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Pelleted Dry Rations for Trout Propagation in Michigan Hatcheries[1]

By

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[1] Contribution from the Institute for Fisheries Research.

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Abstract

Diets consisting of animal and vegetable meals were pelleted to compare dry-meal diets with chopped raw-meat mixtures when fed to rainbow and brook trout. Evaluation of the performance of each diet was based on data gained from feeding large numbers of trout. Bimonthly weight and length measurements, daily losses, and physiological changes were used to determine the nutritional value of each diet.

Pelleted dry-meal diets were not accepted immediately as food by rainbow and brook trout. This was evidenced by a loss of weight during the first two weeks of feeding pelleted food. Lost weight was regained completely after four weeks of feeding.

All dry-meal diet ingredients in the combinations used were acceptable as trout food when supplemented with raw beef liver at least one day every three weeks. The dry diets can be fed at levels one-half to five-eighths lower than those recommended for raw-meat mixtures without reducing trout growth rates.

A diet containing brewers yeast produced a significantly greater percentage gain in weight of rainbow trout than an otherwise identical diet containing torula yeast. Also, it was shown graphically and statistically that one dry pelleted diet (Diet 2) was superior to a raw beef liver diet.

The adoption of dry pelleted diets as standard rations by all state fish hatcheries in Michigan increased trout production (in pounds) by 60 percent and reduced fish food expenditures by 40 percent.

Introduction

Practically all of the trout diets employed before 1951 consisted of raw meat and raw meat-meal mixtures. Dry concentrates such as vegetable and animal meals when mixed with raw meat in various combinations served to reduce the cost per pound of trout raised (McCay, 1937a and 1937b). Nevertheless, food loss from particle separation in water, high labor costs and expensive refrigeration units, meat choppers and mixing units still remained. As the demand for hatchery-reared trout became more imperative, investigations were started to further reduce trout production costs.

In Michigan, investigations to determine the practicability of feeding dry meals in the form of pellets began in 1952. Results of the preliminary feeding tests were satisfactory and further experimentation on a wider scale was started in January of 1953.

The study was directed toward the goals of (1) developing a practical, economical, pelleted, dry-meal diet which could be used to produce healthy, legal-sized trout in the shortest time possible, and (2) eliminating the need for raw meat.

Preliminary Experiments with Pelleted Diets

Objectives of these experiments were to determine the general value of pelleted dry animal and vegetable meals when used as food for hatchery-reared trout.

Comparison of a commercially pelleted trout food with a standard hatchery diet.--In 1952, feeding trials were begun at the State Fish Hatchery, Oden, Michigan, to compare the nutritive value of a commercially pelleted trout food[2] with one of Michigan's standard hatchery diets. Brook trout (Salvelinus fontinalis) approximately 6 inches long were used as test animals. Feeding trials extended over two separate seasons of the year; the first from February to June of 1952, a period of 20 weeks; the second, from November, 1952 to May, 1953, a period of 28 weeks. The standard hatchery diet consisted of 50 parts pork spleen and 50 parts commercial chick starter. The pellet-fed group received pellets 4 days and raw meat 1 day per week. Meat was fed in amounts double those of the daily allowance of pellets.

[2] Trade name "Headtide," manufactured by Headtide Fish Food Company, Eastport, Maine.

Both diets produced poor results. Even though growth was slow, the pellet-fed groups showed a greater gain in weight than the meat-fed groups. This was probably due to the physical rather than the nutrient quality of each diet. Since ground raw meat particles tend to separate upon contact with water, perhaps the trout were able to derive more nutritive benefit from pellets, which do not disintegrate immediately when fed.

Other important advantages attributed to the use of pelleted fish food were observed during this period. Pellets could be fed as purchased and could be stored without refrigeration. When ingesting a pelleted particle of dry meals, the fish received all of the nutrients in the same proportions as manufactured. Since raw meat was fed only periodically, little time was required for raw meat processing. Pelleted food was consumed more completely, which reduced the degree of pond pollution; therefore, less labor was required for pond-cleaning operations.

Considering all of these major advantages a dry diet was formulated to furnish as nearly as possible the required nutrients for normal trout growth and survival.

Formulation of pelleted diet No. 1.--The formulation of Diet No. 1 was based as much on the physical properties for processing the dry ingredients as on the potential nutritive value of the finished diet. Since no data were available on the growth-producing performance of this diet when fed to trout, the first step was to determine which combination of dry meal ingredients, known to have been used as raw-meat supplements, would produce a functional pellet. The desired pellet was one which would disintegrate slowly or not at all in water and which would furnish enough buoyancy to prevent rapid sinking to the bottom of a tank or raceway. For this reason, preliminary studies were carried out to determine which ingredient combination produced a compressed mass that performed as desired when placed in water.

Since miniature laboratory pelleting machines were not available, a hand-operated "Eureka" tablet machine was used. Although awkward in operation

and permitting the production of only one tablet at a time, it served the intended purpose.

On a production scale, steam plays an important role in compressing and extruding dry meals to form compact pellets. In the use of the tablet machine, it was impractical to use steam as a humidifier. To circumvent this problem, a small amount of water was added to the meal mixtures and comparable results were attained.

