Evaluation of Grower Diets for Intensive Culture of Rainbow Trout (*Salmo gairdneri* Richardson)

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ABSTRACT

Tabachek, J.L. 1983. Evaluation of grower diets for intensive culture of rainbow trout (Salmo gairdneri Richardson). Can. Tech. Rep. Fish. Aquat. Sci. 1178: iv + 15 p.

In an investigation to evaluate differences in performance (weight gain and feed conversion) and biochemical composition that a commercial fish producer could expect as a result of feeding different commercial diets and to allow inclusion of pertinent information into a computerized fish data and management system (FISHDAMS), five commercial grower diets, two diets manufactured for government hatcheries and a control diet were fed to rainbow trout for 22 weeks at 12°C.

In terms of performance, the control diet (CTR) was significantly superior to all other diets. Trout fed Purina Trout Chow (PTC) or Rangen Trout Feed (RGT) performed significantly poorer than those fed some or all other diets, respectively. Fish fed PTC had enlarged livers which were not caused by increased moisture or lipid and were probably due to glycogen accumulation. A small degree of liver enlargement caused by increased liver lipid was exhibited by feeding Martin Feed Mill Trout Feed (MTT) or Spearfish Diet Development Center Feed (SPF). Although there were no significant differences in weight gain or feed conversion between trout fed MTT, SPF, Ministry of Natural Resources Feed (MNR), Ewos Salmon and Trout Feeds (EST) or Sterling Silver Cup Trout Feed (SCT), there were significant differences in biochemical composition of their muscle tissue. Muscle lipid content of fish fed CTR, MNR, MTT and EST was significantly higher than that of fish fed all other diets. On a dry weight basis, the muscle protein content of fish fed MNR, MTT or EST was lower than that of SPF-and RGT-fed fish. Only feeding CTR, SPF or RGT produced fish with a protein content that was significantly greater than PTC-fed trout, on a wet weight basis. Fish fed MTT had a slight, but significantly lower percent dressed to round weight than those fed SCT.

Use of any of CTR, PTC or RGT and possibly SPF or EST would have necessitated changes in FISHDAMS while use of MNR, MTT or SCT would not.

Key words: commercial diets; grower diets; freshwater aquaculture; fish nutrition; weight gain; food conversion; biochemical composition.

RESUME

Tabachek, J.L. 1983. Evaluation of grower diets for intensive culture of rainbow trout (Salmo gairdneri Richardson). Can. Tech. Rep. Fish. Aquat. Sci. 1178: iv + 15 p.

On a évalué les différences de rendement (gain de poids et indice de transformation) et de composition biochimique qu'on peut escompter en pisciculture commerciale de différentes préparations alimentaires du commerce et versé les résultats de l'étude au systéme de gestion des données sur les poissons (FISHDAMS); pour ce faire, on a nourri pendant 22 semaines des truites arc-en-ciel gardées à 12°C avec cinq préparations de croissance du commerce, deux préparations produites pour les stations de pisciculture gouvernementales et une préparation témoin.

Le rendement de la préparation témoin (CTR) a été considérablement supérieur à celui de toutes les autres préparations. Le Purina Trout Chow (PTC) a été inférieur de beaucoup à certaines autres préparations, le Rangen Trout Feed (RGT) arrivant bon dernier. Le foie des poissons nourris au PTC a pris du volume probablement à cause d'une accumulation de glycogéne et non par suite d'un élévation de la teneur en eau ou en lipides. Chez les truites nourries au Martin Feed Mill Trout Feed (MTT) ou au Spearfish Diet Development Center Feed (SPF), on a constaté une légère hypertrophie du foie provoquée par une augmentation de la teneur en lipides. On a par ailleurs observé des différences dans la composition biochimique des tissus musculaires des truites nourries au MTT, SPF, Ministry of Natural Resources Feed (MNR), Ewos Salmon et Trout Feeds (EST) et au Sterling Silver Cup Trout Feed (SCT), mais il n'y avait pas d'écart concluant en termes de gain de poids et d'indice de transformation. La concentration musculaire de lipides chez les poissons alimentés avec les préparations CTR, MRN, MTT et EST dépassait largement celle qu'on a mesurée chez les poissons nourris avec les autres préparations. En termes de poids sec, la concentration de protéines dans les muscles des truites alimentées avec les préparations MRN, MTT et EST était inférieure aux valeurs mesurées chez les poissons nourris avec un mélange de SPF et de RGT. La concentration de protéines par unité de poids humide mesurée chez les truites nourries au PTC n'a été dépassée de façon significative que chez les poissons alimentés au CTR, au SPF et au RGT. Le rapport du poids du poissoin paré sur le poids brut chez les truites nourries au MTT était légèrement inférieur, dans une mesure néanmoins concluante, à celui des poissons alimentés au SCT.

Pour employer les préparations CTR, PTC, RGT et peut-être les SPF et EST, il aurait fallu modifier le FISHDAMS; ce ne serait pas le cas avec les préparations MRN, MTT et SCT.

Mots-clés: préparations alimentaires du commerce; pisciculture en eau douce; nutrition des poissons; gain de poids; indice de transformation; composition biochimique.

INTRODUCTION

Solar energy has been used to raise the temperature of groundwater from 6.5 to 11°C at the Rockwood Experimental Fish Hatchery located 65 km north of Winnipeg, Manitoba (Ayles et al. 1980). To develop an intensive production system that could be used on a commercial scale, a large pilot production system has been coupled to this low-grade waste heat source (Ayles et al. 1980; Papst and Hopky 1982). A computerized fish data and management system (FISHDAMS) is being developed to allow the commercial operator to predict and control the growth of salmonids at each level of production (Arnason et al. 1981; Papst et al. 1982).

Evaluations of some commercial feeds and those formulated for use in government hatcheries have been reported for Atlantic salmon (Salmo salar) starter diets (Lemm and Hendrix 1981), rainbow trout (S. gairdneri) grower (Westman et al. 1969) and brood stock diets (Smith et al. 1979) and cutthroat trout (S. clarki) starter (Smith 1975) and fingerling diets (Westgate et al. 1982). In addition, commercial feeds have been evaluated as a control along with other test diets for rainbow trout (Yurkowski et al. 1978; Yurkowski and Tabachek 1981), salmon (S. salar) parr and rainbow trout fingerlings (Austreng 1979).

That diet has an effect on performance (weight gain and feed conversion), survival and body composition of rainbow trout is well recognized (Cho et al. 1976; Lall 1979; Halver 1972; Reinitz and Hitzel 1980; Reinitz et al. 1978). The purpose of this experiment was to provide additional information for FISHDAMS and for the producer concerning the effect on the performance of rainbow trout fed different commercial grower diets and diets formulated for use in government hatcheries. In addition, fish were analyzed to assess any biochemical differences in the composition of the product for the consumer.

