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Chemical Composition of the Flesh and Other Tissues of Antarctic Fish Species of the Families Channichthyidae and Nototheniidae

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ABSTRACT

The muscle, intestinal tract, stomach, spleen, heart, pyloric caeca, gonads and liver of four Antarctic fish species, Notothenia neglecta, Notothenia gibberifrons, Chaenocephalus aceratus *and* Champsocephalus gunnari, *were analysed for moisture, crude protein, carbohydrate, fat, ash, chloride and phosphorus.*

The chemical composition of the flesh of the fish showed that all four species are valuable food fishes with a high protein (17–19%) and a low to moderate fat content (0·8–1·9%).

In all fishes investigated high amounts of trimethylamine oxide-nitrogen were present. Levels of trimethylamine-nitrogen were substantially higher (5 mg/100 g) and that of dimethylamine-nitrogen lower (0·05 mg/100 g) than in North Atlantic fish, while the ammonia-nitrogen content was comparable (10 mg/100 g). During distillation only nototheniids underwent deamination reactions leading to high TVB-N values, ice-fishes were unaffected.

N. neglecta *and* N. gibberifrons *were found to store considerable amounts of carbohydrates and fat in their livers (4·6% and 8·2% carbohydrates and 16·3% and 14·4% fat, respectively),* Ch. gunnari *accumulates fat in intestinal tract, spleen and pyloric caeca. The stomachs of all fishes had high chloride levels.*

The livers of Chaenocephalus aceratus *were heavily infested (up to 20 wt%) by the parasitic nematode* Contracaecum *spec.*

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INTRODUCTION

Since 1969 finfish of the families Channichthyidae (commonly referred to as ice-fishes) and Nototheniidae (Antarctic cods) have been caught commercially in the Antarctic Atlantic mainly by Soviet trawlers. The fish species are affected by the fisheries and the stock sizes are presently much lower than before the fishery started (Kock & Köster, 1989).

Some Antarctic fish species are valuable food fish of excellent taste and can be stored in the deep frozen state for years with minimal loss in quality (Manthey & Oehlenschläger, 1983; Manthey *et al.*, 1990).

The chemical composition of the flesh and of various tissues of the Antarctic fish *Notothenia rossii marmorata* was published in 1982 (Oehlenschläger & Rehbein); complete data on the chemical composition of fish muscle and internal organs of other species are still lacking.

During the Third Antarctic Expedition of the Federal Republic of Germany (1981) with FRV *Walther Herwig* (Anon., 1982) Antarctic fish were fished off Elephant Island from 17–20 March for scientific purposes only and numerous samples of four Antarctic fish species were collected for subsequent chemical analysis. The fillets and various organs of *Chaenocephalus aceratus*, *Champsocephalus gunnari* (Channichthyidae), *Notothenia*

TABLE 1
General Data on the Fish Investigated. (Number of specimens; date, position and depth of catch; arithmetic mean, standard deviation (SD) and range of weight and length)

Species	*N. neglecta*	*N. gibberifrons*	*Ch. aceratus*	*Ch. gunnari*
n	3	13	10	3
Date	March 18	March 17	March 17, 18	March 18
Position	60°51′ S/ 55°33·4′ W	60°51′ S/ 55°33·3′ W	61°02·5′ S/ 55°54·6′ W 61°06′ S/ 55°54·6′ W	61°06′ S/ 55°54·6′ W
Depth (m)	290	76	132, 120	120
Weight (g)				
Mean	570	596	899	693
SD	168	92	189	107
Range	380–700	440–750	580–1 130	600–810
Total length (cm)				
Mean	31·7	37·7	49·7	43·7
SD	5·1	1·7	3·4	1·5
Range	26–33	36–40	44–46	42–45

neglecta and *Notothenia gibberifrons* (Nototheniidae) were analysed for proximate composition, phosphorus, chloride and some aliphatic amines commonly used as spoilage indicators.

MATERIALS AND METHODS

Antarctic fish specimens

Antarctic fish species were caught by the FRV *Walther Herwig* during the second leg (8–26 March, 1981) of the Third Antarctic Expedition (1981) of the Federal Republic of Germany. The fish caught by bottom trawling were randomly collected from the scientific hauls; samples were prepared and stored as described earlier (Oehlenschläger & Rehbein, 1982). Fish organs were weighed separately and pooled prior to analysis because the single organs did not yield enough material for analytical purposes with the exception of gonads which were analysed individually. General data of the fish are given in Table 1, while Table 2 contains information about the organ tissues of the same fish.