The diet ingredients were selected from the group of animal and vegetable meals known to produce favorable results when added to a raw-meat mixture to form a mush-type food. Skim milk, buttermilk, whey, casein, cottonseed and soybean oil meals, yeast and various meals of animal origin have been used successfully for this purpose. Of these, a group of products selected for their availability at nominal cost, and for nutrient quality and quantity, were mixed in various combinations and tableted. Skim milk, cottonseed meal, wheat flour middlings, soybean meal, brewers and torula yeasts, and fish meals were given the most extensive investigation. After tableting, each compressed particle was subjected to a water test employing a glass tube eight feet high and two inches in diameter filled with water. Tablets of each ingredient combination were placed in the water at the top of the tube and allowed to sink to the bottom. The time required to sink from the top to the bottom of the tube and the condition of the tablet with respect to disintegration at various distances from the top were also used as criteria in selecting the diet combination.

Twenty different diet combinations were prepared for tableting in three sizes: 3/32, 1/8 and 3/16 inch in diameter; all tablets were 1/4 inch long

(Grassl[3]). Of these twenty diets the following combination gave the best

[3] Grassl, Edward F. 1956. Pelleted dry rations versus standard meat rations for trout. Ph.D. Thesis. Michigan State University. 113 pp.

laboratory results and was pelleted by a local feed manufacturer for trout feeding trials: 38 parts fish meal, 5 skim milk, 23 wheat middlings, 5 torula yeast, 25 cottonseed meal, 3 condensed fish solubles, and 2 iodized salt. Approximately one part is lost in processing. When pellets were placed in water, no immediate disintegration took place, and they remained intact for as long as 10 minutes. This combination will be referred to hereafter as Diet 1.

Preliminary feeding trials with Diet 1.--This experiment was designed to (1) compare diet performance of an all-meat diet with an all-pellet diet when fed to rainbow trout, and (2) provide tentative data on pellet size preference which are essential for full-scale hatchery-trout feeding.

Eighteen pounds of rainbow trout (Salmo gairdneri) were placed in each of four concrete tanks at the Hastings State Fish Hatchery preparatory to feeding pelleted Diet 1 and raw pork liver. Diet 1 was manufactured by a commercial feed manufacturer in Michigan[4] in three pellet sizes: 3/32, 1/8, or 3/16 inch

[4] Valley City Milling Company, Portland, Michigan.

in diameter, and 1/4 inch long. Each one of three lots of fish was fed a different size of pellet, and the fourth was fed a raw pork liver diet as a control. The experiments were conducted over an 8-week period with rainbow

trout averaging 4.5 inches in total length and 18 grams in weight. These trout previously had been fed a meat diet. All fish were counted before and after the 8-week period. Once a week, all fish were weighed. The length and weight of every fish that died was recorded. Diet 1 was fed throughout without meat supplementation. All diets were fed in amounts greater than required. At no time during the experiment was all of the food consumed.

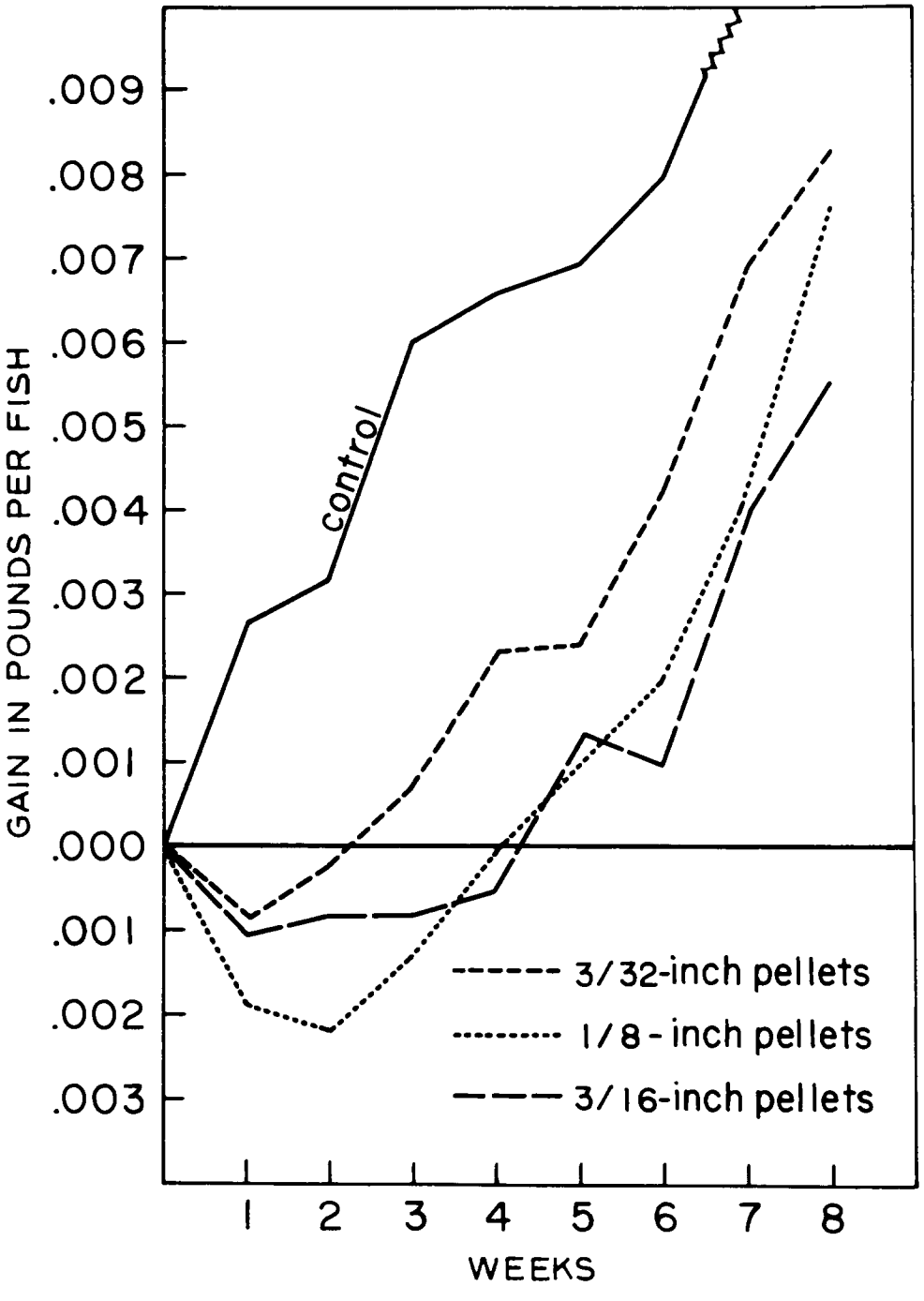
Figure 1 shows the growth rate of rainbow trout when fed the same diet pelleted in three different sizes and when fed a pork liver diet (control). The curves are constructed from weekly individual gains in pounds derived from dividing the total weight at the end of each week by the number of fish present in each group.

