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A NUTRITIONAL STUDY OF COMMERCIAL REARED SALMON (SALMO SALAR), USING WET FISH FEED

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ABSTRACT

During 1972/73 a nutritional study was carried out with 250.000 young salmon fed a wet diet composed mainly of minced fish in a commercial sea enclosure at the West coast of Norway. The experiment lasted one year, during which time the fish grew from an average weight of 0.4 kg to 2.0 kg. The composition of the feed and the feed intake over the entire period are reported. The water temperature was recorded daily, and salinity and oxygen supply were kept under observation. The feeding regimen was varied according to observations of condition factor and depot fat of the fish to obtain maximum growth without overfeeding. During the whole period the feed as well as muscle and liver of the salmon were analysed on six B-vitamins, to observe any deficiencies or discrepancies from the corresponding values in wild salmon. The observed vitamin values were remarkably constant during the experimental period, and agreed well with values for wild salmon. The development of pigmentation was followed visually and by chemical determination of astaxanthin in the muscle and showed a low utilization. The applied feed regimen gave a salmon commercially accepted as a high quality product.

INTRODUCTION

Fish nutrition has been a growing science in recent years, and fish farmers have been increasingly aware of the importance of feed composition. Too often when fish was reared in local areas, the feed was mixed from available byproducts from local fishing and agriculture and based on practical observations of food habits of the species reared. As fish farming has extended, and the reared fish is produced for bigger markets, there is a growing need for a standardized feed aimed at obtaining a more uniform product quality. As a result of economic competition, the success or failure may depend not only on feeding the right ingredients, but also on composing the diet in accordance with the nutritional requirements of the fish. Available feed ingredients may often vary with regard to nutrient contents, and the feed must be mixed according to formula to give optimal utilization of the nutrients available. Lacking research data on metabolism and nutrition in fish, diets analogous to those applied in animal husbandry has been

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applied. Considering that fish is a coldblooded animal in aquatic environment, devitation in nutritional requirements may be expected and have been observed.

Quite extensive data are available for the metabolism and nutrition of many salmonoid species (HALVER, 1972), but much research remains to be carried out on the Atlantic salmon *(Salmo salar)*. The present study is an attempt to follow empirically the development of this species reared on practical rations in a salmon farm at the West-Norwegian coast. Over a period of one year, diet, growth and health of the fish have been followed.

Further environmental factors such as temperature, oxygen and salinity have been recorded. Six B-vitamins have been analysed in the feed, and in liver and muscle tissue of the fish during the experimental period. The results might possibly relate changes during the development of the fish with the content of growth factors in the feed. Factors related to growth and development of the fish, such as the condition factor, muscle fat and depot fats have also been recorded, as well as the development of pigmentation. A unique aspect of the present investigation is that it represents a «feeding experiment» with 250 000 salmon smolt.

EXPERIMENTAL

DESCRIPTION OF THE ENCLOSURES

The experiment was carrid out in two sea enclosures, which have been described by MILNE (1972) and BRAATEN and SAETRE (1973). The smallest (Flogøy-kjølpo) has a surface area of 12 000 square metres and a volume of approx. 55 000 cubic metres, whereas the largest (Veløy-kjølpo) has an area of 35 000 square metres and a volume of 182 000 cubic metres. The water volumes refer to medium tide, the difference between high and low tide being of an order of 1 metre. Both enclosures have two screened openings to the open sea, and pumping installations give additional water exchange.

FISH

251 000 one year old salmon smolt weighing on an average 25 g were transported in underwater containers with optimal water exchange. The smolt derived from farm salmon as well as wild salmon. They had been fed dry pellets from fry to the smolt stage in a fresh water plant at Varaldsøy in Hardanger. The transport to the first enclosure, Flogøy-kjølpo, took 20 hrs, and the whole transfer lasted 3 weeks in June. Less than 100 fish died during the transportation.

The present investigation started three months later, in October 1972, and at that time the fish had an average weight of 400 g. During the next months the fish were transferred to the larger enclosure, Veløy-kjølpo. The

long transfer time was due to unexpected bad weather conditions the winter 1972/73. The feeding regime was, however, the same in both enclosures during this period, and fish were sampled from both places. From February to October 1973 all fish were in the enclosure at Veløy. The total observation period lasted one year.

FEED

The fish was fed on a wet-feed basis. Deep-frozen fish, fish offal and shrimp offal were transported to the feed kitchen, and thawed in running sea-water. The products were ground and mixed with five percent fish meal into which was mixed 8 percent of the binding agents (guar gum). Further was added 0.2 l per 100 kg mixture of a suspension of vitamins (Table 1). Over the experimental year the fish ingredients varied with availability and were mixed according to the environmental conditions and the condition factor of the fish. The composition of the feed is shown graphically in Fig. 1 for periods of about half months. The contents of protein, fat and ash are given per month in Fig. 2.

All ingredients were as fresh as possible, without decomposition and off-flavour to secure a good appetite.

The feed was given shortly after the mixing directly as «worms» from a «wet-pelleting» machine of the company's own construction. The size was increased gradually with increased size of the fish.

