kcal/kg energy) was prepared using Pro-Pak as the fish meal analog. Within the same protein level, the diets were adjusted to contain the same amounts of methionine and lysine by adding the crystalline amino acids (Yanik and Aras, 1996).

Feeding. A container capable of holding 224 test tubes, 7 for each tank, was used to hold the feeds so that the same amount would be distributed to the fish at each feeding time. The feeds were stored in a refrigerator and given by hand twice daily (Yanik and Aras, 1998).

Statistical analyses. The two protein-level groups and the replacement percentages were subjected to a one way analysis of variance (ANOVA) followed by Duncan's multiple

Table 1. Ingredients of experimental diets.

Fixed ingredients	*%*
Brewers' yeast	9
Corn gluten meal	15
Soybean meal	12
Whey	7
Vitamin and mineral premix	2
Tender Jell[1]	1
Cr_2O_3	0.5

Diet no.:	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Fishmeal (%):	*20*	*15*	*10*	*5*	*0*	*40*	*30*	*20*	*10*	*0*
Fish meal analog (%):	*0*	*5*	*10*	*15*	*20*	*0*	*10*	*20*	*30*	*40*
Varying ingredients										
Menhaden fish meal	10	7.5	5	2.5	0	20	15	10	5	0
Herring fish meal	10	7.5	5	2.5	0	20	15	10	5	0
Blood meal	0	1.19	2.38	3.57	4.76	0	2.38	4.76	7.14	9.52
Meat and bone meal	0	1.19	2.38	3.57	4.76	0	2.38	4.76	7.14	9.52
Poultry by-products	0	1.19	2.38	3.57	4.76	0	2.38	4.76	7.14	9.52
Feather meal	0	1.19	2.38	3.57	4.76	0	2.38	4.76	7.14	9.52
Wheat middling	20	20	20	20	20	0	0	0	0	0
Cod liver oil	12	12.38	12.77	13.16	13.54	11.3	12.07	12.84	13.62	14.38
Methionine	0	0.06	0.12	0.17	0.23	0	0.12	0.24	0.35	0.47
Lysine	0	0.07	0.14	0.20	0.27	0	0.13	0.27	0.40	0.54
Alphacel[2]	1.5	1.23	0.95	0.69	0.42	2.20	1.66	1.11	0.57	0.03

[1] To increase the palatability of pellets by tenderizing
[2] Alpha cellulose (or ground cellulose) to increase the efficiency of protein utilization

Table 2. Chemical composition of the diets.

%	Diet									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Protein	35.8	36	36.1	36.2	36.3	46.3	46.6	46.8	47.1	47.3
Methionine	0.85	0.85	0.85	0.85	0.85	1.20	1.20	1.20	1.20	1.20
Lysine	2.02	2.02	2.02	2.02	2.02	2.89	2.89	2.89	2.89	2.89
Fat	15.2	15.5	15.7	16	16.2	15.5	16	16.5	17	17.5
Cystine	0.48	0.51	0.54	0.57	0.60	0.56	0.63	0.69	0.75	0.82
Calcium	0.86	0.85	0.84	0.83	0.82	1.57	1.55	1.53	1.50	1.48
Phosphorus	0.84	0.82	0.80	0.78	0.75	1.11	1.07	1.03	0.99	0.94
Energy (kcal/kg)	3861	3861	3861	3861	3861	4202	4202	4202	4202	4202

range test to determine significant differences among the means ($p<0.05$; Duncan, 1971).

Results

The individual weight, specific growth and feed conversion rates, survival and weight gain are presented in Table 3. The weight gain is compared to the amount of fish meal replaced in Fig. 1. The weight gains of the 47% protein diets were higher than in the 36% protein diets and the diets with the OSU replacements were able to compete with the commercial feed (Pro-Pak).

There were no significant differences ($p>0.05$) among diets 1 through 5 (36% protein) but there were significant differences ($p<0.05$) between diets 6-9 and 10 (47% protein) in feed conversion ratio, specific growth rate and weight gain. The differences between the same replacement levels at the two protein levels were also significant. ($p<0.05$).

Discussion

Fish meal is traditionally used in the production of trout feeds. This commodity is expensive and often in short supply. There is increasing evidence that the nutritional value of several alternate protein sources is not inferior to that of fish meal and their value can be increased significantly by an appropriate blend with other ingredients or addition of limiting amino acids (Dabrowski and Dabrowska, 1981; Dabrowska and Wojno, 1984; Yanik and Aras, 1998).

