PROTEIN AND CALORIE LEVELS OF MEAT-MEAL, VITAMIN-SUPPLEMENTED SALMON DIETS

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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Fish and Wildlife Service, Clarence F. Pautzke, Commissioner
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ABSTRACT

Feeding trials were conducted to determine the effect on the nutrition of fingerling fall chinook salmon (Oncorhynchus tshawytscha) of feeding two protein levels, three caloric levels, vitamin fortification, and meat supplementation of a basic meal mixture for a 12-week period. The results were as follows:

A protein level of 25 percent produced significantly greater gains in weight and higher protein deposition than a protein level of 20 percent.

Caloric levels of 1300, 1650, and 2000 calories per kilogram of diet were fed. At the 20 percent protein level, an increase in caloric intake to 1650 calories, by the addition of peanut oil, increased the protein deposition and protein utilization. Increasing the calorie level to 2000 calories and retaining the 20 percent protein level did not increase either protein deposition or utilization above the 1650 calorie level. A sparing action on the protein, by the addition of supplemental energy calories, is indicated. The optimum protein to energy calorie relationship appears to be 1:1 in these diet combinations.

Fortification of the diets with a concentrated vitamin supplement had no measurable effect on either growth or mortality in these experiments.

Meat supplementations varying from 10 to 50 percent of the meat-meal combination produced no measurable differences in total gain, protein deposition, protein utilization, or mortality.

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Feeding trials were conducted at the Salmon-Cultural Laboratory, Longview, Washington, during 1961 using fall chinook salmon fingerlings (Oncorhynchus tshawytscha) as test animals. The objectives of these experiments were to explore desirable protein levels, caloric intakes, and meat and vitamin supplementation in a single basic ration.

Because of the great emphasis placed on artificial propagation as a means of maintaining salmon runs, adequate, economical diets for fingerling salmon which are applicable to large-scale production operations are required. The high cost of suitable slaughter-house byproducts precludes their use exclusively in diet formulations. Raw salmon products such as viscera and spawned-out carcasses, while providing a valuable and relatively inexpensive source of protein, are undesirable since they are indicated to be vectors for transmitting fish diseases (Guenther, Watson, and Rucker, 1959; Ross, Earp, and Wood, 1959). The utilization of a high quality dry meal combination containing a high level of sterilized salmon carcass meal and supplemented with low

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1/ Salmon-Cultural Laboratory, Longview, Washington

levels of meats appeared to be a practical approach in the development of an adequate, economical diet for salmon fingerlings.

The 1961 trials demonstrated the practicability of the meal combination, the effect of two protein levels on growth, the effect of energy calorie supplementation on protein utilization, and the fact that vitamin supplementation was unnecessary under the conditions of the experiment.

PRELIMINARY INVESTIGATIONS

Feeding trials were conducted at the Entiat station during 1959 and 1960 (unpublished) in an attempt to develop partially reconstituted dry meal diets that would be nutritionally adequate for chinook salmon. Several composite meal formulations were fed at protein levels varying from 15 to 27 percent of the wet weight. The protein levels were controlled by the use of water as a dilutent in the bound diets.

In these experiments the diets were fortified with vitamins either by including relatively high levels of dried brewer's yeast or by feeding a vitamin supplement. In one experiment the vitamin supplement was fed at levels equal to, double, and triple the level required for maximum storage in trout as determined by Phillips (1946) and McLaren et al. (1947). Neither brewer's yeast nor the vitamin supplement proved capable of preventing anemia in the meal combinations fed.

Although no satisfactory diet was developed from these trials, the results indicated that protein levels below 20 percent in the meal combinations fed were inadequate for chinook salmon and that the methods of vitamin fortification employed were insufficient. Based on the results of these experiments, the 1961 feeding trials were formulated to include meat fortification to a meal mixture in an attempt to obtain the normal growth rates and conditions necessary to adequately assess alterations in diet composition.

METHODS AND TECHNIQUES

The techniques, methods, and equipment used in the 1961 experiments were identical to those described by Burrows et al. (1951; 1952) with the following exceptions:

1. Fall chinook fingerlings were utilized as test animals instead of the summer race of chinook which had been used previously in feeding trials conducted at Entiat. The fall chinook adapted to changes in environment and diet more readily than did the summer chinook and proved to be a much more satisfactory test animal.

2. Due to construction of additional facilities during the experimental period the six-foot circular rearing tanks were set up outside and were supplied with Abernathy Creek water for the first nine weeks of the experiment. An undetermined amount of natural food both waterborne and terrestrial was, therefore, available to the fish. These conditions are in contrast with those at Entiat where the tanks were inside and supplied with spring water which was practically devoid of natural food.