Table 1. *Vitamin supplementation per ton wet feed.*

Vitamin:	Mixture I[1)]	Mixture II[2)]
Thiamine HCL	8 g	8 g
Riboflavin	10 »	10 »
Nicotinic acid	25 »	25 »
Pyridoxine HCl	7 »	7 »
Ca-pantothenate	25 »	25 »
Inositol		80 »
Ascorbic acid	50 »	50 »
dl-α-Tocopherol acetate	15 »	20 »

1) Used in the period October 1972 – March 1973.

2) Used in the period April 1973 – October 1973.

For explanation of change, see text.

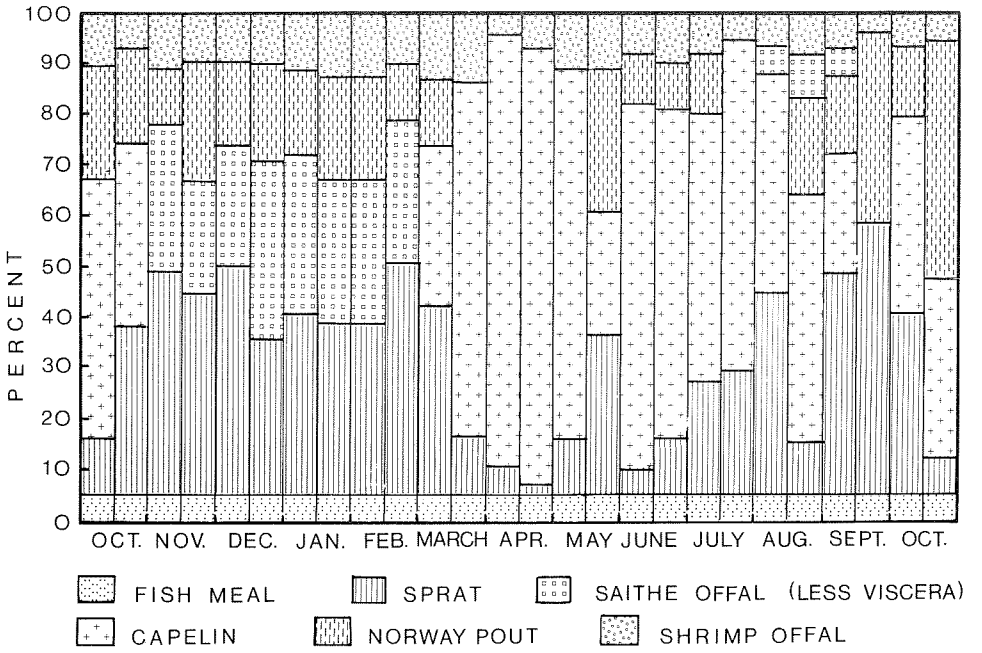

Fig. 1. *Percentage composition of the diet as halfmonthly averages.*

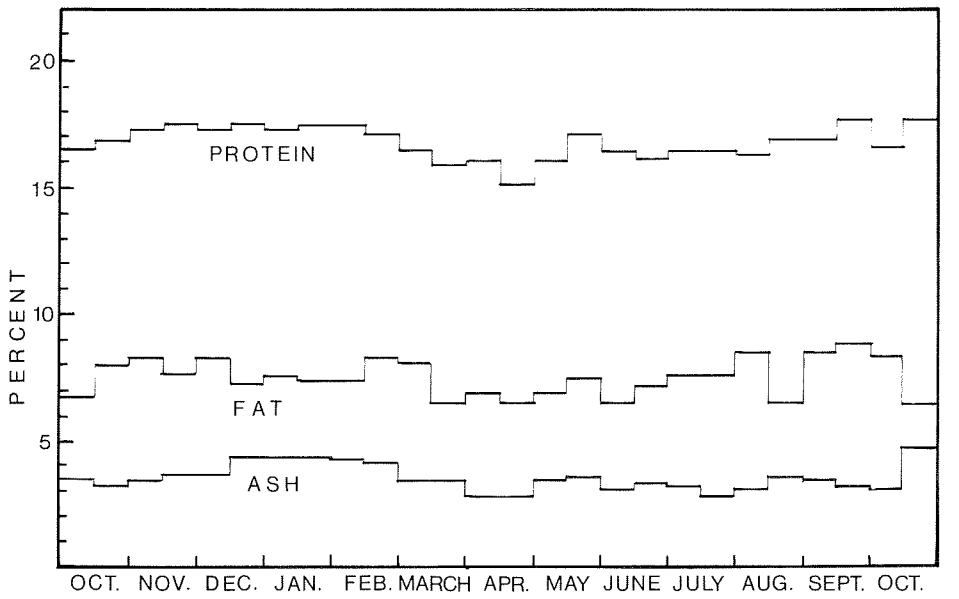

Fig. 2. *Percentage protein, fat and ash in the diet calculated on the basis of analyses of ingredients.*

GENERAL OBSERVATIONS

The temperature was measured daily. Pumping installations working from the deepest point of the enclosure secured practically uniform temperature. The observations are recorded graphically in Fig. 3. Oxygen was measured periodically, with extra observations during warm periods, when the situation was under daily control. Dangerously low values were not observed at any time.

Salinity was measured daily in combination with the temperature observations. It was fairly constant at values around 30‰ ± 1‰, with the exception of one day with extreme rainfall, when a value as low as 22‰ could be observed in upper layers.

