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Replacement of Fishmeal by Krillmeal in experimental diets for rainbow trout

by

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Abstract

In two experiments it could be demonstrated that the fish meal in the control diets could successfully be replaced completely by krill meal in test diets for rainbow trout.

A. Introduction

Continuing previous investigations on the "development of optimal feeds for rainbow trout" and within a current program on "Replacement of fish meal by unconventional and waste proteins"- both projects financed by the Federal Ministry for Research and Technologie - first experiments to replace fish meal by krill meal have been undertaken. Full krill meal from the Antartic Expedition 1975/76 of the Federal Republic of Germany (4) has been used in these experiments.

B. Material and methods

The set up of the experiments and the evaluation of the data are reported according to the recommendations of the ICES-Working Group on Mariculture (1). Two experiments were carried out. In 1975, in experiment A, in which rainbow trouts were kept in cages, a control diet containing 35 % of fish meal, 15 % of hydrolized feather meal and 20 % of poultry by-product meal was compared with a test ratio, in which the fish meal was replaced by krill meal. In 1976, in an aquarium experiment B a ratio, in which the protein was totally supplied by krill meal (full krill meal ratio), was tested against a full fish meal ratio. The nutrient analysis for the krill meal is given in Table 1.

1. Description of experimental design

The cage experiment has been carried in the coastal water of the western Baltic within a harbour area in the experimental station "Eckernförde" (5). Each cage measuring 1.9 x 3.9 x 2.0 m (in water) was stocked with 96 rainbow trouts, which were equally distributed to the cages and had an average length of 22.2 cm $\pm$ 2.7 cm and an average weight of 129 g. 4 resp. 3 replicates were made. The fish were purchased from a commercial trout farm, which was supposed to be free from diseases. No prophylactic or acute medical treatment was applied in the farm or in any phase of the experiment itself. Salinity (12-18^{o}/oo) and temperature changed with season.

During the experimental period from 5 August to 11 November the surface temperature increased within 11 days from 15.8°C to 20.4°C and then gradually decreased down to 7.6°C at the end of the period.
The oxygen content was relatively constant and fluctuated little around the average of 8.7 mg/litre.

The aquarium experiment was carried out from 10 January to 25 April with smaller fish of 9-10 cm and 10.2 g initial average length and average weight respectively. These rainbow trout fingerlings originated from another commercial farm, to be known as disease free. No diseases were observed during the course of the experiment. Both test diets were used in two replicates. Each aquarium measured 44 x 67 x 30 cm and was stocked with 37 fish. The water supply of each aquarium amounted to 2.2 litres per minute, the water being recycled over gravel filter, but 30 % of the water flowing into the aquarium was added from the city water supply. The temperature was measured twice a day and fluctuated between 9.6 and 12.1°C only during the course of the experiment. The oxygen content was high with extreme values for weekly averages of 8.1 and 10.3 mg O_2/litre.

2. Feeding and controls

In both experiments the fish were fed by hand twice a day and six times a week. The ration fed was adjusted daily to the growth of the fish. In the cage experiment the amount of 2 % feed of body weight per day was calculated daily assuming a conversion rate (pelleted feed per wet weight gain) of 1.8 for the first period. For the second part of the experiment the daily feeding rate was reduced due to lower water temperatures and was adjusted to a conversion rate of 1.5 according to the previous control results. In the aquarium experiment the daily feeding rate was kept constant near 2 % of body weight per day. If necessary, the food quantity was daily adjusted to the actual number of fish, whenever losses occured.

The cage experiment lasted 105 days, a control was carried out after 49 days. At the start, at the control and the end of the experiment each set of fish was weighed in total, taking this weight for calculating growth rate, weight gain and conversion rate. In addition all fish were measured on cm-below for the total length at the start and at the end. At the end of the experiment 30 fish per cage were measured and weighed individually. Ten fish per ratio were taken at the end of the experiment for a sensoric test of unspiced, steamed filets, which were compared with fish grown on commercial feeds in the saltwater of the Baltic coast and in a freshwater trout farm. 5 trouts per ratio were examined for macroscopic appearance of internal organs. 8 to 9 fish per ratio were used for chemical analysis at both the beginning and the end of the experiment.

A similar procedure was applied in the aquarium experiment, i.e. registration of total weight of each group at each of the controls including start and end, individual length measurements at start and end, weekly controls during the 15 weeks' period of the experiment.

3. Formulation and composition of test diets

The tested diets used differed only in the exchange of fish meal by krill meal (Table 2). In both experiments the krill meal diets were slightly less in the crude protein content, but due to the higher fat content of the krill meal the energy level was higher in the krill-diets (Table 3).