METHODS

DIETS

Five commercially available feeds (Martin Feed Mill Trout Feed, Ewos Salmon Feed and Trout Feeds, Purina Trout Chow, Rangen Trout Feed and Sterling Silver Cup Trout Feed), feeds (MNR-80G, GR3-30 and GR4-30) made to specifications for two government agencies and a control feed were evaluated (Table 1). Feeds were ordered at approximately the same time and the manufacturing dates are presented in Table 1. Formulations for open-formula diets appear in Table 2 while ingredients listed on bags of closed-formula diets are presented in Table 3. In manufacturing the control (CTR) diet, the vitamin and mineral premixes were prepared in a Patterson-Kelley twin-shell dry blender. After the dry ingredients had been combined in a Marion mixer and ground in a Jacobson hammer mill, fish oil was blended into the mixture. Upon addition of 35% water and mixing in a Hobart mixer, the material was extruded through a 1/8" (3.25 mm) die in a Bauknecht meat grinder modified to cut the extruded material into pellets. These pellets were placed in a drier, air-dried at room temperature, crumbled in a W-W roller mill and finally separated into various sizes in a Kason vibrating screen separator.

Since a recirculation culture system was to be used, all feeds were screened in a Kason separator to remove undersized granules and fines. These were defined as all material that passed through a U.S. equivalent No. 16 sieve for the smaller size granules and through a U.S. equivalent No. 12 sieve for the larger size granules and pellets. After each bag of feed was screened, the screen was removed and cleaned. All fine material that had collected on the screen, on the walls and in the bottom of the separator was included in the screenings. Undersized granules and fines were weighed to determine the percentage removed (Table 5). A composite sample of each screened feed was collected for analysis. Screened feeds were sealed in bags and stored at -20°C.

Ingredients for the CTR diet and samples of all screened feeds were analyzed for moisture, nitrogen and ash contents (AOAC 1980). Nitrogen content was converted to crude protein by multiplication by 6.25. Total lipid was measured by the Bligh and Dyer (1959) method (Tables 4 and 5). Inorganic constituents of CTR diet ingredients (Table 4) were solubilized by digestions with nitric acid and hydrogen peroxide (Lutz, personal communication). Calcium, Mg, Na, K and Zn contents of the digests were determined by atomic absorption spectrophotometry and the P content was determined by the phosphomolybdic spectrophotometric method of Murphy and Riley (1962).

A sieve series separation was carried out on a sample of each screened sample of granular feed. The sample was placed in a Canadian standard series (U.S. series equivalent) No. 6 sieve which was stacked on No. 8, 10, 12, 14, 16 and 18 sieves and the sample was shaken by hand. Each of the fractions of feed remaining on the sieves and in the pan were weighed and calculated as a percentage of the total feed recovered (Table 6). The range and mean diameter and length of each pellet size was determined by direct measurement (Table 6).

FEEDING TRIAL

The feeding trial was conducted at the Rockwood Experimental Fish Hatchery located approximately 65 km north of Winnipeg, Manitoba (Ayles et al. 1980). Experimental tanks were the 60 L fiberglass tanks described by Uraiwan (1982) with tanks situated in two adjacent rows on two levels (Fig. 1). Each set of 12 upper and 12 lower tanks was connected to a separate biofiltration-recirculation system consisting of an 1100 L fiberglass tank (1.5 m diameter x 1 m deep) containing 1.75 m^3 crushed granite rock as the filter medium. Filters were backwashed biweekly. Water supply to the hatchery was from an artesian well at 6.5°C and the flow rate to each tank was regulated at 4-5 L/min. No additional heating of the water was required since recirculation and heat exchange in the building raised the temperature sufficiently. Makeup water was approximately 10% and was adjusted when necessary to maintain water temperature at 12 ± 1.0°C. Dissolved oxygen was monitored weekly with a Y.S.I. Model 54 temperature-oxygen meter and analyses for pH, NH_4-N, NO_2-N and NO_3-N (Stainton et al. 1974) were also conducted on a weekly basis.

Rainbow trout test animals were progeny of those received as eggs from Sunndalsora, Norway and had been fed Sterling Silver Cup Trout Feed from swim-up until the beginning of the experiment. They were graded by weight prior to transferring a random sample of 50 fish to each of 32 tanks (8 tanks/row). Fish were acclimated to their new environment for 3 weeks and had a mean weight of 12.1 ± 0.21 g at the beginning of the experiment.

The eight diets were assigned at random within each of the four rows in a randomized complete block design. Feed was stored in plastic bags in a freezer (-20°C) and was removed several hours prior to opening the bags to prevent condensation of moisture on the feed. Weighed feed was placed in covered 4 L plastic buckets for feeding. Fish were fed to satiation twice a day (0830-0930 and 1500-1600) every day except for the day they were weighed. Feed size was changed when fish accepted the larger size. Total feed intake per tank was measured weekly and total weight and number of fish per tank were measured biweekly. Mortalities were removed and recorded daily.

As density approached 50 kg/m^3, the number of fish was reduced to 25 fish at 10 weeks and to 16 fish at 18 weeks. During thinning at 18 weeks, fish were anaesthetized with phenoxyethanol and visually examined for presence of lens cataracts or any physical abnormalities. A sample of 4 fish per tank were examined at both thinning periods and the condition of kidney, liver and amount of visceral fat noted.

At the termination of the experiment (22 weeks), whole body weight, liver weight and headless dressed weight were measured for each of 6 fish per tank. Liver and muscle (skin and bone removed) samples were taken for analysis from these 6 fish as 3 replicates of 2 fish each.

BIOCHEMICAL ANALYSIS OF MUSCLE AND LIVER

Moisture content of liver and minced muscle were determined by freeze-drying and subsequent oven-drying for one hour at 110°C. Moisture content was calculated by difference in weight between wet and dry tissue. Dry muscle tissue was ground in a Wylie Mill. Total lipid content of dry muscle or liver was determined by a modified Bligh and Dyer (1959) extraction and spectrophotometric assay of the extract using acid dichromate oxidation (Fales 1971). Nitrogen content of dry muscle was determined by AOAC (1980) methods and converted to crude protein by multiplication by 6.25.

STATISTICAL ANALYSIS

Data on performance and biochemical composition of muscle and liver were subjected to analysis of variance for a randomized complete block design and Duncan's new multiple range test (Duncan 1955) using the Statistical Analysis System (SAS Institute 1979) (Tables 7 and 8). Prior to statistical analysis, square root transformation (Steel and Torrie 1980) was applied to data on percentage of mortalities. Data is presented in the non-transformed form (Table 7).

HISTOLOGY

Samples of kidney and spleen were taken from two fish from each tank and fixed in Bouin's solution. Tissues were washed for 2 days in 70% ethanol, prior to embedding them in paraffin. Tissue sections were cut at 8 µm and stained with Harris's hematoxylin and eosin (Edwards 1967).