METHODS

Sampling took place in connection with the company's monthly growth control. The weight data comprice these observations and refer to 100 fish or more. In the last months the sampling coincided with harvesting which started in August and continued to prevent overstocking of the enclosure.

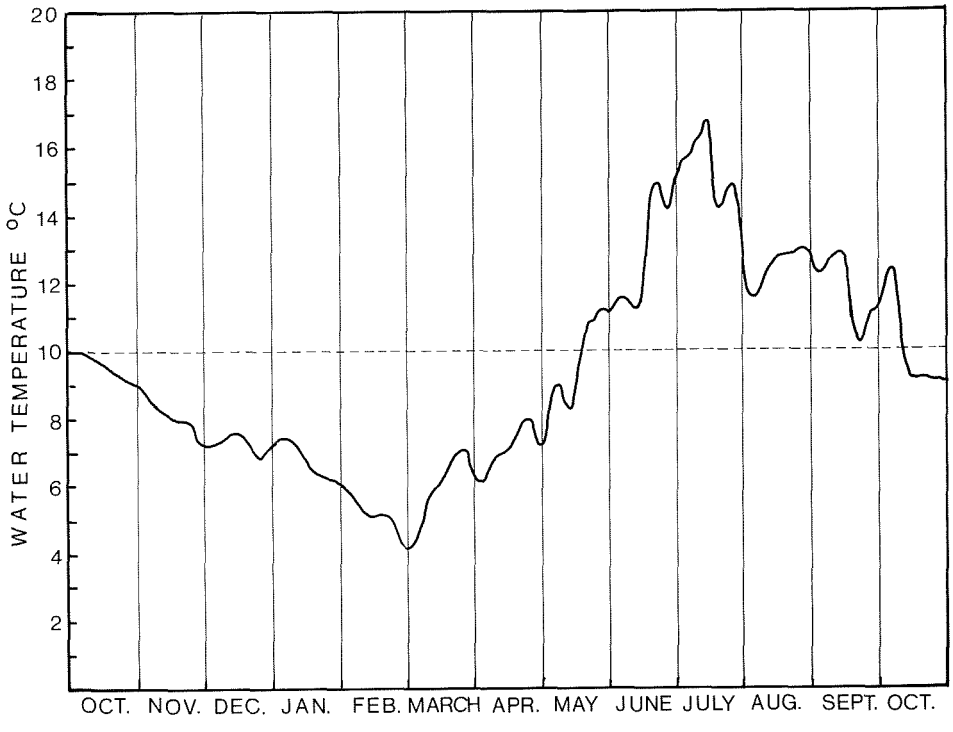

Fig. 3. *Water temperature in the enclosure based on daily observations.*

Each time eight fish were selected randomly during the weight control. They were laid fresh on ice in foamplastic containers and transported to the laboratory for analysis. From each fish were taken the total dorsal part of the lateral muscle cut to avoid bones, and the skin was removed. Samples for fat determination were taken from the dorsal front and back muscle. The resulting fillets were ground in a meat mincer. The ground fish was frozen and stored at ÷ 20° during the period of analysis.

Total dry matter was determined by drying in an oven at 105°C for 4 hrs or until a constant weight was observed.

The fat content was determined by ether extraction of the dry matter in a Soxhlet apparatus for 4 hours.

Ash was determined by ignition of the dried sample, first carefully over a gas burner, then in an oven at 550°C until constant weight was obtained.

Protein was calculated on the basis of Kjeldahl-N multiplied by the factor 6.25.

Thiamine was determined microbiologically with *Lactobacillus fermenti* (ATCC 9338), and the response was measured turbidimetrically after incubation at 37°C for 18 hrs. The vitamin was extracted by steaming 2 g sample with 50 ml 0.1 N H_2SO_4 for 30 min. After cooling the pH was adjusted to 4.5 ml with 2.5 M sodium acetate solution. 2 ml of a suspension of 20 mg papain + 20 mg takadistase pr. ml were added and the mixture was layered with toluene and incubated for 20 hrs. The mixture was then steamed for 30 min, made up to volume and filtered. Suitable aliquots were adjusted to pH 5.5 before final dilution. The amount of thiamine in the enzymes had been checked to be negligible, thus a blank could be omitted.

Riboflavin was determined microbiologically with *Lactobacillus casei* (ATTC 7469) after incubation at 37°C for 72 hrs. The response was measured by potentiometric titration. The vitamin was extracted by digestion of 5 g sample with 25 ml 0.15 M sodium acetate buffer of pH 4.5, and 2 ml of a suspension of 20 mg takadiastase + 20 mg papain per ml were added. The mixture was layered with toluene and incubated for 20 hrs. at 37°C, and thereafter autoclaved for 5 min at 120°C, cooled, made up to volume and filtered. To remove interfering fatty acids, an aliquot was extracted three times with ethyl ether by shaking in separatory funnels. Aliquots of the extracted filtrate were adjusted to pH 6.8 and diluted to suitable concentrations for the assay. Blanks could be omitted, as the enzymes were practically free from riboflavin.

Pantothenic acid was determined microbiologically using *Lactobacillus plantarum* (ATTC 8014) after incubation at 30°C for 20 hrs. The response was measured turbidimetrically. The vitamin was extracted as for riboflavin, with the omission of extraction with ethyl ether.