The radical change from a soft meat diet to a hard pellet diet was reflected in loss of weight in the groups fed the pelleted diet. It was necessary to feed the 1/8- and 3/16-inch pellets 4 weeks before lost weight was regained, whereas only 2 weeks were required for the group receiving 3/32-inch pellets (Fig. 1). Even though the 3/32-inch group recovered more quickly than the others, the 1/8-inch group showed a steadier gain in weight after recovery. The group fed raw pork liver did not lose weight, but gained steadily throughout the experiment.

It is believed that the curves shown in Figure 1 are reliable in respect to loss and gain in weight of trout but do not show conclusively that a particular size pellet was preferred by 5-inch fish. It is shown, however, that any one of the three pellet sizes used will support life and growth of 5-inch trout for 8 weeks. As determined by loss and gain of weight per unit of time, rainbow trout should be allowed a 2- to 4-week adjustment period when changing from a meat to a pellet diet.

Figure 1.--Comparison of loss and gain in weight of rainbow trout fed the same dry-meal diet pelleted in three sizes, with control fish fed pork liver.

Figure 1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GAIN IN POUNDS PER FISH
control
3/32-inch pellets
1/8-inch pellets
3/16-inch pellets
1
2
3
4
5
6
7
8
WEEKS

In summary of the pellet-size preference tests, it can be stated that even though rainbow and brook trout are capable of ingesting large particles of relatively soft foods, they are temporarily reluctant to accept particles of nonresilient food which are not easily crushed or indented when first moved through the buccal cavity of the pharyngeal area. In other words, teaching fish to eat pellets of any size is an important function in changing from a meat to a dry pelleted diet.

The results of these experiments were encouraging enough to warrant further work to determine what combination of pelleted feedstuffs would furnish adequate nutrition for trout when fed alone or in combination with raw meat.

Evaluation of Pelleted Diets Fed to Rainbow Trout

Materials and methods.--Large-scale feeding experiments with rainbow trout were carried out at the Wolf Lake State Fish Hatchery, located 10 miles west of Kalamazoo, Michigan. The water supply for the hatchery comes from a spring which has a flow of approximately 1,500 gallons per minute. The clear spring water is impounded in an area 100 yards long, 30 yards wide, and 18 feet deep. The water from this pond flows through underground metal pipes into the hatchery building. In the hatchery, the water temperature varied from 42° to 58° F. during the year. The concentration of dissolved oxygen varied between 6.0 and 9.0 p.p.m. and free carbon dioxide averaged 2.2 p.p.m. The pH varied between 7.5 and 8.1, with an average of 7.7. Chemical analysis of the water showed a methyl orange alkalinity of 160 p.p.m.

Twelve concrete tanks and 16 small wooden troughs were used in the study. Each tank measured 25 by 2.5 by 3.2 feet and was divided into two individual water-tight compartments that measured 11.5 by 2.5 by 3.2 feet. Each compartment had an individual water inlet and outlet. The rate of flow of water was regulated by two 1-inch gate valves inserted in a 2-inch pipe feeder line.