RESULTS

DIETS

Formulation

Within each of CTR, MNR and MTT diets, the same formulation was used for all sizes of feeds obtained (Tables 1 and 2). However, SPF, EST, PTC and SCT were known to have different formulations for the granular vs pelleted feeds (Tables 2 and 3), with #5 PTC being the only floating extruded feed evaluated. The ingredient list for EST was not provided but the granular size was available only in a salmon feed formulation and the pellets only in a trout feed formulation (Table 1). Whether or not the formulation was the same for all sizes of RGT used in this experiment is not known.

Proximate composition of diets

Proximate compositions of grower diets (Table 5) showed that all contained over 43% crude protein except #4P EST (38.7%) and #5 and #4 PTC (39.4% and 41.0%, respectively). The total lipid content was greater than 11.0% in all cases except #5 PTC (6.8%) and #5 RGT (9.9%). The four open-formula diets (CTR, MNR, MTT, SPF) and EST contained less than 10.0% ash while PTC, RGT and SCT contained levels greater than 10.0%. Moisture varied from 7.2 to 9.5% with the exception of #5 extruded PTC which had a moisture content of 4.2%. Metabolizable energy was lower for RGT (3.08-3.17 kcal/g) and #5 PTC (2.80 kcal/g) than for other diets (3.40 -3.91 kcal/g).

Sizes of diets

The smaller granule size used in all diets contained less than 4.6% "fines" (Table 6) except for #4 SPF (GR3-30) from which 9.7% "fines" were removed. The larger granule sizes contained less than 2.7% "fines" except for RGT from which 8.8% was removed. The pellets all contained less than 2.7% "fines".

The screen series (Table 6) showed the relative percent of particle sizes present in the first feed granule used was similar for CTR, MNR, MTT and EST. The smaller granule size of RGT and SCT were similar, but were larger than CTR, MNR, or EST. The second granule size used was also similar for CTR, MNR and MTT while SCT was somewhat larger. SPF and PTC granules were an intermediate granule size being larger than the first granule size and smaller than the second granule size of all the other feeds except RGT. The second size used in RGT was only slightly larger than the first size used and was very similar to the only granule size available for SPF and PTC. Since EST had only one suitable granule size available, as intermediate pellet size of 3/32" (2.5 mm) was used which was not available for SPF or PTC. Except for PTC, diameters of the larger pellet size used were between 1/8" (3-3.5 mm). Mean pellet length was 3-4 mm for CTR, MNR, MTT and EST, 6 mm for RGT and SCT and 7 mm for SPF. PTC pellets were an extruded product and were almost round with a diameter of 4.5 mm which was larger than for other diets.

Feed sizes were changed when fish accepted the larger size. Trout were fed the smallest size of feed for the first 6 weeks of the experiment. At that time fish fed all diets except EST, SPF and PTC were fed the larger granule size. Trout fed EST were fed the smaller pellet (3/32") after 8 weeks. Fish were maintained on these sizes for a further 8 weeks for CTR, MNR, MTT and EST, 10 weeks for SCT and 12 weeks for RGT. At that time the larger pellets were fed until the end of the experiment. Those fed SPF and PTC were fed the granule size for 18 weeks since there was only one granule size available and the pellet size was very large (in either length and/or diameter) and difficult for the fish to consume.

PERFORMANCE

As the experiment proceeded, the difference in weight gain between fish fed different diets increased. Until 14 weeks, trout fed CTR were not significantly different in weight gain from those fed MTT, MNR, SPF or SCT ($P>0.05$; Duncan's new multiple range test; (Tabachek, unpublished data). By 18 weeks, those fed CTR were significantly different in weight gain and feed conversion from fish fed all diets except MTT ($P<0.05$) and it was only during the last 2 weeks of the experiment (22 weeks) that both parameters for CTR-fed trout became significantly different ($P<0.05$) from those for all other diets including MTT (Table 7). Throughout the experiment trout fed RGT exhibited a significantly lower weight gain ($P<0.002$; ANOVA) and higher feed conversion ($P<0.0005$; ANOVA) than those fed all other diets (Tabachek, unpublished data). In addition, fish fed MTT and SCT gained significantly more than those fed PTC (Table 7). There were no significant differences in final weight gain between trout fed MNR, MTT, SPF, EST or SCT. Feed conversion was significantly lower for MTT than for PTC or RGT (Table 7). A decline in growth rate, relative to other diets, was observed when the EST feed was changed from the #4 salmon formulation to the #4P trout formulation (Tabachek, unpublished data).

Feed intake was significantly greater for fish fed SCT than for those fed PTC or RGT (Table 7). There was a significantly greater feed intake with MNR, MTT, SPF and SCT than with RGT.

Mortalities were low and did not differ significantly with diet (Table 7).

Early in the experiment, 2/3 of the fish in one tank of fish fed RGT died due to a human error. The remaining fish were maintained throughout the experiment in the same way as fish in all other tanks except that reducing the density at 10 and 18 weeks was not necessary. However, it became apparent that there was greater food loss in feeding a small number of fish (14) compared to the other replicates with 50 fish. Therefore, the data from this tank was excluded since it would have resulted in an erroneous mean with a high variance between replicates for feed intake and feed conversion. Data in Table 7 show the means of 3 replicates for RGT. The weight gain of 4 replicates is given in parentheses and indicates that the weight gain per fish of the deleted replicate differed little from the other 3 replicates.

At the termination of the experiment at 22 weeks, fish fed MTT had a significantly lower percent dressed weight to round weight (DRW) than those fed SCT or RGT, although this difference was less than 2.5% (Table 8).

Percent liver weight to body weight (LBW) (Table 8) ranged from 1.08 to 1.92 with a value for PTC which was significantly greater than all other diets and with MTT significantly greater than CTR and SCT. In addition, the LBW for trout fed SCT was significantly lower than that for MNR and SPF.

BIOCHEMICAL COMPOSITION OF MUSCLE AND LIVER

Differences were observed in moisture, lipid and protein contents of tissues of trout fed different diets (Table 8).

Moisture content of the liver of fish fed PTC was significantly lower than those fed all other diets except CTR and MTT which were significantly lower than SPF, RGT and SCT.

On a dry weight basis, liver lipid was significantly higher in SPF-fed trout (17.6%) than for all other diets except MTT (16.0%) while those fed PTC had livers with a significantly lower lipid content (11.1%) than all others except SCT, CTR and RGT (Table 8). Results on a wet weight basis indicated similar effects.

Mean muscle moisture varied by only 2% across diets with fish fed CTR and MTT being significantly lower than all others except MNR and EST.

Muscle lipid, on both a wet and dry weight basis, showed a wide range in values across diets. Trout fed MTT, EST, MNR and CTR had muscle lipid contents which were significantly greater than for those fed RGT, SPF, SCT and PTC with MTT significantly greater than CTR and RGT significantly lower than PTC.