Niacin was determined microbiologically with *L. plantarum* after incuba-

tion at 37°C for 72 hrs. The growth was measured by potentiometric titration. The extraction was carried out by autoclaving 2 g sample with 100 ml 0.5 N H_2SO_4 for 20 min at 120°C. After cooling the digest was adjusted to pH 4.5, diluted to suitable concentration and filtered. Aliquots were adjusted to pH 6.8 before diluting to suitable concentrations.

Vitamin B 6 was determined microbiologically with *Saccharomyces carlsbergensis* (ATTC 4228) as test organism after incubation at 30°C for 18 hrs in a shaking incubator with teflon balls in the test tubes. The growth was measured turbidimetrically. The vitamin was extracted by autoclaving 2 g sample with 200 ml 0.055 N H_2SO_4 for 4 hrs. After cooling the extract was adjusted to pH 4.5, diluted to volume and filtered. Aliquots were diluted to suitable concentration.

Biotin was determined with *L. plantarum* as test organism after incubation for 20 hrs at 30°C. The response was measured turbidimetrically. The extraction was carried out by autoclaving 2 g sample with 25 ml 3 N H_2SO_4 for 3 hrs at 120°C. The digest was adjusted to pH 4.5, made up to volum and filtered. Aliquots were diluted to suitable concentrations.

Depot fat units were determined by visual inspection and estimation of visceral fat. HJORTH (1914) applied this principle to herring (*Clupea harengus*), and later several authors proposed similar scales. Thus PROZOROVSKAIA (1952) used numerical units from 0 to 5 for the depot fat of Caspian roach *(Rutilus rutilus)*. The visceral tissue may differ from one species to another, and for fish the form and extent of the pyloric caeca is one of the pronounced differences. We found it convenient to judge the depot fat in salmon *(Salmo salar)* by inspection of the amount of visceral fat connected to the pyloric caeca. Visual inspection may show degrees of fat depots from absence of fat to the pyloric caeca almost covered with fat. The degree of depot fat was given in units from 0 to 5, as defined in Table 2.

Table 2. *Depot fat unit scale for salmon (Salmo salar).*

Unit 0	No fat observed between the fingers of the pyloric caeca.
Unit 1	Narrow threads of fat observed attached to the connective tissues between fingers of the pyloric caeca.
Unit 2	Pronounced threads of fat between the fingers of the pyloric caeca.
Unit 3	Almost equally much fat and fingers visible on inspection of the pyloric caeca.
Unit 4	Pronounced more fat visible than fingers of the pyloric caeca.
Unit 5	The pyloric caeca is almost covered by visceral fat.

The condition factor was determined by the formula $C = W\ 100/L^3$, where W is the weight of the fish in gram, and L is the length of the fish from the nose to the fork of the tail in cm (JENSEN & GAUDET, 1968).

Pigmentation was judged visually and measured by chemical determination of astaxanthin in the muscle tissue by the method described by LAMBERTSEN and BRAEKKAN (1971). The visual inspection followed an empirical decimal scale from 0 to 1.0. The maximum value corresponded with a well pigmented wild salmon, where values between 2 and 3 μg astaxanthin per g muscle tissue was found.

RESULTS AND DISCUSSION

GROWTH AND HEALTH

The growth is recorded in Fig. 4, which gives average weight per month and percentage average weight increase per day in each month. The corresponding feed intake as percentage of the average weight of the fish, and the dietary calorie intake per g weight gain are given in fig. 5. The calorie value of the feed was calculated from the analytical data for protein and fat

