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Comparison of Cadmium Concentrations in Atlantic Salmon (*Salmo salar*) Fry Fed Different Commercial Feeds

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There has been a tremendous growth of the Norwegian fish farming industry from a production of 7,500 tons of Atlantic salmon (Salmo salar) and rainbow trout (Salmo gairdneri) in 1980 to a production of about 90,000 tonnes (mostly salmon) in 1988. The great economic value of this production has also led to interest in any toxic substance that could possibly reduce fish growth and/or impair fish health.

Cadmium is known to be an acute toxic trace element with well known adverse effects on mammals (Samarawickrama 1979) and on freshwater fish (Sprague 1987). Sublethal effects of cadmium to salmonid fish exposed through water have also been elucidated (Haux and Larsson 1984). It has been shown that salmonids can synthesize a metal-binding protein, metallothionein, as a response to sublethal effects of cadmium (Olsson et al. 1989).

Data on effects and relative amount of dietary cadmium in fish are scarce. Although dietary contribution is regarded as the major route of many toxic elements to fish both in the field (Dallinger and Krautzky 1985) and in laboratory experiments (Harrison and Klaverkamp 1989), little is known about dietary heavy metal levels that may cause adverse effects. If fish feeds are contaminated with heavy metals, this could also be a diffuse source of pollution of heavy metals to the marine environment.

In this study the concentration of cadmium in four commercial feeds for salmon fry and the cadmium concentration in the growing fry fed these diets were studied.

MATERIALS AND METHODS

Nearly two million "swim up" salmon fry were distributed into 24 circular tanks, with about 80,000 fish in each, in a commercial hatchery. The tanks were located in two different production halls, 12 in each, under constant light. Frequent water analyses carried out by commercial laboratories showed pH: 6.0-6.6; Ca: 1.5-1.8 mg/L; Mg: 0.37-0.51 mg/L; Zn: 10 μg/L; Cu: 3 μg/L; and Cd: 0.38 μg/L.

Four different commercial starter feeds with small grain size (no.1) were used.Each feed was fed in six replicate tanks, three in each production hall. The fish were fed ad libitum. Fifty fish were randomly caught for mean weight measurements each week. This was repeated 2-4 times in each tank.
After four weeks four fish from each tank were randomly caught, weighed, and prepared for carcass element analyses.

Proximate composition of diets was determined by standard procedures at our Institute (Maage et al. 1989). Samples for element analyses were digested overnight in 2 ml (9 :1) $HNO_3/HClO_4$, boiled under pressure for 2 hours and diluted to 10 ml. The content of calcium, iron, copper and zinc were determined by flame atomic absorption (Perkin Elmer 3030 AAS) and cadmium was analyzed by graphite furnace atomic absorption spectrophotometry (Perkin Elmer 5000 AAS provided with a Perkin Elmer 500 Furnace).

Statistical analyses were performed by means of Student's t-test and correlation analysis using a Luxor 806 computer equipped with an IDA 800 statistical program.

Table 1. The proximate and element content of four commercial salmon diets fed to salmon fry.

	Diet			
	A	B	C	D
Major components (g/kg):				
Fat	158	175	153	165
Protein	528	531	510	550
Ash	92	89	120	83
Carbohydrate (by difference)	222	205	217	202
Elements (mg/kg):				
Ca	16,100±1000	16,100±900	25,200±600	14,000±400
Zn	201± 4	197±10	211±18	292±26
Fe	65± 4	51± 4	107± 7	105± 8
Cu	4.8±0.1	3.3±0.1	5.4±0.9	17.0±0.9
Cd	0.11±0.01	0.09±0.01	0.13±0.01	0.57±0.05

RESULTS AND DISCUSSION

The composition of the four commercial starter feeds are shown in Table 1. The levels of the essential elements calcium, zinc, iron and copper in the diets are discussed elsewhere (Maage et al. 1989).
The levelst of fat, protein and carbohydrate were nearly similar in the four feeds, but the high ash content in diet C is noteworthy.