On a dry weight basis, fish fed RGT and SPF had a significantly higher muscle protein content (81.2 and 80.1%) than those fed all other diets, while the values for MTT-fed trout were significantly lower (73.0%) except for EST and MNR. On a wet weight basis, fish fed CTR, RGT and SPF had a significantly higher protein content than those fed PTC (Table 8).

HISTOLOGY AND GROSS EXAMINATION

Lens cataracts were observed in less than 1.5% of fish fed any of the diets. There were no other gross physical abnormalities that could be attributed to diet. Histological examination revealed no evidence of cell atrophy, pycnotic nuclei or degenerative changes in the spleen or kidney of fish fed different diets.

WATER QUALITY

Throughout the experiment, water quality parameters were as follows:

	Range	Mean ± Standard Deviation
NH_4-N (µg/L)	28-585	207 ± 152
NO_2-N (µg/L)	2-314	53 ± 82
NO_3-N (µg/L)	3-1746	662 ± 410
pH	7.7-8.3	8.0 ± 0.1
Temperature (°C)	10.0-12.8	12.0 ± 0.7
D.O. (mg/L)	7.7-10.3	9.1 ± 0.8
No. tanks sampled weekly	2-4	3
No. weeks sampled		20

Nitrite-N (NO_2-N) values of 66-314 µg/L were evident during the first 2-5 weeks of the study in the initial biofilter conditioning period. Thereafter, mean values were always below 38 µg/L NO_2-N. Although Russo et al. (1974) showed that the asymptotic LC50 for 12 g rainbow trout was 140-150 µg/L NO_2-N after 8 days, mortalities were very low (Table 7) throughout this experiment.

DISCUSSION

The CTR diet was superior to all other diets in terms of weight gain and feed conversion. The formulation of this diet is similar to one evaluated by Cho et al. (1974) in which the performance of rainbow trout with initial weight of approximately 0.5 g was surpassed only by feeding a diet in which some of the soybean meal was replaced by corn gluten and alfalfa meals. The less than 10% difference in mean percent final weight gain of trout fed MTT, SCT, MNR, SPF and EST would probably be an acceptable range within which a producer could work. Both weight gain and feed conversion were significantly poorer with fish fed PTC compared to MTT and were significantly poorer for those reared on RGT than on all other diets. Excluding CTR and RGT, the results from PTC extend the range in mean percent final weight gain to 17.9%. It is estimated that it would have required less than 1 week for MNR and SCT, 1.5-2 weeks for SPF and EST and 2.5-3 weeks for PTC-fed fish to reach the same final mean weight of MTT-fed fish and a further 1.5-2 weeks to reach the same final weight of CTR-fed trout. Using MNR, MTT, or SCT would not have required any adjustments in the use of the growth model of Papst et al. (1982) or the computerized fish data and management system (FISHDAMS) of Arnason et al. (1981) described in the introduction. However, use of CTR, PTC or RGT and possibly SPF or EST would have required changes. Reinitz and Hitzel (1980) found that increasing the metabolizable energy (ME) of the diet increased the growth rate of rainbow trout. RGT and #5 extruded PTC had lower ME than other diets. This may partially account for the lower growth rate of fish fed these two diets. Without knowing the formulations for either diet it is difficult to speculate further on the reasons for their resulting poorer (especially RGT) performance. One cannot rule out the possibility of an error at the manufacturer that created the RGT product which resulted in inferior growth and feed conversion. An additional 8-10 weeks would have been required for these fish to reach the same final mean weight as MTT-fed trout.

Direct comparisons between this study and those conducted by others are not possible since other researchers have used feeds available in their areas to produce fish which were not necessarily of the species and/or size with which this study was concerned. For example, commercial diets for Atlantic salmon fry and parr have been evaluated by Lemm and Hendrix (1981) and Austreng (1979) respectively. In addition, Smith (1975) and Westgate et al. (1982) conducted diet evaluations for cutthroat trout fry and fingerlings respectively. The evaluations of Westman et al. (1969) involved raising rainbow trout from 34.5 g up to 214.4 g but since it was conducted in Finland none of the 9 commercial diets evaluated are available in Canada. Other evaluations involving rainbow trout included only one or two commercial diets with larger than 100 g fish (Yurkowski and Tabachek 1981) or brood stock (Smith et al. 1979). Although Austreng (1979) used Ewos as one of two commercial feeds in the production of rainbow trout from fingerlings to over 120 g, the proximate composition of the Norwegian-made diet was quite different from that of the Ewos (EST) used in this study. The diet used by Austreng contained 58.0% protein and 9.3% fat on a dry matter basis compared to the 38.7-50.4% protein and 13.8-18.7% total lipid present in the Ewos Salmon and Trout Feed formulations (EST) used in this study. Since protein and lipid levels have an effect on performance and body composition (Lee and Putnam 1973; Reinitz et al. 1978; Reinitz and Hitzel 1980), it is not possible to make further comparisons for that diet. Westgate et al. (1982) found that percent weight gain and feed conversion were significantly better for cutthroat trout fingerlings fed SCT or

SPF (GR3) than they were for those fed RGT which was also the case with rainbow trout in the present study. The proximate composition of their diets was also quite similar to the respective diets used in the present study.

Feed conversion of SPF and PTC might have been improved had there had been an intermediary size to use between the granule and pellet. The pellets were so large (6-7 mm) (Table 6) that fish were unable to accept them until the last 4 weeks of the experiment. Fish fed all other diets, except RGT, were taking pellets 2-4 weeks earlier. Undoubtedly, there is more feed loss with fish being fed a granular size compared to a pellet and more energy expenditure is required to consume the same amount of feed. The two granular sizes of RGT were so similar (Table 6) that it was of little value in switching from the #5 to the 5/32" crumbles especially since the feed cost of the two sizes was the same.

The economics of using different feeds is left to the producer since feed costs will vary for each producer depending on volume of purchase, bulk vs bag feed and shipping costs.

Trout fed MTT had a significantly higher percent liver to body weight (LBW) (Table 8) than those fed CTR or SCT but their low liver moisture and high liver lipid content (Table 8) suggests that their larger livers were due to greater storage of lipid in the liver when fish were fed MTT compared to other diets. Liver lipid content of fish reared on MTT was exceeded only by that of SPF-fed trout which had a LBW that was not significantly different from MTT-fed fish. Both LBW and liver lipid content were low and not significantly different for fish reared on CTR, SCT, EST and RGT (Table 8).