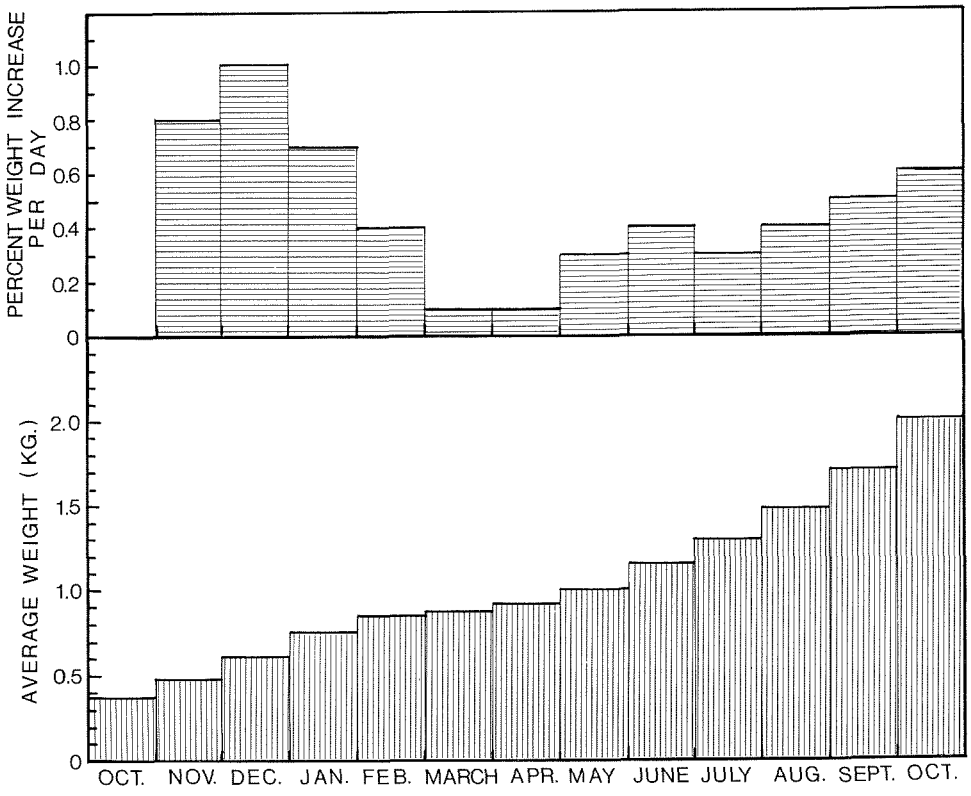

Fig. 4. *Monthly average weight and percent weight increase per day during the experimental period.*

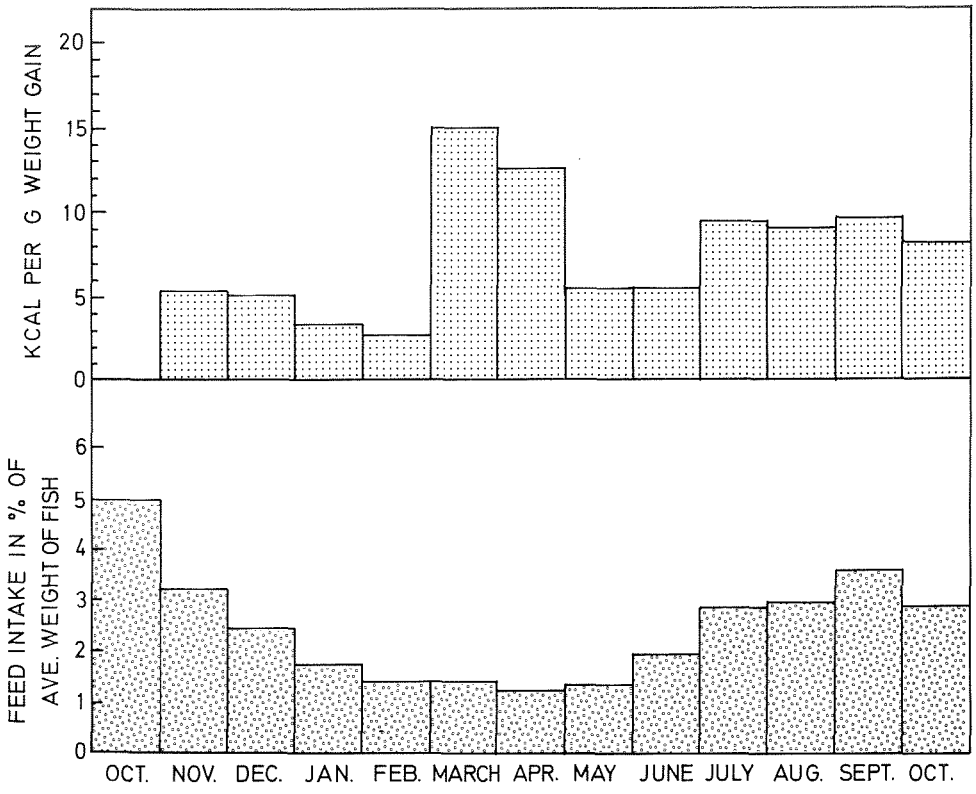

Fig. 5. *Monthly feed intake as percent of average fish weight and corresponding kcal per g weight gain.*

(Fig. 2), using the conversion factor 3.9 for protein and 8.0 for fat (PHILLIPS and BROCKWAY, 1959).

From October to January the growth was very good, with an increase in the average weight from 0.4 to 0.75 kg. This corresponded to an average of 0.8 percent weight increase per day. In the same months the condition factor showed the highest values, ranging between 1.14 and 1.18. During the same time the water temperature decreased from 10 to 6°C (Fig 3). In February the weight gain was reduced to an average of 0.4 percent increase per day. This may be caused by the further drop of the water temperature to about 4°C, but the decrease also coincided with the transfer of the fish from Flogøy-kjølpo to Veløy-kjølpo. The average percent weight increase showed, however, a further reduction during March and April, with values down to 0.1 percent per day. This coincided with a strongly reduced appetite, and with lower values for the condition factor, 1.03 and 1.04, respectively (Table 3). During the same period the water temperature increased from 4 to 8°C. In this period the first spawners could be observed, and the occur-

rence of spawners increased the following months to a maximum of 14% in June. Attempts were made to correlate the stop in the growth with some environmental factors, but with negative results. The oxygen values were generally above 90 percent saturation, thus sufficient oxygen was present to support the physical and physiological activity of the fish. The pH remained normal at 8.0, and only traces of ammonia could be detected. Organic suspended matter from outside or from the feed was considered, but measurements showed no value above 20 ppm, which should be well tolerated. The salinity also remained fairly constant at 30‰, with the one exception given above.

Although no symptoms of any disease or parasite infection could be observed, fish samples were sent for pathological examination, which gave negative findings. A visual examination of the gut cavity indicated the possibility of fatty livers in a few fishes. As a counter-measure the vitamin supplementation was extended to include 80 g inositol per ton feed, and the tocopherol supplement was increased from 15 to 20 g per ton.