Chemical analysis

Dry matter (and, by difference, moisture), ash, crude protein, carbohydrates, phosphorus and chloride were determined as described by Oehlenschläger & Rehbein (1982).

Total lipid content was evaluated using a modification (Oehlenschläger, 1986) of the Bligh & Dyer (1959) method.

Total volatile basic nitrogen (TVB-N), dimethylamine (DMA), trimethylamine (TMA), trimethylamine oxide (TMAO) and ammonia were estimated using the procedures of Rehbein & Oehlenschläger (1982).

RESULTS AND DISCUSSION

The individual organs of fish species investigated differed in weight between species. The intestinal tracts of *Ch. aceratus* are heavier than those of the other species. This can be explained by the fact that this species deposits fat in the intestines as shown by its high fat content (see Table 5 below). The weight of whole fish differ only a little (Table 1) but the emptied stomach of *Ch. aceratus* has 4-fold the weight of other species' stomachs.

TABLE 2
Weight (g) (arithmetic mean, standard error(s) and range) of Antarctic Fish Tissues Analysed and Sex (for gonads only). (The fish investigated correspond to the data given in Table 1)

Species	*N. neglecta*	*N. gibberifrons*	*Ch. aceratus*	*Ch. gunnari*
Tissue				
Intestinal tract:				
Mean	8·8	10·1	14·5	5·4
s	—	1·5	2·5	—
Range	—	7·7–12·2	12·8–21·0	—
Stomach:				
Mean	11·4	10·4	37·5	8·9
s	—	2·0	14·9	—
Range	—	6·8–14·8	29·4–74·1	—
Heart:				
Mean	1·0	0·53	2·7	2·4
s	0·3	0·16	0·6	0·6
Range	0·6–1·3	0·27–0·74	1·9–3·6	2·0–3·2
Spleen:				
Mean	1·6	0·83	3·3	0·6
s	0·9	0·16	1·5	0·2
Range	1·1–2·6	0·53–1·04	2·1–5·9	0·4–0·8
Pyloric caeca:				
Mean	9·0	5·2	4·1	4·1
s	4·9	1·1	1·1	1·1
Range	5·0–14·5	3·38–7·15	2·0–5·5	2·8–4·7
Liver:				
Mean	15·6	15·7	33·6	27·3
s	5·1	5·2	7·6	12·9
Range	11·3–21·3	7·02–23·48	25·5–46·4	12·5–35·6
Gonads:				
Mean	40·6	10·9	7·5	55·1
s	12·8	6·3	4·5	39·0
Range	25·9–49·0	2·73–21·08	2·7–16·2	10·2–80·8
Sex	Male	11 Female	7 Female	3 Female

The hearts of the two ice-fishes were bigger than the hearts of the nototheniids (3- to 4-fold) as were the livers (2-fold). The size of the livers cannot be explained by its function of storing lipids. From Table 5 (see below) it is evident that ice-fishes store mostly carbohydrates (glycogen) in this organ while the nototheniids use it as a fat depot.

The proximate composition of the fish muscle (Table 3) makes it evident that these fish species are valuable food fishes with a high content of crude

TABLE 3

Contents of Crude Protein (N × 6·25), Moisture, Fat, Ash, Phosphorus and Sodium Chloride in Edible Parts (fillets) of Antarctic Fish Species. (Data in wt% on a fresh weight basis, arithmetic mean (standard error) and range (below))

Species	*N. neglecta*	*N. gibberifrons*	*Ch. aceratus*	*Ch. gunnari*
Crude protein	19·1 (1·0) 17·9–19·8	18·5 (0·4) 18·0–19·1	17·3 (0·8) 15·9–18·1	17·0 (0·6) 16·9–17·5
Moisture	78·4 (1·0) 77·8–79·6	79·8 (0·4) 79·0–80·3	81·2 (0·8) 80·1–82·7	81·0 (0·4) 80·6–81·4
Fat	1·9 (0·7) 1·2–2·5	0·8 (0·2) 0·5–1·2	0·9 (0·1) 0·8–1·1	1·5 (0·07) 1·4–1·6
Ash	1·4 (0·07) 1·3–1·4	1·3 (0·1) 1·2–1·5	1·2 (0·03) 1·1–1·2	1·2 (0·01) 1·2–1·3
Phosphorus	0·13 (0·01) 0·12–0·14	0·11 (0·02) 0·14–0·24	0·1 (0·01) 0·1–0·12	0·12 (0·01) 0·11–0·12
NaCl	0·15 (0·02) 0·14–0·17	0·18 (0·04) 0·14–0·24	0·15 (0·03) 0·11–0·20	0·12 (0·02) 0·11–0·14

protein and a low to moderate fat content. The crude protein content is similar to that found in *N. rossii marmorata* but the fat content is lower (average 4% in *N. rossii marmorata*) (Oehlenschläger & Rehbein, 1982). The range of moisture content is very narrow, varying between 78% and 83% in all species investigated. The proximate composition resembles that of food fishes as consumed in the northern hemisphere (Sidwell, 1981; Souci *et al.*, 1989). The phosphorus and the sodium chloride contents in the edible part are (with approx. 120 mg P/100 g and 150 mg NaCl/100 g) lower than found in North Atlantic fishes which have an average content of 200 mg P/100 g and >300 mg NaCl/100 g, respectively.