C. Results

1. Growth and feed conversion

In the cage experiment in which the 50 % crude protein from fish meal was replaced by krill meal, the krill meal group was at a rate of 7 % significantly superior (Table 4). The improved growth and conversion rate could be demonstrated for both control-periods (days 1 - 49 resp. 50 - 105) and is likely to be related to the 4.7 % higher energy level (Table 4).

In the aquarium experiment the small fingerlings with a starting weight of 10.2 g grew slower within the first weeks because of a slightly worse feed conversion. Within the course of the experiment, however, the krill groups improved and after a few weeks they turned to better growth and feed conversion rates than the fish meal groups. The cumulated data for the 15 weeks -period were equal in weight gain (42g) and feed conversion (1.00)(Table 5). It is possible that for the small sized fish of the first weeks the higher content of crude fibre in the krill meal diet (5.4 against 2.0 %) had a negative effect.

2. Utilization of nutrients and energy

The calculation of the utilization of nutrients is based on the comparision of the amount of nutrients fed with the gain in nutrients of the fish from beginning to the end of experiment. Nutrient analyses have been carried out for the feed (Table 2) and the fish at the beginning and the end of the experiment (Table 6) for the cage experiments only.
PER (Protein Efficiency Ratio) and PPV (Productive Protein Value) were at a rate of 10% superior for the krill diet (Table 7).
The values for metabolizable energy per weight gain and for energy retention by energy in-take were slightly better for the control diet; however, it has to be mentioned that data for metabolizable energy are based on calculated and not experimentally proved figures.

For the aquarium experiment these utilization data could not be evaluated, but they can soon be added when results of corresponding cage experiments, in which the full krill meal ratio is on the way to be tested, will be available.

3. Internal organs and sensoric test

Internal organs were inspected only in the fish from the cage - experiment, in which a 50 % krill meal diet has been fed. No significant difference was visible from the macroscopic view of the organs. Both groups showed normal gills of dark red colour.

In both groups the livers of the fish were slighly paler than normal and the intestins heavily fattened. The krill fish were strikingly more intensively coloured, with pink to reddish glances at the sides of the body, red components in the colour of the pectoral and pelvic fins and with typically pinkish coloured flesh. An organoleptic test gave equal findings for both groups. The krill fish were regarded to be of excellent quality, concerning colour, taste, smell and consistence.

D. Reference

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Table 1: Analysis of krill meal

Crude nutrients (%)

Crude protein	56.2
Crude fat	9.2
Crude fibre	5.7
Crude ash	15.9
Water	8.8
Calcium	4.00
Phosphorus	2.08

Amino acid pattern (g/16 N)

Lysine	5.9	Leucine	6.5
Methionine	3.4	Tyrosine	2.7
Cysteine	1.1	Histidine	1.3
Phenylalanine	3.8	Arginine	4.9
Threonine	3.6	Asparagic acid	9.4
Glycine	4.3	Serine	4.0
Valine	4.5	Glutamineic acid	11.6
Isoleucine	4.4	Alanine	4.7

Carotinoid conc. 35 ppm

Table 2: Formulation of test feeds

	Experiment A		Experiment B	
	Control diet	Test diet	Control diet	Test diet
Peru fish meal	35.0	--	70	--
Hydrolized feather meal	15.0	15.0	--	--
Poultry by-product meal	20.0	20.0	--	--
Krill meal	--	35.0	--	70.0
Fish oil	7.0	7.0	7.0	7.0
Precooked wheat starch	22.1	22.1	22.1	22.1
Vit. Premix[1)]	0.6	0.6	0.6	0.6
Ca-propionate	0.3	0.3	0.3	0.3

1) Vitamin Premix on soy bean meal contains (per kg final mixture):

Vit. A	32 000 I.U.	Vit. B_{12}	60 mcg
Vit. D_3	4 000 I.U.	Biotine	200 mcg
Vit. E	100 mg	Folic acid	400 mcg
Vit. K_3	2.6 mg	Ca-pantothenate	40 mg
Thiamine	10 mg	Nicotinic acid	100 mg
Riboflavine	12 mg	Ascorbic acid	160 mg
Pyridoxine	6 mg	Choline chlorid	560 mg

Table 3: Crude nutrient analysis of diets

	Experiment A		Experiment B	
	Control diet	Test diet	Control diet	Test diet
Crude protein	49.8	47.4	42.8	41.8
Crude fat	12.5	15.6	11.8	13.0
Carbohydrates(NFE)	n.d.[1)]	n.d.	21.6	22.4
Crude fibre	n.d.	n.d.	2.0	5.4
Crude ash	9.6	7.9	16.2	11.3
Water	8.0	8.3	5.6	6.1
Kcal(J) ME[2)]	3,479(14,550)	3,644(15,240)	3,390(14,180)	3,480(14,550)
Calcium	2.05	1.31	4.52	2.68
Phosphorus	1.39	1.09	2.30	1.48
Magnesium	0.09	0.22	n.d.	n.d.
Sodium	0.58	0.35	n.d.	n.d.
Potassium	0.33	0.30	n.d.	n.d.