The 16 wooden troughs measured 32 by 6.5 by 14 inches. One end was fitted with a 2-inch galvanized metal outlet tube directly in front of which was inserted a 6-mesh screen. At the opposite end water entered through a 1/2-inch spigot from a 2-inch feeder pipe line. A 1/4-inch-mesh screen was placed directly beneath each inlet spigot to collect incoming debris. All troughs were completely covered by a framed 1/4-inch-mesh screen. Flow of water entering individual troughs was restricted to 8 gallons per minute. The source of water for troughs was the same as for the tanks. No attempt was made to filter out small organisms entering the hatchery building with the water supply.

The experimental work at Wolf Lake State Fish Hatchery was designed to follow a system of planning whereby the first phase of the experimental work was carried out in small troughs; the second, in large tanks inside the building; the third, in outside concrete and gravel-bottom raceways on a semiproduction scale. For the third phase, tests were run in raceways both at the Wolf Lake Hatchery (Michigan's most southerly trout hatchery) and at the Marquette Hatchery (the most northerly). Finally the results were subjected to full-scale hatchery feeding by all Michigan trout hatcheries.

The small troughs were used for preliminary tests on new diet ingredients and/or combinations. The diet in question was fed to a small lot (3 pounds)

of trout for a sufficient length of time to determine whether further investigation was warranted. After it was determined that the diet warranted further investigation, a more extensive experiment was carried out in the larger concrete tanks with larger numbers of fish. For these experiments a total of 12,000 rainbow trout 2.9 to 5.9 inches in total length, 4 to 20 grams in weight, and 7 months old were employed. Their diet prior to the experiment had consisted of raw beef liver, sheep liver and pork spleen in various combinations. One thousand fish were placed in each of the 12 tanks previously described. The investigation included 14 two-week periods, extending from October 1, 1953, to April 28, 1954.

Seven different dry animal and vegetable meal combinations (Tables 1 and 2) were compressed into 3/32-inch pellets at the beginning of the experiment and were used until the fish were large enough to accept 1/8-inch pellets. All diets were then returned to the feed mill, crushed, and repelleted to 1/8-inch size. This size pellet was used for the remaining experimental period.

As pointed out above, the percentages of ingredients were selected primarily for their pelleting properties. Since it had been established that Diet 1 would support trout life, all other diets were prepared as modifications of Diet 1. As shown in Table 1, the diet variables were yeast, cottonseed meal, soybean oil meal, condensed fish solubles, xanthophyll, stablized fat, and gelatin. Each diet contained one or more variables. Diets 1, 2, 3 and 4 were fed to duplicate groups and Diets 5, 6 and 7 to single lots of fish. Diet 8 served as the raw-meat control. Since the diet as a whole had not been tested for a sufficiently long time, the experiments were not designed to test the

Table 1.--Pelleted diet composition (parts)

[Control diet (No. 8), beef liver 100 parts]

Ingredients	Diet No.						
	1	2	3	4	5	6	7
Red fish meal	38	38	40	40	40	36	36
Cottonseed meal	23	23	...	...	23	...	...
Wheat flour middlings	25	25	26	26	25	22	22
Torula yeast	5	...	...	5	3	3	3
Brewers yeast	...	5	5	...	3	3	3
Condensed fish solubles	3	3	...	...	3	3	3
Skim milk	5	5	5	5	5	5	5
Iodized salt	2	2	2	2	2	2	2
Soybean oil meal	...	...	23	23	...	25	25
Xanthophyll	...	...	...	...	0.2	...	...
Gelatin	...	...	...	...	...	2	...
Stabilized fat	...	...	...	...	...	...	2

Table 2.--Proximate analysis of various diets (in percent)

Diet No.	Moisture	Crude protein	Ether extract	Fiber	NFE	Ca	P	Ash
1	8	39.6	5.08	4.70	25.2	3.20	2.10	13.30
2	8	39.3	4.40	4.90	25.3	2.90	2.00	12.80
3	8	40.8	4.23	2.27	27.1	3.34	1.91	13.43
4	8	40.8	4.22	2.27	27.1	3.34	1.91	13.43
5	8	41.9	5.36	4.99	26.3	3.36	2.06	13.80
6	8	41.8	3.84	3.28	25.8	3.05	1.78	12.78
7	8	40.3	5.84	3.28	25.8	3.05	1.78	12.78
8 wet	70	20.2	3.10	0.00	6.0	0.01	0.36	1.30
8 dry	0	66.6	9.99	9.00	20.0	0.02	1.30	4.32

value of a specific diet ingredient. However, several diet ingredients can be evaluated when gain in weight and mortality are used as criteria of diet performance. For this reason, emphasis was placed on duplication and on determining the performance of dry pelleted meal diets when supplemented periodically with raw beef liver.