Although trout fed PTC had the highest percent liver to body weight (LBW) (Table 8), their livers contained the lowest moisture and lipid contents (Table 8). Hilton et al. (1981) found that LBW and percent liver glycogen were significantly higher in rainbow trout reared on extruded pellets compared to those reared on steam pellets when the same formulation was used for both diets. Since PTC #5 floating extruded pellets were fed during the last 4 weeks of the experiment, the enlarged livers may have occurred as a result of glycogen accumulation. Hilton et al. (1981) also found that trout reared on extruded pellets showed significantly lower weight gain but higher feed efficiency (lower feed conversion) than those reared on steam pellets. Although the weight gain of fish fed PTC was significantly lower than those reared on SCT, MTT and CTR, feed conversion was significantly higher and therefore poorer than it was for MTT-or CTR-fed trout (Table 7).

Although there was no significant difference in the weight gain or feed conversion of fish fed MNR, MTT, SPF, EST or SCT (Table 7), there were significant differences in the composition of the muscle tissue (Table 8). Trout fed MNR, MTT and EST had significantly lower muscle protein contents on a dry weight basis, than those fed SPF while only that of MTT-fed fish was significantly lower than that of trout reared on SCT. On a wet weight basis, there were no significant differences in protein content between fish fed any of the above 5 diets.

Muscle lipid content was significantly higher in fish fed MTT, EST, MNR and CTR compared to all others on both a dry and wet matter basis (Table 8). In addition, a greater amount of fat storage in the viscera of MTT-fed fish was indicated by the fact that they had a significantly lower percent dressed to round weight than those fed SCT (Table 8). Fish lipids contain a high proportion of unsaturated fatty acids, which are susceptible to oxidation causing fatty fish to have a shorter storage life than lean fish (Hobbs 1982). Therefore, it would be preferable to both the producer and the consumer for muscle tissue to be low in lipids such as that of SCT-, SPF- or PTC-fed fish. It should be recognized that all these hatchery-reared fish were still much lower in wet muscle lipid content (3-5%) than wild rainbow trout (8.8%) (Iredale and York 1983).

The influence of feed on the body composition of several species of fish has been summarized (Buckley and Groves 1979). Percent body fat has been found to be correlated with dietary fat and energy levels in rainbow trout (Ogino et al. 1976; Reinitz et al. 1978; Takeuchi et al. 1978; Watanabe 1977) while dietary protein levels had no significant influence on either carcass percent fat or protein (Reinitz et al. 1978). Westman et al. (1969) who compared the growth and body composition of rainbow trout fed 9 commercial diets in a cage culture situation in Finland also observed that the greatest variation occurred in the body fat content rather than in protein content of either whole or gutted fish. Wide differences have been found between the apparent digestibility coefficients of many of the common feed ingredients (Cho and Slinger 1979) used in these diets (Tables 2 and 3). That is, the digestibility of diets composed of different ingredients may be different even though their crude protein and lipid contents may be identical. Therefore, in the present evaluation it is not possible to attribute the differences in weight gain or body composition to specific differences in dietary protein, lipid or energy.

Due to changes in availability and cost of ingredients, manufacturers may change their formulations in order to keep them cost-effective. In addition, quality and composition of ingredients may also change. This may result in variability in performance and body composition of trout, even in using feed from the same manufacturer. One would hope that, except for RGT, this would not be sufficient to cause wide variation from the results presented. This could only be determined by conducting similar evaluations over a period of time.

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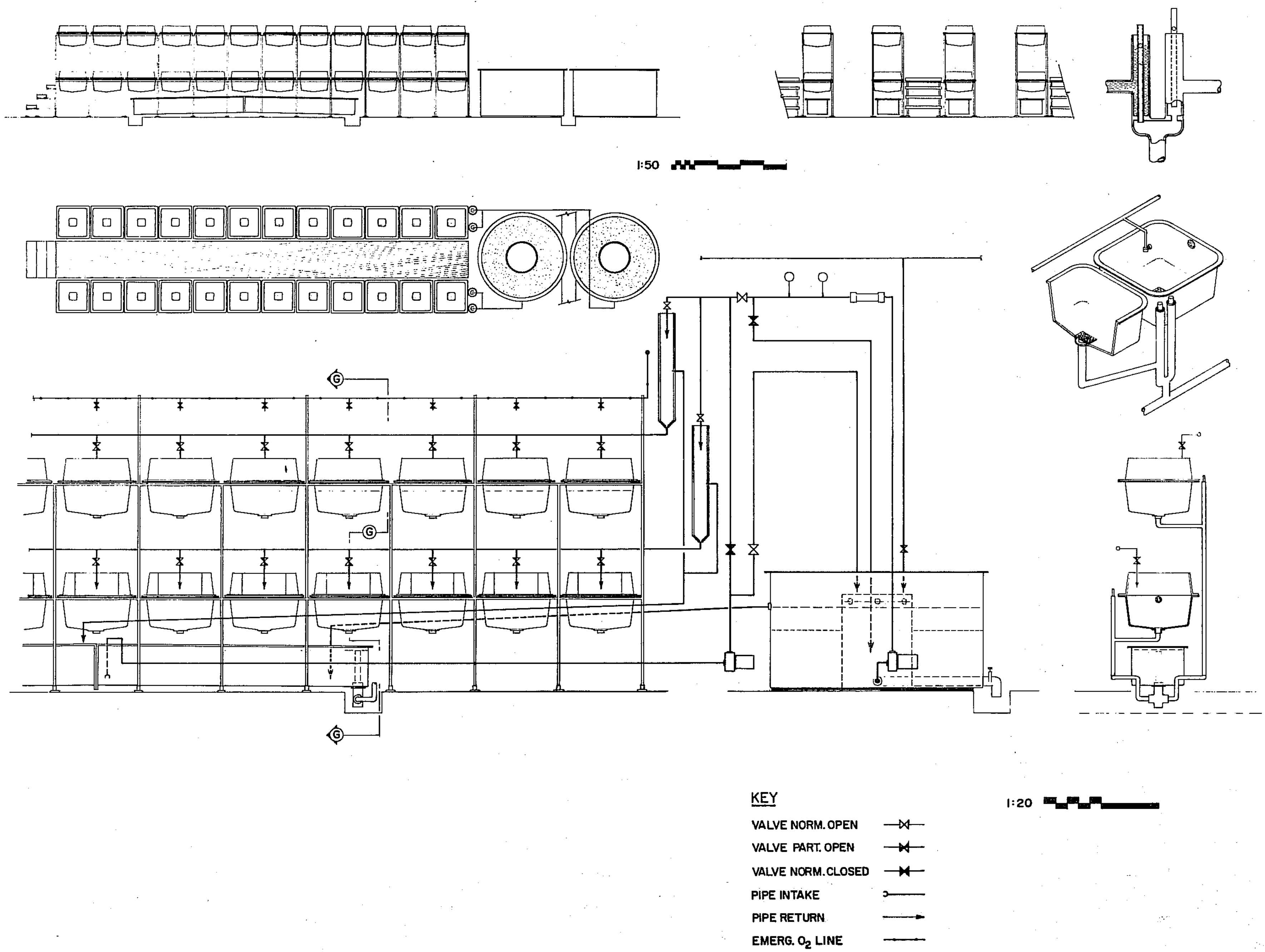

Fig. 1. Various views showing tanks and filters.