The cadmium level between 0.09 and 0.13 mg/kg in diets A, B and C is what is expected in feeds based on fish meal as protein source. A similiar level was also found in a practical fish-meal based salmon diet made at our laboratory (Maage et al. unpublished).
The concentration of 0.57 mg Cd/kg dry feed found in diet D is, on the other hand, rather high.

The feed conversion factor provides the amount in kg of dry feed needed to produce 1 kg of fish. A feed conversion factor of 1.5 is commonly used when evaluating the environmental impact of aquaculture (Håkanson et al. 1988). The production of salmonid fish in Norway is estimated to be about 140,000 tons in 1989. Given a feed conversion factor of 1.5, the feed with the highest concentration of cadmium would give a flow of cadmium of 119.7 kg through salmonid feeds. The feed with the lowest cadmium concentration would give a flow of only 18.9 kg cadmium.

The weight of the fry was 0.17 g at the start of the experiment. At the end of the experiment the weight was more than doubled in all groups. The final weights are shown in Table 2. The term day-degrees refers to the actual water temperature in the tanks of each of

Table 2. Final weights of salmon fry fed four different commercial diets (in brackets the numbers of weighings, each representing fifty fry)

Day-degrees	Diet A	Diet B	Diet C	Diet D
	Hall 1			
804	0.398±0.06 (12)^{ab} 1)	0.432±0.07 (10)	0.466±0.09 (11)^{a}	0.475±0.05 (11)^{b}
	Hall 2			
750	0.376±0.03 (12)^{abc}	0.423±0.04 (12)^{ad}	0.494±0.04 (12)^{bde}	0.445±0.07 (12)^{ce}

1) Common superscript letters in one line indicate significant differences ($p<0.05$).

the production halls multiplied by the number of days of feeding. Fish fed diets C and D grew best in both production halls. These results show that the level of 0.57 mg Cd/kg feed found in diet D did not retard the growth of the salmon fry. It should be noted that growth, although economically important, is not a good indicator of adverse effects of cadmium in growing cultured fish (Papoutsoglou and Abel 1988).

On an individual basis there was found a significant, positive correlation between the dietary cadmium level and the carcass cadmium concentration (r=0.46, N=94), showing a diet-dependent cadmium concentration in the fry. The mean concentrations of cadmium in the fry varied between 26 and 38 μg/kg as shown in Table 3. These values are about one tenth of the values reported by Yamamoto and Inoue (1985) in rainbow trout which died from high cadmium exposure through water.

The levels of cadmium in the fry fed diets A and D showed significantly higher cadmium concentrations than fry fed diets B and C. Absorption and retention of cadmium has been shown to differ with different dietary sources of cadmium in rats (Maage and Julshamn 1987).

In this experiment it was more likely that other dietary factors influenced cadmium absorption by the fish. In fish exposed to cadmium in water it has been shown that toxicity of cadmium is dependent on the calcium concentration (Nakagawa and Ishio 1989). The same effect could be the cause of the low carcass cadmium concentration in fry fed diet C which contained the highest calcium concentration. The higher cadmium concentration in fry fed diet A and B compared to C, in spite of lower dietary cadmium concentration, could also have have been a result of the rather low iron concentration in these feeds. Such effects have been reported in iron deficient mice and humans (Flanagan et al. 1978)

Table 3. The concentration of cadmium in Atlantic salmon fry fed four different commercial diets for four weeks.

	Diet			
	A (n=24)	B (n=23)	C (n=24)	D (n=24)
Cd (μg/kg)	35 ± 6^{ab} 1)	28 ± 7^{ac}	27 ± 4^{bd}	38 ± 6^{cd}

1) Common superscript letters indicate significant differences (p<0.01).

There were no significant correlations found between the weight of the growing fry and carcass cadmium concentrations in the fry in any of the four dietary regimes. Thus, at the natural water cadmium concentration and the given dietary cadmium concentrations in the feeds there was no increase in the whole body cadmium concentration in the fry as the fry grew.

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