After pelleting, the food was stored in a cool, relatively dark, dry place. The amount fed per day was based on percentage of body weight. The control group was started at a 6.0-percent level and all others at a 3.0-percent level. Since definite feeding levels have not been established for pelleted foods, the levels used here are tentative. They were determined by calculating the dry equivalents of the levels suggested for raw meats by Deuel, Haskell, and Tunison (1942). The amounts of foods to be fed were determined by using a metal container marked at a level which corresponded with the desired weight of food for each feeding. Although this procedure may have introduced minor errors, it eliminated the necessity for weighing many small amounts of pellets or ground raw liver. All fish were allowed to adjust to the pelleted food for a period of 4 weeks. Each morning before feeding operations began all tanks and troughs were cleaned and dead trout were counted, weighed and measured. The cause of death was determined when possible. A Fairbanks-Morse platform scale of 1,000-pound capacity was used to weigh each lot of fish at two-week intervals. All fish were weighed in a container sufficiently large to hold a volume of water plus the fish. The water was weighed before adding the fish, and weight of fish was determined by the difference. In dipping fish from the tanks for weighing, excess water was allowed to drain from the net and its contents for about 15 seconds.

The amount of food fed per day was held constant throughout the experiment because it was observed near the beginning of the experiment that not all the food was consumed. This partially invalidates the conversion factors, but establishment of a definite feeding level was held to be more important than the determination of accurate conversion factors. Since the tanks used were adequate in size to compensate for increase in growth, no "thinning" was carried out.

Feeding schedules included four feedings of pellets per day for four days and raw beef liver for one day every week. The control group received raw beef liver four times per day, five days a week. Due to conditions beyond the control of the investigator, all food was withheld on Saturday and Sunday. The usual practice of adding water to ground raw beef liver before feeding was not followed; the liver was fed in the form that it came from the meat chopper. This reduced the amount of particle separation during feeding.

Regression analysis, standard error of estimate, and "t" values according to the method of Snedecor (1946) were used for statistical analysis of differences in the percentage gain in weight between groups fed pelleted diets and a raw beef liver diet and between groups fed various pelleted diets.

Comparison of gains in weight of rainbow trout fed on different diets.-- Performances of Diets 1 to 8 inclusive are summarized in Table 3. The results of feeding Diets 1, 2, 3 and 4 concurrently to two different groups of rainbow trout are included. Conversion factors are calculated by dividing the total pounds of food fed for the twenty-eight week period by the total gain in

Table 3.--Performance of various diets during a period of 28 weeks when fed to individual lots of 1,000 rainbow trout

[Average water temperature 47° F. in each test]

Item	Diet No.											
	1	1	2	2	3	3	4	4	5	6	7	8
Number of fish at end	863	864	911	880	963	922	816	934	...[1]	823	...[1]	948
Weight at end (pounds)	144.9	144.4	164.0	163.5	169.0	133.5	115.0	139.0	130.5	134.0	156.0	158.5
Weight at start (pounds)	39.6	39.3	39.9	36.6	38.1	36.5	29.1	35.5	34.5	31.3	38.5	39.5
Gain in weight (pounds)	105.3	105.3	124.1	126.9	130.9	97.0	85.9	103.5	96.0	102.7	117.5	119.0
Cost per pound of food	$0.07	$0.07	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.07	$0.08	$0.08	$0.14
Conversion	2.4	2.4	1.4	1.4	1.3	1.6	1.6	1.5	1.6	1.5	2.0	3.0
Cost per pound of fish gain	$0.16	$0.16	$0.11	$0.11	$0.11	$0.12	$0.13	$0.13	$0.11	$0.12	$0.16	$0.42
Percentage gain	266.0	267.4	311.0	346.7	343.5	265.8	295.2	291.5	278.3	328.1	305.1	301.2
Food proportions fed:												
Meat (percentage)	17.1	16.8	25.7	23.7	24.4	26.9	28.8	26.3	16.2	25.9	17.1	100
Pellets (percentage)	82.9	83.2	74.3	76.3	75.6	73.1	71.2	73.7	83.8	74.1	82.9	...
Percentage of recorded loss	1.4	1.7	4.3	2.5	2.6	1.9	3.0	4.5	...[1]	4.0	...[1]	3.2
Percentage of unaccountable loss	12.3	11.9	4.6	9.5	1.1	5.9	15.1	2.1	...[1]	13.7	...[1]	2.0
Percentage of total mortality	13.7	13.6	8.9	12.0	3.7	7.8	18.4	6.6	...[1]	17.7	...[1]	5.2

[1] No data.

weight of fish. Percentage gain is calculated by dividing the total gain in weight of fish during a period by the weight at the start. Other entries in the table are self-explanatory.

A graphic comparison of percentage gain in weight in relation to average water temperature and amount of food fed is given in Figure 2. The curves represent the results of feeding Diet 2 and Diet 8 to rainbow trout. The percentage of food fed includes both pellets and meat.

The amount of food fed per day in terms of percentage of body weight was not adjusted after each weighing period. However, since the trout were growing at a steady rate the percentage of food fed per day, in relation to body weight, decreased progressively. This continued throughout the experiment for all groups in an attempt to establish a definite daily food requirement for trout of a particular size and at a specific water temperature. This appeared to occur near the end of the sixth month of feeding when the amount of food fed per day was equal to 1.5 percent of total fish weight and at a water temperature of 42° F. At this time the average length was 6.4 inches (range, 3.0-10.1) and the average weight was 2.3 ounces.