3. The chemical composition of feeds was used as the basis for diet formulation. Proximate chemical analyses of feeds and of fish were conducted using official AOAC methods for determining moisture, protein, and ash. Fat was analyzed by a modification of the chloroform-methanol method as described by Folch et al. (1951). Caloric levels were calculated on the basis of available calories as developed by Phillips and Brockway (1959).

4. Protein levels were controlled by the addition of water to provide bulk in the diets. This method of controlling protein intake, developed by Phillips and Brockway (1959), is versatile in that the caloric level may be increased by substituting fat or carbohydrate for a portion of the water while still retaining the desired protein level. The addition of water allows preparation of mush-type diets which, when adequately bound and ricer fed, are readily consumed by chinook salmon.

5. The experimental diets fed in the 1961 trials differed radically from those used in previously reported experiments in that they were composed principally of dry meals supplemented with meats. Meat supplementation varied from 10 percent to 50 percent of the meat-meal

combination. The composite meal consisted of 35 percent vacuum-dried salmon carcass meal, 30 percent dried skim milk, 20 percent cottonseed meal, and 15 percent wheat germ. The meat mixture fed in combination with the composite meal consisted of 50 percent each of beef liver and hog liver. The composition of the diets and the vitamin supplement are given in table 1. The ingredients of the basic mixtures and their proximate analyses are shown in table 1A.

A vitamin supplement containing the water soluble vitamins essential for chinook salmon, as determined by Halver (1957), was included in one series of diets. High-viscosity CMC (carboxymethyl cellulose) was used as a carrier for the vitamins and as a diet binding agent. The composition of the vitamin mixture was such that 0.5 gram per kilogram of fish weight per day was sufficient to provide for maximum storage (Halver et al. 1960). Additional CMC was added to the rations to provide two grams per 100 grams of diet. The composition of the vitamin supplement fed is presented in table 1B.

6. Diets containing high levels of dry meals required a different mixing technique than that usually employed for rations composed principally of meats. The dry ingredients including meals, vitamin mixture, salt, and CMC were pre-mixed to insure homogeneity. The meat and meal components were then mixed together with measured amounts of water to produce mush-type diets similar in consistency to meat diets.

7. The feeding trials were intended to continue for a 24-week period; however, due to high mortalities they were discontinued after 14 weeks. The cercariae of the digenetic trematode Nanophyetus salmincola which were prevalent in Abernathy Creek were believed to be the principle cause of the mortality. Data included in this report were compiled after 12 weeks of feeding before losses became excessive.

8. The chemical composition of the fish, as determined by proximate analysis, was the criterion used for analyzing the results of the experiments. Protein deposition instead of total gain in weight was used as the measure of growth since total gain includes fat deposition which is not considered to be true growth (Gerking, 1955; Phillips, et al., 1956). Protein utilization, a measure of the efficiency of a diet for growth production, was calculated by dividing the amount of protein fed by the amount of protein deposited in the fish. In order to compensate for the high mortalities sustained in all groups, calculation of protein and fat deposition was based on average weight per diet corrected for mortality.

RESULTS OF EXPERIMENTS

The test diets included a standard control and 20 experimental diets which were designed to measure the effect of four levels of meat supplementation, the addition of a vitamin supplement, two protein levels, and three calorie levels. A summary of the results of the experiments is presented in table 2. All of the experimental diets produced gains comparable to or exceeding that produced by the control diet. The control has been fed on a production basis at Entiat for several years and at Longview during 1961 with excellent results.

Effect of Meat and Vitamin Supplementation

Diets containing the lowest level of meat supplementation, a ratio of 10 parts meat to 90 parts meal, proved adequate in maintaining the fish. The vitamin supplement fed had no measurable effect on growth or mortality. The composite meal fed was apparently of high value for chinook salmon since calculation of vitamin content had revealed possible deficiencies in certain of the low meat-high meal diets. However, since the rearing tanks were outside and were supplied with creek water during most of the experimental period, the contribution of natural food may have been sufficient to fortify marginal diets.

Effect of Protein Levels

The 25 percent protein diets produced significantly more weight and greater protein deposition than comparable diets fed at the 20 percent level. There was a trend toward greater protein deposition and more efficient protein utilization in the groups fed the diets containing