Table 1. Diets evaluated.

Diet	Code	Formulation	Manufacturer	Size	Date of manufacture
Control (University of Guelph formulation)	CTR	C-201	DFO-Winnipeg	#4 & #5	25/5/81 - 4/6/81
		"		1/8"	
Ministry of Natural Resources	MNR	MNR-80G	Martin Feed Mills	2GR	17/3/81
		"		3GR	16/3/81
		"		4PT	11/3/81
Martin Feed Mill Trout Feed	MTT	GRT-G	Martin Feed Mills	#4	4/3/81
		"		#5	16/3/81
		"		4MM	17/3/81
U.S. Fish and Wildlife Service	SPF	GR3-30	Rangen Inc.	#4	First Quarter
Spearfish Diet Development Center		GR4-30		1/8"	1981
Ewos Salmon Feed	EST		Rundle Feed Mills	#4	18/3/81
Ewos Trout Feed				4P	11/5/81
"				5P	11/2/81
Purina Trout Chow	PTC	Sinking	Ralston Purina	#4	26/2/81
		Extruded		#5	24/2/81
Rangen Trout Feed	RGT		Rangen Inc.	#5	24/3/81
				5/32"	18/3/81
				Crumble	
				1/8"	13/3/81
Sterling Silver Cup Trout Feed	SCT		Murray Elevators	#4	18/6/81
				#5	22/6/81
				1/8"	19/6/81

Table 2. Formulation (%) of the open-formula diets.

Diet	CTR	MNR	MTT	SPF	
	C-201	MNR-80G	GRT-G	GR3-30	GR4-30
Fish Meal	35.0[1]	25.0[2]	24.0[3]	35[4](minimum)	24[5](minimum)
Soybean meal (48% crude protein (CP))	20.0	10.0	10.0	30	25[6]
Wheat middlings (15-17% CP)	32.4	20.6	28.3	-	20
Wheat feed flour (14% CP)	-	-	-	15.3	10
Corn gluten meal (60% CP)	-	9.0	9.0	-	-
Poultry by-product meal (60% CP)	-	7.0	7.0	-	-
Feather meal, hydrolyzed (80-82% CP)	-	5.0	5.0	-	-
Whey (12% CP)	-	8.0	-	-	-
Brewer's dry yeast (45% CP)	-	5.0	5.0	-	-
Blood meal, ring-dried	-	-	-	10	10
Fish oil, stabilized	10.0[7]	8.0[8]	8.0[9]	7(minimum)	7(minimum)
DL-methionine	0.2	-	0.2	-	-
Choline chloride (50%)	0.4	0.4	0.8	0.175	0.175
Vitamin premix	1.0[10]	1.0[10]	-	0.4[11]	0.4[11]
Vitamin + mineral premix	-	-	1.0[12]	-	-
Mineral premix	1.0[13]	1.0[13]	-	0.1[14]	0.1[14]
Ascorbic acid	-	-	-	0.075	0.075
Iodized salt	-	-	0.3	-	-
Calcium phosphate (21.0% Ca)	-	-	1.4	-	-
Sodium phosphate, monobasic (21.8% P)	-	-	-	-	0.25
Lignin sulfonate binder	-	-	-	2	2

\- Absent.
1 Herring meal, 68% CP
2 Herring or capelin meal, 69% CP
3 Capelin meal, 70% CP
4 Herring meal, 67.5% CP, or anchovy fish carcass meal, 65% CP
5 Herring meal, 67.5% CP, anchovy fish carcass meal, 65% CP, or menhaden fish carcass meal, 60% CP
6 Cottonseed may replace soybean for not more than 15% of the total diet.
7 Capelin oil
8 Capelin, herring or salmon oil with 5.0% of this sprayed on after pelleting.
9 Herring oil
10 VIT-8004 premix (in g/kg premix unless otherwise specified): vitamin A acetate, 500,000 IU; vitamin D_3, 200,000 IU; dl-alpha-tocopheryl acetate, 20,000 IU; menadione sodium bisulfate salt, 3; thiamine HCl, 3; riboflavin, 5; d-calcium pantothenate, 15; biotin, 0.04; folic acid, 1; vitamin B_{12}, 0.003; niacin, 20; pyridoxine HCl, 3; ascorbic acid, 30; wheat middlings to make 1 kg premix.
11 Vitamin premix No. 30 (in g/kg premix unless otherwise specified): vitamin A palmitate or acetate, 1,651,982 USP; vitamin D_3, 110,132 IU; d-or dl-alpha-tocopheryl acetate, 88,106 IU; menadione sodium bisulfite complex, 2.75; thiamine mononitrate, 8.8; riboflavin, 13.2; d-calcium pantothenate, 26.4; biotin, 0.088; folic acid, 2.2; vitamin B_{12}, 0.0055; niacinamide, 55.1; pyridoxine HCl, 7.7; wheat or soybean product base to make 1 kg premix.
12 Vitamin-mineral premix 1-79 (g/kg premix unless otherwise specified): vitamin A (100,000 units/g), 8; vitamin D_3 (20,000 units/g), 2.8; vitamin E (500 units/g) 149.6; menadione (50%), 5.6; thiamin (98%), 5.2; riboflavin (5.28%) 76; calcium pantothenate (17.6%), 85.2; biotin (2%), 4.8; folic acid (1.32%), 76; vitamin B_{12} (132 mg/kg), 22.8; niacin (100%), 25.2; pyridoxine (98%), 3.2; ascorbic acid (97.5%), 41.2; ethoxyquin, 50; KI (17.25%), 4.4; $MnSO_4 \cdot H_2O$ (25% Mn), 34.8; $FeSO_4 \cdot 7H_2O$ (20% Fe), 30; $CuSO_4 \cdot 5H_2O$ (25% Cu), 10; $ZnSO_4 \cdot H_2O$ (36% Zn) 40; ground corn shot, 325.2.
13 MIN-8004 premix (g/kg premix): NaCl (99%), 300; KI (75% I), 1; $MnSO_4 \cdot H_2O$ (33% Mn), 25; $FeSO_4 \cdot 7H_2O$ (21% Fe), 30; $CuSO_4 \cdot 5H_2O$ (25% Cu), 10; $ZnSO_4 \cdot H_2O$ (36% Zn), 40; wheat middlings to make 1 kg premix.
14 Mineral premix No. 1 (g/kg premix): KIO_3(61% I), 0.84; $MnSO_4$ (36% Mn), 207; $FeSO_4 \cdot 7H_2O$ (20% Fe), 49.6; $CuSO_4$ (40% Cu) 3.85; $ZnSO_4$ (40% Zn), 185; inert carrier to make 1 kg premix.

Table 3. Ingredients[1] included in closed-formula diets[2].