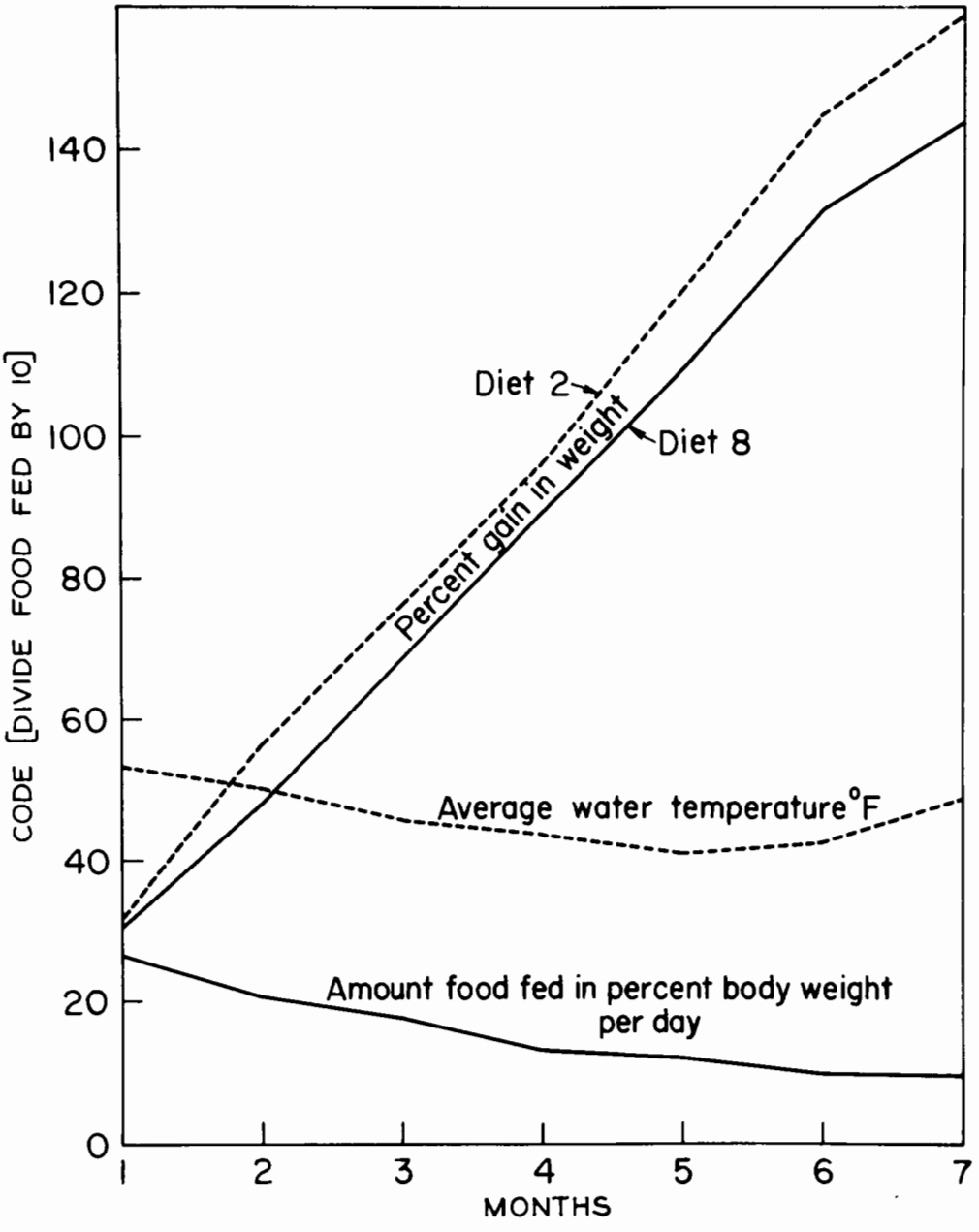
The performance of all diets when presented graphically depicts a reduction in rate of gain during the last period similar to that shown in Figure 2.

Diets 2 and 6 produced greater gains than any of the other diets; Diets 3, 7 and 4 were next, in that order. The average rates of growth produced by Diets 1, 4 and 5 were less than that of Diet 8 (control).

The only known difference in the formulation of Diets 1 and 2 was the use of two different yeast products (Table 1). Diet 1 contained

Figure 2.--Comparison of growth rates of rainbow trout fed different diets.

Figure 2


CODE [DIVIDE FOOD FED BY 10]
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
MONTHS
Diet 2
Diet 8
Percent gain in weight
Average water temperature °F
Amount food fed in percent body weight per day

torula yeast, and Diet 2, brewers yeast. Diet 2 produced gains considerably higher than Diet 1. The similarity in the performance of Diets 3 and 4 indicates no differences in the two yeasts when soybean oil meal is substituted for cottonseed meal. Diet 6, containing gelatin, resulted in a steadier rate of gain in weight of fish than did Diet 7 which contained a stabilized fat. Diet 5 produced a rate in gain of weight consistently lower than Diet 8 (the control).