From May to the end of the experiment in October, the weight showed a steady increase. Over these last six months the percent weight increase per day averaged 0.4. In this period the water temperature increased to about 17°C in July and then decreased to about 9°C in October. Over the same period the condition factor remained at about 1.0, and the fish were vital and healthy. Table 3 records observations related to depot fat «units» and percent muscle fat. The depot fat never increased above 4 units (Table 2). The values were usually 2—3 units, and this may reflect that the feed was well composed and that no apparent overfeeding took place. Externally the fish had a shape closely resembling wild salmon. The percentage fat in the dorsal front and back muscle showed no relation to the growth of the fish on the present diet.

When the growth is related to the feed intake, some points may be commented on (Fig 5). After the transfer to the enclosures the young fish had a very good appetite and had a feed intake averaging 5 % of the body weight during the first month. The next three months the intake fell evenly to 1.5 % of the body weight. This trend may reflect the decrease in the water temperature as well as the growth of the fish, as the food intake falls with increased weight (size). In March and April weight increase was very low, giving a feed intake of up to 15 kcal per g weight gain. The total calories supplied cover maintenance energy as well as growth energy, and it seems justified to estimate that a feed supply of approx. 1 % of the body weight is needed to meet maintenance requirement at a temperature of 5— 7°C. SCHAPERCLAUS (1933) and PHILLIPS et al. (1960) reported a doubling of the maintenance requirement and metabolic activities with 10 degrees increase in water temperature. This would correspond to a dietary need of about 2 %

Table 3. *Some factors related to the growth and development of the fish.*

	Number of fish (n)	Condition factor[1] M ± s.d.	Muscle fat (%)		Depot[2] fat "units"
			Dorsal front	Dorsal back	
October	108	1.18 ± 0.081	4.2	–	2
November ...	74	1.17 ± 0.092	6.0	4.0	1
December ...	206	1.14 ± 0.087	4.1–9.9	2.5–5.8	3
January	139	1.15 ± 0.087	5.0–10.7	3.6–6.9	3 – 4
February	175	1.11 ± 0.085	6.0–9.0	3.2–4.7	3
March	146	1.03 ± 0.066	6.3–10.7	2.8–6.7	2 – 3
April	6	1.04 ± 0.050	5.4–7.3	2.6–3.2	2 – 3
May	63	0.97 ± 0.092	3.4–9.5	1.9–5.0	2 – 3
June.....	151	0.99 ± 0.103	5.1	3.2	1 – 3
July	–	–	–	–	–
August.....	129	0.99 ± 0.082	–	–	2
September ...	–	–	–	–	2 – 3
October	8	1.02 ± 0.114	9.6	5.4	3 – 4

[1]) Condition factor: $C = W \cdot 100/l^3$, where W = weight in gm, L = length (fork length) in cm.
[2]) Visual estimation of visceral fat in units 0–5 as defined in Table 2.

of the body weight to cover the maintenance requirement at 15—17°C. With the falling temperature from October to February, this was reflected by the increased efficiency of the total calorie intake per g weight increase. In May and June the feed intake increased up to 2 % of the body weight of the fish. In July the water temperature was at its peak, about 10°C above the temperature in March—April. Thus about 2 % of the 2.8 % feed level would be needed for maintenance, indicating a reasonably high conversion factor for the diet. During the next months a falling temperature did not increase the calorie efficiency of the diet in relation to growth as in the first months. Some factors may be considered as an explanation. During this period harvesting took place continually, with a possible stress to the fish, further the influence of sexual maturation should not be overlooked.

When the enclosure was emptied (May, 1974) a detailed record showed that 71% of the smolts planted in the enclosure were recovered. Large dead fish could be easily observed and would be recorded, and in the day to day record 60 dead fish had been accounted for. Most probably the fish lost died during the first few months after the transfer of the smolt to the enclosure, and partly as a result of cannibalism.

VITAMINS AND COLOR

HASHIMOTO (1969) has reviewed the importance of vitamins in fresh water culture. HALVER (1972) gave a more detailed review of the role of vitamins in fish nutrition, with reference to salmonoid species. He discussed the clinical assessment of the nutritional status of several B-factors, empha-

sizing the levels of respiratory enzymes where the vitamins constitute parts of different coenzymes. He further discussed the levels of liver storage as a mean of clinical assessment. A subcommittee on Fish Nutrition established by the National Research Council of U.S.A. has given recommendations relating to the nutrient requirements of trout, salmon and catfish (1973). These are referred to below as NRC-recommendations.

The present study includes an investigation of the relation between the dietary supply of the main B-vitamins and their utilization assessed by liver storage and levels in the muscle tissue. The results of the vitamin determinations are summarized for the feed analyses in Table 4, the liver storage values in Table 5 and the levels in the muscle tissues in Table 6.

The feed showed reasonably stable contents of the analyzed B-vitamins, with the exception of thiamine. The thiamine value for the March sample is particulary low. An error during the almost weekly preparation of the vitamin premix cannot be ruled out, and the presence of thiaminase in the feed must also be considered. Such observations emphasize the importance of frequent preparation of the vitamin mixture.