For rainbow trout, poultry by-product meal with feather meal appeared to be an excellent replacement for a portion of the fish meal. Higgs et al. (1979) found that poultry by-product meal replacing 75% of herring meal protein in a coho salmon diet allows the fish to maintain the same growth rate as in the controls. Tacon and Jackson (1985) reported that a mixture of meat and bone meal with blood meal (4:1) successfully replaced up to 50% of the fish meal in a rainbow trout diet. Yanik and Aras (1996) also reported on replacement of 25-50% of the fish meal with animal by-products in rainbow trout feeds. However, meat and bone meal alone was a poor replacement of herring meal in a

Table 3. Means±standard deviation for weight, specific growth rate, feed conversion ratio, survival, and percent weight gain of rainbow trout, fed experimental diets at 10°C water temperature during 14 weeks. Significance of results are compared only within the same protein levels.

	Diet									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Initial weight (g)	1.91±0.04[a]	1.93±0.06[a]	1.90±0.03[a]	1.94±0.01[a]	1.88±0.01[a]	1.92±0.01[a]	1.91±0.03[a]	1.93±0.03[a]	1.91±0.02[a]	1.94±0.04[a]
Final weight (g)	12.49±0.42[a]	12.56±0.25[a]	12.92±0.54[a]	12.96±0.56[a]	13.00±0.46[a]	15.70±0.07[a]	16.76±0.89[a]	17.19±0.96[a]	15.98±0.47[a]	13.34±0.10[a]
Specific growth rate (%)	1.92±0.03[a]	1.91±0.05[a]	1.96±0.04[a]	1.94±0.05[a]	1.97±0.04[a]	2.14±0.01[a]	2.22±0.07[a]	2.23±0.07[a]	2.16±0.03[a]	1.97±0.01[b]
Feed conversion rate	1.08±0.03[a]	1.08±0.04[a]	1.45±0.68[a]	1.07±0.05[a]	1.04±0.03[a]	0.96±0.01[a]	0.94±0.04[a]	0.92±0.03[a]	0.99±0.01[ab]	1.06±0.02[c]
Survival (%)	93.33±0.01[a]	90.00±6.67[a]	92.22±8.39[a]	91.11±7.70[a]	93.33±3.33[a]	94.44±3.85[a]	91.11±10.18[a]	92.22±5.09[a]	98.89±1.92[a]	94.44±6.94[a]
Weight gain (%)	554±18[a]	550±30[a]	581±25[a]	567±31[a]	592±28[a]	718±39.25[a]	778±56[a]	793±61[a]	734±21[a]	589±10[b]

Means in a row with different superscripts differ significantly ($p < 0.05$).