The results of statistical analysis (Table 4) for differences in percentage gain in weight (based on cumulative percentage gain per 2-week period) between groups fed pelleted diets and a raw beef liver diet and between groups fed various pelleted diets showed a highly significant difference ($t = 2.96^{**}$) between Diets 1 and 2 and a difference approaching significance (calculated $t = 2.01$, tabular $t = 2.56^{*}$) between Diets 2 and 8 (control). All other diets compared in Table 4 did not differ significantly.

In Michigan, it is the policy to plant hatchery trout shortly after they reach the legal length of 7 inches. Thus many of the experiments were terminated when the majority of fish had reached this size.

Trout in each experimental lot were counted before, during, and at the end of the experiment, and counts were verified by a second person. Thus it was possible to evaluate diets in respect to numbers and length of fish as well as weight gained.

Among other factors, Table 3 presents the recorded loss and unaccountable loss. The recorded losses consisted of fish which died from

Table 4.--The results of statistical analyses for differences in the percentage gains in weight between groups fed pelleted diets and a raw beef liver diet and between groups fed pelleted diets

Diets compared	Total cumulative percentage gain	Percentage loss or gain	Calculated "t" values[1]
1[2] and 8[3]	139.4--143.3	Diet 1, - 3.9	1.27
2[2] and 8	152.9--143.3	Diet 2, + 9.6	2.01
3[2] and 8	151.6--143.3	Diet 3, + 8.3	1.65
4[2] and 8	143.5--143.3	Diet 4, + 0.2	1.30
6 and 8	153.8--143.3	Diet 6, + 10.5	1.96
1 and 2	139.4- 152.9	Diet 1, - 13.5	2.96**
3 and 4	151.6--143.5	Diet 3, + 8.1	1.22

[1] Tabular t_{05}, 26 d.f. = 2.056* (significant); Tabular t_{01}, 26 d.f. = 2.779** (highly significant).

[2] Replicated diets.

[3] Control diet.

jumping out of the tank and from handling during tank cleaning and weighing operations. It was never possible to diagnose the cause of death as malnutrition.

It is difficult to determine specifically the reason for the extremely high and varied unaccountable loss. All experiments were conducted within a building, preventing losses by predators except trout. Since there was a considerable variation in length of fish in each group, it appears that cannibalism operated as the major factor in producing unaccountable losses. Grading each lot of fish to a uniform size at the beginning of the experiment would have, no doubt, prevented most of the cannibalism.

In several groups some factor other than difference in size could have caused a greater cannibalistic urge than in other groups. From the data presented in Tables 1 and 3, the evidence is inconclusive that one dietary constituent operated more than another to instigate cannibalism. Nevertheless, it appears probable that one or perhaps a combination of dietary factors in several of the diets influenced the natural cannibalistic instinct. It is believed that a dietary solution for this major problem can be found.

Results from the several diets varied with respect to production of legal-sized trout (7 inches and over), and with respect to mortality and condition factor. Diets 6, 8, 1 and 2 (in that order) produced the highest percentage of legal-sized fish; Diets 3 and 4, the lowest. Recorded losses in groups receiving Diet 1 were the lowest, and those receiving Diet 4, the highest. However, one group fed Diet 3 showed the lowest total loss of any group. When comparing Diet 8 with pelleted dry diets, the average

length of large fish produced by the raw beef liver diet at the end of the 6-month period was approximately 1 inch less than for those groups receiving pellets; at the end of the 7-month period, however, almost the same percentage of legal-sized trout were present as there were in the groups fed pellets. As expected, the condition factor of the rainbow trout in the control group (Diet 8) was somewhat higher than that of the others.

Brook Trout Feeding Experiment

This experiment was carried out on a production scale at the Marquette Hatchery, and was designed to serve a dual purpose. It was desired to know the performance of a pelleted diet when fed to brook trout, and, since a meat supplement was used periodically, it was designed to determine what length of time could intervene between raw meat feedings. Four lots of 4,000 young-of-the-year brook trout were placed in gravel-bottom raceways sufficiently large to compensate for normal growth during the experimental period without danger of overcrowding. Group A received Diet 1 four days per week and raw beef liver one day per week. Group B received Diet 1 nine days, and raw beef liver one day, every two weeks. Group C received Diet 1 fourteen days, and raw beef liver one day, every three weeks. A diet consisting of 8 percent torula yeast and 92 percent beef liver served as the control. (This control was used because it was the usual practice at the hatchery to use this mixture for the regular hatchery diet.) All fish in each group were weighed at the end of each month. The methods were similar to those previously described. The experiments were conducted over

a 28-week period. The meat-control group received food equal to 3.6 percent of body weight per day and the other groups received amounts equal to 1.7 percent of body weight per day.

Table 5 shows the differences among the four groups in respect to conversion, average percentage gain at 28-day intervals, cost per pound of trout reared, and cost per hundred pounds of diet. The cost per pound of trout in the meat-fed control group was more than twice that of pellet-fed fish, and a lower percentage gain was evident. Feeding of pelleted foods for a 3-week period without a raw-meat supplement did not adversely affect growth rate.