The liver storage of the different B-vitamins (Table 5) gives the following picture:

Thiamine was supplied in amouts of 10.75 ± 6.46 μg/g wet feed (the March value excepted). The high standard deviation may reflect destruction of the thiamine by thiaminase in the raw fish mixture. The content was, however, about three times higher than the NRC-recommendation of 10 μg/g dry feed. The liver showed 9.9 ± 2.6 μg thiamine/g fresh weight with single values from 5.7—13.8 μg/g. BRAEKKAN (1959) found 8 μg/g fresh weight for liver from wild Atlantic salmon, whereas HALVER (1972) reported saturation levels for liver of Pacific salmon in the range 15—20 μg thiamine/g. Fingerling chinook salmon reared on a diet containing 15.5 μg/dry feed was reported to store 8—10 μg thiamine/g wet liver. Thus the thiamine supply apparently was more than sufficient in the present experiment.

Table 4. *Analysis of the feed.*

Component:		Nov. 72	Jan. 73	Febr. 73	March 73	Average ± S.d.
Dry matter %		35.3	35.3	34.8	36.8	35.55 ± 0.87
Fat %		6.8	7.9	8.6	9.4	8.18 ± 1.10
Thiamine	μg/g	5.1	17.7	8.9	(0.35)	10.75 ± 6.46
Riboflavin	»	8.0	6.3	11.8	8.0	8.05 ± 2.82
Niacin	»	44.0	52.8	48.1	52.7	49.4 ± 4.21
Pantothenic acid	»	24.0	39.6	29.5	33.3	31.6 ± 6.55
Pyridoxine	»	7.9	11.6	9.3	9.4	9.5 ± 1.44
Biotin	»	0.071	0.080	0.085	0.110	0.087 ± 0.017

Table 5. *The storage of some B-vitamins in the liver of salmon (Salmo salar) fed freshly mixed wet feed.*

Month	Number of samples	Thiamine µg/g	Riboflavin µg/g	Niacin µg/g	Pantotenic acid µg/g	Pyridoxine µg/g	Biotin µg/g
October 72	2	8.3	13.5	69.2	30.5	6.4	1.60
November 72	2	12.2	13.9	95.1	33.3	6.4	1.95
December 72	2	12.4	10.4	74.8	26.9	7.0	1.54
January 73	2	11.1	12.9	79.8	32.5	5.6	1.91
February 73	2	8.9	11.3	68.4	29.3	7.5	1.80
March 73	2	11.2	11.6	89.6	34.5	10.6	1.84
April 73	2	13.8	19.2	69.9	31.9	9.2	1.79
May 73	3	8.3	15.3	55.0	21.7	7.4	1.39
June 73	3	7.2	14.0	73.6	20.7	8.3	2.11
October 73	3	5.7	16.5	84.2	26.1	13.6	1.96
M ± s.d.		9.9 ± 2.6	13.7 ± 2.6	76.0 ± 11.6	28.7 ± 4.8	8.2 ± 2.4	1.79 ± 0.22

Riboflavin was present in amounts of 8.05 ± 2.82 µg/g wet feed, compared to a NRC-recommendation of 20 µg/g dry feed. The liver storage showed 13.7 ± 2.6 µg/g fresh weight. BRAEKKAN (1959) found 8 µg/g liver from wild Atlantic salmon, whereas HALVER (1972) reported 6—8 µg/g liver from actively feeding Pacific salmon, and 3.5—4.0 µg/g in young fish in freshwater environment at 15°C. The high liver storage in the present experiment indicate a sufficient, probably somewhat high supply of riboflavin in the feed. The NRC-recommendation of 20 µg riboflavin/g dry feed for salmon and trout is most probably above the requirement of Atlantic salmon.

Niacin showed fairly stable values in the wet feed, 49.4 ± 4.21 µg/g compared with the NRC-recommendation of 150 µg/g dry feed. The liver values averaged 76.0 ± 11.6 µg/g fresh weight, compared with 46 µg/g liver from wild Atlantic salmon (BRAEKKAN 1959). HALVER (1972) reported 70—80 µ niacin/g liver tissue from wild Pacific salmon and 35—40 µg/g in liver from fingerlings fed a diet with 500—750 µg/g dry feed. The present supply of about 50 µg niacin/g wet feed seemed to cover the requirement and the NRC-recommendation would meet the requirement of Atlantic salmon.

Pantothenic acid was found in the wet feed in amounts of 31.6 ± 6.55 µg/g. This is more than twice the NRC-recommendation of 40µg/g dry feed. Analyses of the liver gave 28.7 ± µg/g fresh weight. BRAEKKAN (1959) found 17.3 µg pantothenic acid in liver from wild Atlantic salmon. HALVER (1972) reported that actively feeding Pacific salmon had a content of 18—20 µg/g fresh liver tissue, and that fingerlings fed a dry feed containing 165 µg/g showed liver stores of the order 14—16 µg/g fresh weight. The supply of pantothenic acid in the present experiment seemed more than sufficient,

Table 6. *B-vitamin contents of the muscle of salmon (Salmo salar) fed freshly mixed wet feed.*