Ingredients	PTC	RGT	SCT
Fish Meal	+	+	+
Soybean Meal	+	+	+
Cottonseed Meal (De-gossypolized)	-	-	+[5]
Ground yellow corn	+	+	-
Corn distillers dried grains	-	+	-
Corn fermentation solubles	-	+	+
Corn gluten meal	+	-	-
Brewer's dried grains	-	-	+
Brewer's dried yeast	+	+	+
Dried whey	+	+	+
Dehydrated alfalfa meal	+	-	+
Hydrolyzed feather meal	-	-	+
Blood meal	-	+	+
Wheat germ meal	-	-	+
Meat meal	-	-	+[5]
Meat and bone meal	+[3]	+	-
Shrimp meal	-	-	+[6]
Wheat middlings	+[4]	-	+
Wheat mill run	-	+	-
Soybean oil	+	-	+
Fish oil	-	+	-
Animal fat preserved with BHA	+[3]	-	-
Lecithin	-	+	+
Copper sulphate	+	-	-
Copper carbonate	-	-	+
Copper oxide	-	+	-
Cobalt carbonate	-	+	-
Cobalt sulphate	-	-	+
Calcium carbonate	+	+	-
Dicalcium phosphate	+[3]	+	-
Magnesium oxide	+[4]	-	+
Manganous oxide	+	-	+
Calcium iodate	+	+	-
Ethylene-diamine-dihydroiodide	-	+	+
Zinc sulphate	+	-	-
Salt	+	+	+
Ferric oxide	-	-	+
Ferrous carbonate	+	+	+
Vitamins[7]	+	+	+
DL-Methionine	+	+	-
Lignin sulfonate	-	+	+
Ethoxyquin	+	+	-
Butylated hydroxytoluene	-	-	+
Added mineral matter (not greater than 2.50%)	-	-	+

\+ Present

\- Absent

1 Order of ingredients does not indicate proportion of each ingredient in the diets.

2 Ingredients in EST feeds not listed on bag.

3 Present only in #5 extruded diet.

4 Present only in #4 sinking diet.

5 Present only in #5 and 1/8" diet.

6 Present only in 1/8" diets.

7 Vitamins include ascorbic acid, biotin, calcium pantothenate or pantothenic acid, choline chloride, folic acid, menadione sodium bisulfite (except RGT), niacin, pyridoxine hydrochloride, riboflavin, thiamine, vitamin A acetate or palmitate, vitamin B_{12} deactivated animal sterol (source of vitamin D_3) and vitamin E (D-α-tocopherol).

Table 4. Proximate and mineral composition of ingredients used in control diet (C-201) (dry weight basis except for moisture content).

Ingredient	Moisture (%)	Crude protein (%)	Total lipid (%)	Ash (%)	Ca (%)	Mg (%)	Na (mg/kg)	K (%)	Zn (mg/kg)	P (%)
Herring meal [1]	7.0	74.6	12.2	14.4	3.49	0.15	4690	0.78	94	1.98
Soybean meal [2]	7.1	51.1	1.8	6.5	0.24	0.31	75	2.23	49	0.68
Wheat middlings [3]	8.1	19.2	4.8	3.0	0.06	0.24	57	0.57	75	0.50

1 Supplied courtesy of B.C. Packers Ltd., Vancouver, B.C.
2 Supplied by Federated Cooperative, Brandon, Man.
3 Supplied by Master Feeds Division of Maple Leaf Mills, Winnipeg, Man.

Table 5. Proximate composition of diets evaluated (dry weight basis except for moisture content).

Diet	Formulation	Size	Moisture (% as fed)	Crude protein (%)	Total lipid (%)	Ash (%)	Crude fiber (%)	Nitrogen-free extract [3] (%)	Metabolizable energy [4] (kcal/g)
CTR	C-201	#3 & #4	7.2	43.6	15.7	7.7	3.5 [1]	29.5	3.56
	"	1/8"	9.1	45.2	17.1	7.5	3.5	26.7	3.70
MNR	MNR-80G	2GR	8.5	47.2	16.1	7.4	2.8	26.7	3.69
	"	3GR	8.7	47.3	15.9	8.1	2.8	25.9	3.67
	"	4PT	8.8	47.2	15.7	8.3	2.8	26.0	3.66
MTT	GRT-G	#4	8.0	44.9	16.3	8.3	3.2	27.3	3.63
	"	#5	8.9	45.8	16.1	7.8	3.2	27.1	3.65
	"	4mm	7.9	47.2	15.8	7.3	3.2	26.5	3.67
SPF	GR3-30	#4	8.5	54.3	11.9	9.3	1.6	22.9	3.60
	GR4-30	1/8"	8.1	47.6	11.3	8.7	1.5	30.9	3.40
EST	Salmon	#4	8.6	50.4	18.7	9.6	3.0 [2]	18.3	3.91
	Trout	4P	8.4	38.7	16.2	7.9	3.0	34.2	3.47
	"	5P	9.5	43.1	13.8	8.0	3.0	32.1	3.43
PTC	Sinking	#4	8.4	41.0	18.1	10.3	5.0	25.6	3.73
	Extruded	#5	4.2	39.4	6.8	11.5	5.0	37.3	2.80
RGT		#5	8.0	48.6	9.9	13.7	8.0	19.8	3.15
		5/32" crumble	9.4	49.1	11.1	13.6	8.0	18.2	3.17
		1/8"	7.3	43.1	11.0	13.6	8.0	24.3	3.08
SCT		#4	7.2	52.7	17.1	10.6	7.0	12.6	3.78
		#5	7.7	51.4	15.7	10.2	7.0	15.7	3.67
		1/8"	8.1	49.3	14.8	12.3	7.0	16.6	3.52
Range			4.2-9.5	38.7-54.3	6.8-18.7	7.3-13.7	2.8-8.0	19.6-42.3	2.80-3.91

1 Fiber content of CTR, MNR, MTT and SPF estimated from diet formulations and proximate composition of feedstuffs (NRC 1973, 1981).
2 Fiber content of EST, PTC, RGT and SCT represents maximum limit of fiber specified on the feed bag.
3 Nitrogen-free extract determined by subtraction of protein, lipid, ash and fiber from 100.0%.
4 Based on values of Brett and Groves (1979) for estimating caloric value of diet ie. 4.2 kcal/g protein, 8.0 kcal/g lipid and 1.6 kcal/g carbohydrate.

Table 6. Percent fines removed by prescreening and sizes of feed as fed.