1) n.d. = not determined

2) calculated metabolizable energy per kg

Table 4: Growth and feed conversion of trout fed with a 50 % fish meal control diet resp. a 50 % krill meal test diet.(Experiment A).

	Control diet	Test diet
Protein compounds		
Fish meal	+	-
Poultry by-product and feather meal	+	+
Krill meal	-	+
number of replicates	4	3
initial average weight (g)	130	129
weight gain		
day 1- 49	116	122
day 50-105	141	153
total period[1)]	257	275
relative values	100	107
feed conversion (g feed/g weight gain)		
day 1- 49	1.11	1.06
day 50-105	1.22	1.12
total period 1)	1.17	1.09
relative values	100	93

1) significantly different ($1\% < P < 2\%$); according to Wilcoxson-Mann-Whitney U-test applied after Kruskal-Wallis H-test.

Table 5: Cumulated growth and feed conversion of trout fed with a 100 % fish meal control diet resp. a 100 % krill meal test diet (weight of the fish was 10.24 g resp. 10.19 g). (Experiment B).

week	Fish meal groups		Krill meal groups	
	weight gain (g)	feed conversion (feed/gain)	weight gain (g)	feed conversion (feed/gain)
1	0.86	0.86	0.72	1.04
2	2.67	0.83	2.36	0.93
3	4.46	0.84	3.96	0.94
4	6.41	0.85	5.74	0.95
5	7.95	0.90	7.11	1.01
6	10.50	0.88	9.44	0.98
7	12.90	0.91	11.97	0.98
8	15.58	0.93	14.80	0.98
9	18.56	0.94	17.80	0.98
10	21.78	0.96	21.15	0.99
11	25.53	0.97	25.06	0.99
12	29.06	0.98	28.70	0.99
13	35.04	0.95	34.67	0.95
14	37.31	0.99	37.31	0.98
15	42.03	1.00	41.49	1.00

Table 6: Body composition of fish from Experiment A at the beginning and at the end of the experiment

	Start of experiment	End of experiment	
		Fish meal groups	Krill meal groups
average weight (g)	116	341.0 ± 70.0	370.9 ± 112.7
n	10	8	9
dry matter (%)	22.5	33.0 ± 3.9	33.0 ± 0.8
in % of dry matter			
Crude protein	73.6 ± 4.0	51.8 ± 3.7	50.9 ± 2.6
Crude fat	9.3 ± 4.1	39.9 ± 3.6	39.5 ± 3.4
Ash	12.1 ± 1.6	6.8 ± 0.5	6.5 ± 0.4
Calcium	2.69 ± 0.42	1.07 ± 0.16	1.08 ± 0.14
Phosphorus	2.33 ± 0.28	1.23 ± 0.20	1.16 ± 0.05
Magnesium	0.14 ± 0.10	0.08 ± 0.01	0.08 ± 0.01
Sodium	0.41 ± 0.06	0.22 ± 0.03	0.21 ± 0.01
Potassium	1.24 ± 0.44	0.79 ± 0.06	0.80 ± 0.04

Table 7: Nutrient and energy utilization, Experiment A (calculated by data from Tables 3 and 6)

		Fish meal groups	Krill meal groups
Fish beginning of experiment			
total weight	(g)	49,920	37,158
	n	384	288
total dry matter	(g)	11,232	8,361
Protein	(g)	8,267	6,153
total N	(g)	1,323	985
total energy	(kcal (J))	57,043 (238,530)	42,461(177,550)
Fish end of experiment			
total weight	(g)	148,681	115,976
	n	384	287
weight losses	(g)	-	84
final weight plus weight losses	(g)	148,681	116,060
dry matter (total)	(g)	49,065	38,300
Protein	(g)	25,416	19,495
total N	(g)	4,066	3,119
total energy	(kcal (J))	330,849 (1,383,450)	254,839 (1,065,610)
Food			
total feed fed	(g)	115,419	86,303
total protein fed	(g)	57,479	40,908
total N fed	(g)	9,197	6,545
total metabolizable energy	(kcal (J))	401,543	314,480
total gross energy	(kcal (J))	551,703 (2,306,950)	418,570 (1,750,250)
Utilization			
PER (g weight gain per protein intake)		1.72	1.93
PPV ($\frac{\text{N gain}}{\text{N intake}}$ x 100)		29.8	32.6
gross energy utilization ($\frac{\text{energy increase}}{\text{energy intake}}$ x 100)		50	51
net energy (kcal (J)/kg feed))		2,372 (9,920)	2,461 (10,290)