Table 1.--Diet composition

A. Basic mixtures fed in the 1961 feeding trials

	Percentage Composition	Proximate analysis (percent)				
		Water	Protein	Fat	Ash	Nitrogen-Free Extract
Entiat Production Diet (Control)	100.0	68.7	19.8	5.9	3.6	2.0
Hog liver	12.5	68.9	18.4	5.9	1.3	5.6
Beef spleen	12.5	78.0	15.8	4.8	1.4	
Arrowtoothed halibut	25.0	72.9	15.9	8.0	3.3	
Salmon viscera	40.0	77.3	16.6	4.5	1.2	0.4
Salmon carcass meal	5.0	7.2	68.7	16.5	10.2	
Distiller's solubles	5.0	12.4	30.7	9.6	6.8	40.5
A-1 Meal Mixture	100.0	9.5	48.2	9.1	6.8	26.6
1/ Salmon carcass meal	35.0	7.2	68.7	16.5	10.2	
Dried skim milk	30.0	6.6	36.1	0.7	7.5	49.2
Cottonseed meal	20.0	14.8	43.8	3.8	5.6	32.0
Wheat germ	15.0	13.7	30.7	15.6	4.2	35.5
Meat Mixture	100.0	68.2	19.4	6.4	1.3	4.7
Beef liver	50.0	67.6	20.4	6.9	1.3	3.8
Hog liver	50.0	68.9	18.4	5.9	1.3	5.6

1/ Prepared from spawned-out carcasses of chinook salmon. The carcasses were steam cooked and semi-vacuum dried. The solubles were dried and returned to the meal.

The control diet was bound by the addition of two grams of salt per 100 grams of diet.

The experimental diets were bound by the addition of two grams of salt and two grams of CMC per 100 grams of diet.

B. Composition of Vitamin Supplement

Thiamine	.20 mg.	Inositol	20.00 mg.
Riboflavin	1.00	Biotin	.04
Pyridoxine	.43	Folic acid	.15
Choline	60.00	Total	90.82
Niacin	7.00	CMC	409.18
Pantothenic acid	2.00		500.00 mg.

Table 2.--Summary of 1961 feeding trials, 12-week period

Initial number per tank: 612 fish
Initial weight per tank: 500 grams
Initial average weight per fish: .817 grams
Initial number per pound: 556 fish
Period: 5/17/61 to 8/10/61
Average water temperature: 55° F.

Vitamin	Protein	Diet components	Percentage composition	Average weight per fish (grams)	Percent mortality	Food conversion	Protein deposition (grams)	Protein utilization	Fat deposition (grams)	Calories per kg. of diet	Caloric ratio protein to energy
No vit. supp.	20% protein	1. Entiat production	100.00	6.08	21.16	2.65	498	3.71	165	1250	1:0.60
Vitamin supplement	25% protein	2. Meat-meal ratio 50:50 Meat mix. A-1 meal mix. Water	 38.075 38.075 23.850	9.09	8.56	2.12	812	3.63	200	1650	1:0.63
Vitamin supplement	25% protein	3. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water	 19.76 46.10 34.14	8.71	8.66	2.12	761	3.76	198	1650	1:0.60
Vitamin supplement	25% protein	4. Meat-meal ratio 20:80 Meat mix. A-1 meal mix. Water	 12.34 49.36 38.30	8.40	7.76	2.17	754	3.78	190	1650	1:0.59
Vitamin supplement	25% protein	5. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water	 5.80 52.22 41.98	8.44	5.88	2.16	739	3.88	219	1650	1:0.58
Vitamin supplement	20% protein	6. Meat-meal ratio 50:50 Meat mix. A-1 meal mix. Water	 30.46 30.46 39.08	6.51	13.56	2.48	525	3.66	137	1300	1:0.63
Vitamin supplement	20% protein	7. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water	 15.81 36.88 47.31	6.22	15.44	2.52	514	3.67	129	1300	1:0.60
Vitamin supplement	20% protein	8. Meat-meal ratio 20:80 Meat mix. A-1 meal mix. Water	 9.87 39.49 50.64	6.20	16.10	2.43	498	3.63	107	1300	1:0.59
Vitamin supplement	20% protein	9. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water	 4.64 41.77 53.59	5.75	11.93	2.57	471	3.84	108	1300	1:0.58
No vitamin supplement	25% protein	10. Meat-meal ratio 50:50 Meat mix. A-1 meal mix. Water	 38.075 38.075 23.850	8.95	9.07	2.15	802	3.64	218	1650	1:0.63
No vitamin supplement	25% protein	11. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water	 19.76 46.10 34.14	8.73	8.50	2.13	770	3.72	221	1650	1:0.60
No vitamin supplement	25% protein	12. Meat-meal ratio 20:80 Meat mix. A-1 meal mix. Water	 12.34 49.36 38.30	8.98	9.15	2.10	781	3.74	220	1650	1:0.59
No vitamin supplement	25% protein	13. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water	 5.80 52.22 41.98	8.73	8.58	2.14	755	3.84	226	1650	1:0.58
No vitamin supplement	20% protein	14. Meat-meal ratio 50:50 Meat mix. A-1 meal mix. Water	 30.46 30.46 39.08	6.88	12.17	2.31	564	3.36	168	1300	1:0.63
No vitamin supplement	20% protein	15. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water	 15.81 36.88 47.31	6.42	16.01	2.42	518	3.55	149	1300	1:0.60
No vitamin supplement	20% protein	16. Meat-meal ratio 20:80 Meat mix. A-1 meal mix. Water	 9.87 39.49 50.64	6.26	15.52	2.43	495	3.69	138	1300	1:0.59
No vitamin supplement	20% protein	17. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water	 4.64 41.77 53.59	6.96	18.22	2.33	544	3.50	165	1300	1:0.58
Vitamin supplement	20% protein	18. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water Peanut oil	 15.81 36.88 43.51 3.80	7.84	8.33	2.18	643	3.23	187	1650	1:1.01
Vitamin supplement	20% protein	19. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water Peanut oil	 4.64 41.77 49.76 3.83	7.51	9.80	2.21	613	3.34	265	1650	1:1.00
Vitamin supplement	20% protein	20. Meat-meal ratio 30:70 Meat mix. A-1 meal mix. Water Peanut oil	 15.81 36.88 39.71 7.60	8.03	5.23	2.25	663	3.39	325	2000	1:1.42
Vitamin supplement	20% protein	21. Meat-meal ratio 10:90 Meat mix. A-1 meal mix. Water Peanut oil	 4.64 41.77 45.94 7.65	7.48	5.06	2.32	601	3.63	235	2000	1:1.40
		Least difference at the 5% confidence level:		.64	7.92		32	.23	18		