Diet	Size	Pellet diameter (mm)	Pellet length Mean (mm)	Pellet length Range (mm)	% Removed as fines[2]		Relative percent recovered in screen series							
						Through sieve no[1]:	-	6	8	10	12	14	16	18
						Over sieve no:	6	8	10	12	14	16	18	-
CTR	#4	-	-	-	-		0	3	29	35	24	7	1	<1
	#5	-	-	-	-		1	81	15	2	<1	<1	<1	<1
	1/8"	3.0	4	2-5	-									
MNR	2GR	-	-	-	3.3		0	10	28	28	24	9	2	1
	3GR	-	-	-	1.1		<1	80	15	3	<1	<1	<1	<1
	4PT	3.5	4	2-5	0.8									
MTT	#4	-	-	-	3.8		0	11	26	28	24	8	3	<1
	#5	-	-	-	1.2		0	79	17	4	1	<1	<1	<1
	4mm	3.5	3	2-4	1.1									
SPF	#4	-	-	-	9.7		1	40	30	23	7	<1	<1	<1
	1/8"	3.0-3.5	7	4-10	1.0									
EST	#4	-	-	-	2.9		0	7	36	38	16	2	1	<1
	4P	-	3	2-6	1.3									
	5P	3.0	4	3-6	0.6									
PTC	#4	-	-	-	3.2		<1	49	29	14	7	1	1	<1
	#5	4.0	4.5	4.5	0.3									
RGT	#5	-	-	-	4.2		0	26	36	28	9	1	1	<1
	5/32"						<1	37	31	23	8	<1	<1	<1
	Crumbles	-	-	-	8.8									
	1/8"	3.0-3.5	6	4-8	2.1									
SCT	#4	-	-	-	4.6		0	29	38	22	5	2	2	1
	#5	-	-	-	2.7		13	67	15	4	1	<1	<1	<1
	1/8"	3.0-3.5	6	3-8	2.7									

\- Not measured.

1 Canadian (equivalent to U.S.) sieve series mesh openings: No. 6 (3.35 mm), No. 8 (2.36 mm), No. 10 (2.00 mm), No. 12 (1.70 mm), No. 14 (1.40 mm), No. 16 (1.18 mm) and No. 18 (1.00 mm).

2 Fines are defined as the material passing through a No. 16 sieve (for the smaller granular feed) and through a No. 12 sieve (for all pelleted feed and for the larger granular feed when there was one available).

Table 7. Performance of rainbow trout fed test diets for 22 weeks at 12°C. Values represent the mean of four replicates with means in each column followed by different superscript letters being significantly different ($P<0.05$; Duncan's new multiple range test).

Diet	Initial wt (g)	Wt gain (g)	Feed intake (g)	Feed conversion (dry wt feed ÷ wet wt gain)	Mortality (fish/tank)
CTR	12.4	161.2^{a}	176.7^{abc}	1.10^{a}	0.50
MNR	12.4	135.2^{bc}	184.4^{ab}	1.36^{b}	0.75
MTT	12.3	143.2^{b}	185.3^{ab}	1.30^{b}	0.75
SPF	11.7	129.9^{bc}	179.0^{ab}	1.40^{bc}	0.50
EST	12.1	129.4^{bc}	177.4^{abc}	1.38^{bc}	0.75
PTC	12.2	117.6^{c}	173.9^{bc}	1.49^{c}	0.25
RGT[1]	12.0	$88.6^{d}(90.3^{d})$	163.6^{c}	1.85^{d}	2.00
SCT	11.8	137.6^{b}	191.4^{a}	1.40^{bc}	0.75
GLM-SAS[2]	P>0.1	P<0.001	P<0.05	P<0.001	P>0.1
Mean	12.1	131.7	179.4	1.39	
SEM[3]	0.08	2.08	1.58	0.018	

1 Means of three replicates. Value in parentheses for weight gain is the mean of four replicates.
2 General Linear Model - Statistical Analysis System (SAS Institute 1979). Analysis of variance (ANOVA) for a randomized complete block design.
3 Standard error of the mean from the ANOVA.

Table 8. Biochemical composition[1] of liver and muscle tissue, percent dressed weight to round weight and percent liver weight to body weight of trout. Means in each column followed by different superscript letters are significantly different ($P<0.05$; Duncan's new multiple range test).

Diet	Percent dressed wt to round wt[1]	Percent liver wt to body wt[1]	Liver[2] Moisture (%)	Liver[2] Total lipid (% wet)	Liver[2] Total lipid (% dry)	Muscle[2] Moisture (%)	Muscle[2] Total lipid (% wet)	Muscle[2] Total lipid (% dry)	Muscle[2] Crude protein (% wet)	Muscle[2] Crude protein (% dry)
CTR	83.2^{abc}	1.11^{cd}	73.1^{bc}	3.59^{bc}	13.6^{bc}	74.9^{c}	4.64^{b}	18.5^{b}	19.0^{a}	75.8^{b}
MNR	82.2^{abc}	1.24^{bc}	74.4^{ab}	3.69^{bc}	14.4^{b}	75.0^{bc}	4.84^{ab}	19.3^{ab}	18.7^{ab}	75.0^{bc}
MTT	81.5^{c}	1.30^{b}	73.3^{bc}	4.29^{ab}	16.0^{ab}	74.5^{c}	5.42^{a}	21.1^{a}	18.6^{ab}	73.0^{c}
SPF	83.1^{abc}	1.27^{bc}	75.0^{a}	4.42^{a}	17.6^{a}	76.2^{a}	3.50^{cd}	14.6^{cd}	19.1^{a}	80.1^{a}
EST	82.3^{abc}	1.19^{bcd}	74.6^{ab}	3.66^{bc}	14.4^{b}	75.2^{bc}	4.85^{ab}	19.4^{ab}	18.5^{ab}	74.5^{bc}
PTC	81.7^{bc}	1.92^{a}	72.2^{c}	3.09^{c}	11.1^{c}	76.6^{a}	3.69^{c}	15.7^{c}	18.0^{b}	77.1^{b}
RGT	84.0^{a}	1.18^{bcd}	75.1^{a}	3.42^{c}	13.8^{bc}	76.6^{a}	2.94^{d}	12.5^{d}	19.0^{a}	81.2^{a}
SCT	83.6^{ab}	1.08^{d}	74.8^{a}	3.28^{c}	13.2^{bc}	75.8^{ab}	3.57^{cd}	14.6^{cd}	18.5^{ab}	76.8^{b}
GLM-SAS[3]	$P<0.05$	$P<0.001$	$P<0.001$	$P<0.05$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.05$	$P<0.001$
Mean	82.7	1.29	74.1	3.68	14.3	75.6	4.18	17.0	18.7	76.7
SEM[4]	0.22	0.018	0.17	0.086	0.34	0.10	0.079	0.27	0.08	0.32

1 Each value represents the mean of 24 fish (4 tanks x 6 fish/tank).
2 Each value represents the mean of 12 analyses (4 tanks x 3 analyses of 2 paired fish/tank).
3 General Linear Model-Statistical Analysis System (SAS Institute 1979). Analysis of variance (ANOVA) for a randomized complete block design.
4 Standard error of the mean from the ANOVA.