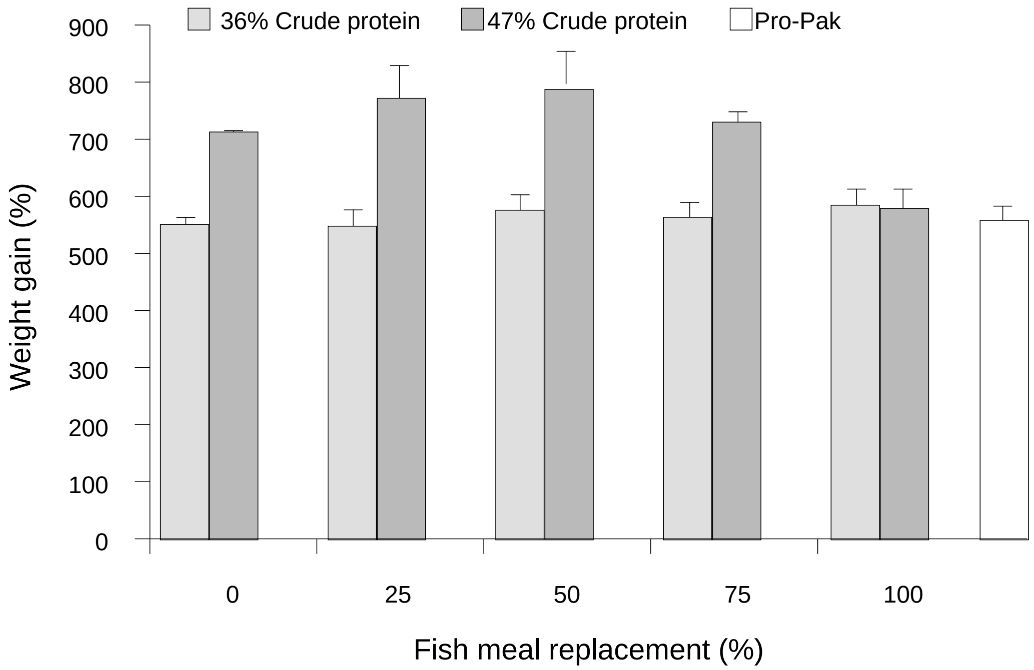

Figure 1. Weight gain (mean ± SD) of rainbow trout fed 10 different experimental diets and a commercial diet (Pro-Pak) based on fish meal replacement with the Ohio State University Fish Meal (OSUFM) analogue.

chinook salmon diet (Fowler and Banks, 1976) and replacement of fish meal with soybean and poultry offal meals in the diet of Australian snapper caused a reduction in weight gain as the amount of fish meal decreased below 30% (Quartararo et al., 1998).

In the present study, the fish grew better on a combination of herring, menhaden and OSU fish meal analogue than on herring and menhaden fish meal alone. Although better results were obtained in all respects in diets with a high fish meal content, no significant differences were observed among diets 1 through 6, indicating that up to 100% of the fish meal can be replaced at this protein level. Webster et al. (2000) reported that diets without fish meal can be fed to juvenile sunshine bass without adverse effects on growth, survival or body composition. Davis and Arnold (2000) also reported that replacement of fish meal with co-extruded soybean poultry by-product meal resulted in equivalent final weight, percent weight gain and feed efficiency and that replacement of 40%, 60% and 80% of the fishmeal protein with flashed-dried poultry by-product meal resulted in a significant increase in weight gain and feed efficiency in Pacific white shrimp, *Litopenaeus vannamei*. However, Regost et al. (1999) reported that total replacement of fish meal adversely affected growth in the turbot *Psetta maxima* fed a diet containing 20% corn gluten meal. Also in the present study, at the 47% protein level, there were significant differences between 100% replacement and no replacement, although there were no significant differences between no replacement and other replacement percentages, indicating that up to 75% of the fish meal can be successfully replaced in rainbow trout diets.

The reason for these contradictory results could be that the 36% protein level does not meet the protein requirements of rainbow trout fry since fish require different protein levels at different growing stages (Dabrowski, 1993; Bureau et al. 1999). Therefore, due to the insufficient protein, there were no significant variations at the 36% protein level but significant differences in the 47% protein level when all of the fish meal was replaced. Therefore, a suitable protein level should be used when studying the differences in fish performance in a nutritional experiment.

No significant differences were observed in weight gain of Atlantic salmon between the control and feeds in which the fish meal was replaced by soybean meal or protein concentrates at 25% and 33% (Carter and Hauler, 2000). Millamena (2002) formulated eight isonitrogenous diets containing 45% protein and 12% lipid by replacing none, 10%, 20%, 30%, 40%, 60%, 80% and 100% of the fish meal with meat meal and blood meal (4:1 mixture) and reported that up to 80% of the fish meal protein can be replaced by processed meat meal and blood meal coming from terrestrial animals with no adverse effects on growth, survival, and feed conversion ratio of *Epinephelus coioides* juveniles. In the present study, up to 30% OSU analogue was used without a significant adverse effect on growth, feed conversion ratio, survival or specific growth rate. Similarly, Lee et al. (2001) reported that animal by-products (a mixture of 25% meat and bone meal, 24.5% leather meal. 20% squid liver powder, 15% feather meal, 7.5% spray-dried blood meal, 7.5% poultry by-product meal and 0.25%, each, methionine and lysine) could replace up to 28% of the fish-meal protein in diets for juvenile rainbow trout for 16 weeks without adverse growth effects. However replacement of 40%, 60% and 100% by the mixture resulted in significantly lower growth performance than that of fish fed the control or the 20% replacement diets.

The high survival and growth rates of rainbow trout achieved in the current study are characteristic of this species when good fish husbandry and pond management techniques are used (Yanik and Aras, 1996). Although the highest weight gains were obtained from the 50:50 mixing, the findings of this study suggest that animal by-product meals can replace 75% of the fish meal. To discover the best mixture, further work is needed using different ingredients since nutritional requirements can vary amongst fish species and growing stages.

Acknowledgements

We would like to thank the North Central Aquaculture Researh Center, Michigan State University, East Lancing, and the Fats and Proteins Research Foundation, Blumington, Indiana, for support of this project.

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