Month	Number of samples	Thiamine µg/g	Riboflavin µg/g	Niacin µg/g	Pantotenic acid µg/g	Pyridoxine µg/g	Biotin µg/g
October 72	8	0.58±0.16	1.26±0.15	81.6±11.7	14.2±1.30	8.55±0.67	0.042±0.0048
November 72	8	1.09±0.17	1.08±0.13	90.0±11.2	13.8±0.66	9.11±0.94	0.047±0.0068
December 72	6	2.05±0.42	–	80.3±6.84	13.2±1.14	9.00±0.78	0.048±0.002
January 73	6	2.1 ±0.39	–	87.9±14.8	14.8±1.16	8.20±0.94	0.037±0.0021
February 73	6	3.85±0.55	–	84.1±8.59	12.8±1.09	9.34±1.22	0.040±0.0031
March 73	6	2.52±0.33	1.43±0.16	80.1±6.67	13.1±1.52	9.02±0.83	0.050±0.012
April 73	6	2.55±0.57	1.49±0.13	83.9±13.9	12.7±1.28	8.65±0.70	0.045±0.0063
May 73	6	1.98±0.18	1.42±0.10	75.3±6.10	10.8±1.64	8.10±0.24	0.045±0.0026
June 73	8	2.39±0.37	1.37±0.05	77.9±7.00	12.8±3.93	8.42±0.48	0.040±0.0059
October 73	8	1.94±0.56	1.46±0.14	75.6±18.1	12.6±2.85	8.15±1.56	0.055±0.012
(M±s.d.)		2.10±0.88	1.36±0.14	81.7±4.89	13.1±1.08	8.65±0.44	0.045±0.005
Wild salmon [1]		2.0	1.5	70	7.0	6.0	0.048

[1] BRAEKKAN (1969).

and the NRC-recommendation of 40 µg/g dry feed may be applicable to the rearing of Atlantic salmon, judged by the liver storage.

Pyridoxine was found in the feed in amounts of 9.5 ± 1.44 µg/g wet feed, three times higher than the NRC-recommendation of 10 µg/g dry feed. The liver storage in the present study was 8.2 ± 2.4 µg/g fresh weight. HALVER (1972) reported that actively feeding Pacific salmon had contents of 5—6 µg pyridoxine/g fresh weight, whereas fingerlings fed a dry diet containing 16.5 µg/g showed liver stores of 2—3 µg/g fresh tissue.

Biotin was not supplemented to the feed, but analysis showed a natural content of 0.087 ± 0.017 µg/g wet feed. The NRC-recommendation is 1 µg/g dry feed or three times higher,than this. The liver content was 1.79 ± 0.22 µg biotin/g wet weight. This may be considered fairly high. Thus BRAEKKAN and BOGE (1965) reported values between 0.32 and 0.65, with an average of 0.52 µg biotin/g wet weight in livers from different gadidae. HALVER (1972), however, reported the presence of 10—12 µg biotin/g fresh liver tissue from actively feeding Pacific salmon. A diet containing 1.65µg/g was reported to give a liver storage of 6—8 µg biotin/g wet weight in fresh water reared fish. The highly differing values may indicate analytical differences, making comparisons difficult.

Table 6 summarize the determinations of B-vitamins in the muscle tissue of the salmon. Thiamine increased during the first two months from 0.58 ± 0.16 µg/g in October to 2.05 ± 0.42 µg/g in December. Later the values were fairly constant throughout the experiment with the exception of a higher value in February, 3.85 ± 0.55 µg/g. All the other vitamins analyzed showed remarkably constant values throughout the whole experiment. The year averages in Table 6 agree very well with the wild salmon values (BRAEK-

KAN, 1969) for all investigated vitamins except for pantothenic acid. The content for pantothenic acid was 13.1 μg/g in reared salmon compared with 7.0 μg/g in wild salmon. This may be a result of the fortification of the feed. The liver storage of pantothenic acid reported above was also higher in the reared than in the wild salmon.

The red coloured meat of wild salmon derives from the pigment astaxanthin. This carotenoid is not formed in the fish, but comes from the feed. Strongly pigmented wild salmon showed 2—3 μg astaxanthin/g muscle tissue. The main source of astaxanthin in the present experiment was shrimp offal. Unfortunately the supply was short during the year of this investigation. From Fig 1 can be seen that about 10 % shrimp offal was mixed into feed the first six months. The content in the following mounths varied between 3 and 10 percent. Normally during this period, the addition of shrimp offal is increased to 15 % of the feed. A visual inspection based on a 0 to 1.0 scale with decimal intervals gave 0.4 the first month, and later for most months 0.6. The last month 0.7 colour units were recorded. Chemical determinations of the astaxanthin content were limited due to lack of analytical capacity. Samples for the months Jan.—June gave 0.24, 0.89, 0.23, 0.58, 1.25 and 1.16 μg astaxanthin/g muscle tissue respectively. In the last month 5 individual fish were analyzed and found to contain 1.15 ± 0.19 μg astaxanthin/g meat. A rough estimation based on feed supply and fish production, indicated that 6—8 % of the astaxanthin supplied with the feed was deposited in the meat.

The vitamin study indicates that the NRC-recommendations as to the vitamin requirement for salmonoid fishes are too high. For Atlantic salmon *(Salmo salar)* no special requirements studies have been carried out, and such studies are important in relation to economic feed compositions. Most studies so far have been carried out for freshwater rearing, but studies in salt water environment could be more adequate.

The low utilization of astaxanthin in the feed shows a need for studies of this problem. Any improvement in the dietary utilization is a direct contibution to the economy of salmon and trout farming.

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