the higher proportions of meat indicating the possibility that the protein quality of the meat was superior to that of the meal for chinook salmon.

Effect of Caloric Levels

Peanut oil was added to four diets fed at the 20 percent protein level to determine the effect of increased caloric intake on protein deposition and utilization and on fat deposition. Diets 7, 18, and 20 were each fed at a meat-meal ratio of 30:70 with caloric levels of 1300, 1650, and 2000 calories per kilogram respectively. The caloric level was increased in diets 18 and 20 by substituting peanut oil for a portion of the water in the mixed rations. Diets 9, 19, and 21 were fed at a meat-meal ratio of 10:90 and at caloric levels corresponding to 7, 18, and 20.

Protein deposition and utilization:--An increase in caloric level from 1300 to 1650 calories per kilogram in 20 percent protein diets resulted in greater protein deposition and more efficient protein utilization. The additional calories supplied by the peanut oil were apparently utilized to meet, at least partially, the energy requirement of the fish, thereby sparing the protein. These results concur with those of Phillips et al. (1961) who reported that in feeding trials with trout, diets which contained cod liver oil produced more growth than comparable diets fed without oil. Diet composition may be an important factor influencing the utilization of lipids for energy since Buhler and Halver (1961) reported decreased protein efficiency and an inhibition in fish growth when dextrin was isocalorically replaced with corn oil in semi-synthetic diets fed chinook salmon.

Fat deposition and protein calorie to energy calorie relationship:--A further increase in caloric level from 1650 to 2000 calories per kilogram did not increase protein deposition or protein efficiency but increased fat deposition in the fish fed the 2000 calories diet at the 30:70 meat-meal ratio. A caloric level of 1650 calories per kilogram with a protein calorie to energy calorie ratio of 1:1 appears to be near optimum in the 20 percent protein diets tested. The fish fed the 2000 calorie diet at the 10:90 meat-meal ratio contained a fat deposit significantly less than that of the fish fed at the 1650 calorie level. It is considered likely that the fish withdrawn for analysis from the 2000 calorie group were not a representative sample.

SUMMARY

The results of the 1961 feeding trials with fall chinook salmon fingerlings may be summarized as follows:

1. Experimental diets consisting of a composite meal supplemented with meats produced gains equal to or exceeding those produced by a standard production control diet.

2. A ratio of only 10 parts meat to 90 parts of the composite meal in mixed diets proved adequate for maintaining chinook salmon fingerlings.

3. A synthetic vitamin supplement had no measurable effect on either growth or survival under the conditions of the experiment.

4. Diets fed at the 25 percent protein level produced significantly greater gain in weight and higher protein deposition than comparable diets fed at the 20 percent protein level.

5. An increase in caloric level from 1300 to 1650 calories per kilogram in 20 percent protein diets resulted in significantly greater gain, higher protein deposition, and more efficient protein utilization. A sparing action on the protein by the addition of energy calories as peanut oil is indicated.

6. Increasing the caloric level to 2000 calories per kilogram in 20 percent protein diets did not produce either greater protein deposition or increased protein efficiency above that of comparable 1650 calorie diets. A protein calorie to energy calorie ratio of 1:1 is indicated to be near optimum in the 20 percent protein diets tested.

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