Savings Due to Feeding Pelleted Dry Meals to Hatchery-Reared Trout

The first Michigan trout food, Diet 1, was formulated and pelleted in 1953. After several months of use at a number of Michigan hatcheries, the results were so favorable as compared to previous diets that it was adopted by the Michigan Department of Conservation as a standard production diet. Some state fish hatcheries were slow in adopting the pellet food on a production scale, but all are now feeding pellets.

Since the pellet-feeding program started in 1953, fish food expenditures decreased and number of pounds of trout planted increased (Table 6). This is directly reflected in the cost per pound of fish produced.

Before the pellet-feeding program was adopted, it cost 68 cents for food to produce one pound of trout. During the three fiscal years of 1953-1956, when pellets were fed, Michigan hatcheries produced a total of 1,105,822 pounds of trout. The cost of food for this quantity of fish at

Table 5.--Summary of brook trout growth experiments (average water temperature, 40.8° F.)

Feeding schedule[1]	Weeks	Cost per 100 pounds of food	Cost per pound of trout reared	Conversion	Percentage gain per 28 days
Group A					
Diet 1, 4 days/week					
Meat, 1 day/week	28	$7.00	$0.23	2.7	23.0
Group B					
Diet 1, 9 days/2 weeks					
Meat, 1 day/2 weeks	28	7.00	0.20	2.5	22.5
Group C					
Diet 1, 14 days/3 weeks					
Meat, 1 day/3 weeks	28	7.00	0.19	2.3	23.3
Yeast and meat control[2]	28	9.90	0.50	5.0	20.8

[1] No feeding on Saturdays and Sundays.

[2] Eight percent torula yeast and 92 percent raw beef liver, 5 days per week.

Table 6.--Production costs prior to, and following the start of pellet feeding

Year	Cost of food	Pounds trout planted	Food cost per pound of trout	Calculated cost at 68¢	Difference[2]
		Prior to pellet feeding			
1951	$200,498	282,641	$0.71	...	...
1952	180,971	284,628	0.64	...	...
		Pellet feeding program started			
1953	159,452	297,774	0.54	202,486	43,034
1954	141,736	390,613	0.36	265,617	123,881
1955	127,521	417,495	0.30	283,896	156,375
Total	428,709	1,105,882		751,999	323,290
Other expenditures[1]	...	...		...	18,000
					305,290

[1] Salary and expenses allotted investigator for formulating and testing dry pelleted diets during 3-year period.

[2] Calculated cost at 68¢ minus actual food cost.

the 68-cent rate would have been $751,999; but the actual cost of the pelleted food used was $428,709--a saving of $323,290 for the three-year period.

The indirect savings resulting from the use of pellets also constitute a major item. In addition to the averages already cited, more trout reached legal or planting size in the second year when fed pelleted food. This means fewer trout have to be carried over into the third year, making more pond space available for smaller fish.

Summary and Conclusions

In feeding trials conducted with rainbow and brook trout several pelleted diets were formulated and tested. The study was directed toward developing practical pelleted dry diets which could be fed to trout to produce strong, healthy, legal-sized fish in the shortest time possible and eliminate the need for raw meat mixtures as much as possible. Large numbers of trout were used as test animals, both on an experimental scale and on a production scale.

The following conclusions were drawn:

1. The binding properties of feed constituents used for Diets 1 through 7 were suitable for pellet production. These combinations remain intact in pellet form for as long as 8 minutes when put in water.

2. As determined by loss and gain of body weight, rainbow trout require 1 to 2 weeks to adjust from a relatively soft meat diet to a hard pelleted diet. They lose weight during the adjustment period but begin to regain it after the first 2 weeks of pellet feeding.

3. Rainbow trout averaging 4.5 inches in length will eat pellets 3/16, 1/8, and 3/32 inch in diameter and 1/4 inch long. The evidence from this study is inadequate to demonstrate definitely that any size pellet is preferred by rainbow trout 4.5 inches long.

4. Dry pellet diets can be fed at levels one-half to five-eighths lower than those recommended for raw meat mixtures without reducing trout growth rates.

5. The difference between Diet 1 (containing torula yeast) and Diet 2 (containing brewers yeast) and between Diet 2 and Diet 8 (control) was statistically significant. Under the conditions described and in the combinations used, brewers yeast was superior to torula yeast on the basis of percentage gain in weight of rainbow trout. Also statistical analysis showed Diet 2 to be superior to Diet 8 (control) and Diets 1, 3, 4 and 6 to be equal to Diet 8.

6. Feeding a raw-meat supplement can be dispensed with, on a production scale, for as long as three weeks without adversely affecting trout growth rate.

7. All of the diet ingredients listed in Table 1 are suitable, in the combinations shown and with a weekly meat supplementation, to rear rainbow and brook trout on a production scale.

8. The dry pelleted rations used during these experiments are superior to raw meat diets in enough respects to warrant their adoption for full-scale hatchery feeding. A direct result of the adoption of dry pelleted Diets 1 and 2 by all the state fish hatcheries in Michigan as standard diets was an increase in trout production (in pounds) by 60 percent and a reduction in fish food expenditure by 40 percent.

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