All four species showed a high amount of trimethylamine oxide-nitrogen (Table 4). The trimethylamine-nitrogen levels in the Antarctic species are generally higher than reported for North Atlantic fish species which contain approx. 2 mg TMA-N/100 g if freshly caught. The dimethylamine-nitrogen content, on the other hand, is lower (0·04 mg/100 g) than in Northern species (0·1–0·2 mg/100 g).

Ammonia-nitrogen levels in Antarctic fishes equal that of North Atlantic fish species having a mean content of 10 mg/100 g (Oehlenschläger, 1989). The total volatile nitrogen content determined by the direct distillation method in nototheniids differs from that in ice-fishes. In the latter the TVB-N content is as high as the sum of the individual amines (ammonia-N, DMA-N and TMA-N), in nototheniids (e.g. *N. neglecta*); the TVB-N far exceeds

TABLE 4

Contents of Trimethylamine Oxide-, Trimethylamine-, Dimethylamine-, Ammonia- and TVB-Nitrogen in Edible Parts (fillets) of Antarctic Fish Species. (Values in mg nitrogen/100 g fresh weight, mean (standard error) and range (below))

Species	*N. neglecta*	*N. gibberifrons*	*Ch. aceratus*	*Ch. gunnari*
TMAO-N	136 (0)	111 (7)	149 (14)	132 (17)
	—	105–121	118–166	113–143
TMA-N	3·0 (0)	4·5 (0·2)	7·0 (2·5)	4·4 (1·4)
	—	4·3–4·8	3·3–12·4	2·8–5·4
DMA-N	0·05 (0)	0·03 (0·01)	0·06 (0·02)	0·06 (0·03)
	—	0·01–0·04	0·05–0·08	0·04–0·09
Ammonia-N	10·2 (0)	11·2 (0·7)	9·7 (0·6)	12·5 (0·7)
		10·0–11·9	8·4–10·9	11·9–13·3
TVB-N	27·1 (1·6)	22·4 (3·8)	17·9 (1·5)	17·7 (1·6)
	25·2–28·0	16·8–30·8	16·8–19·6	16·8–19·6

this sum, indicating that deamination reactions occur during the distillation process.

The chemical composition of the various organ tissues, as given in Table 5, leads to the following conclusions:

—The crude protein content (with the exceptions of gonads) in organ tissues is lower than the content in fish muscle. In contrast to this, in *N. rossii marmorata* the highest content of crude protein was found in the stomach (Oehlenschläger & Rehbein, 1982).

—High amounts of fat are stored in the intestinal tract, the spleen and the pyloric caeca of *Ch. gunnari*, indicating that this species stores fat in its intestines, while *N. neglecta* and *N. gibberifrons* exhibit high fat contents in their livers, showing that, in these species, the liver acts as the main fat accumulating organ. In another Antarctic species, *N. rossii marmorata*, fat was stored in the intestinal tract and pyloric caeca but in liver as well (Oehlenschläger & Rehbein, 1982).

—The stomachs of all four species exhibit a sodium chloride content (approx. 1%) which exceeds that of muscle tissue five-fold. This high chloride level is necessary for maintaining the hydrochloric acid production in stomachs.

—Considerable amounts of carbohydrates were stored in the livers of all species.

—Liver and pyloric caeca are richest in minerals (ash content).

—Due to the different stages of maturity in the fishes investigated the

TABLE 5

Proximate Composition and Sodium Chloride Content in Various Organ Tissues of Antarctic Fish Species. (All values in wt% on a fresh weight basis. In liver tissues carbohydrates (carb.) were also estimated.)

	Moisture	*Crude protein*	*Fat*	*Ash*	*NaCl*	*Carb.*
Intestinal tract:						
N. neglecta	77·8	15·1	3·9	1·7	—	—
N. gibberifrons	74·8	12·8	8·4	2·4	—	—
Ch. aceratus	77·6	12·1	8·0	1·5	—	—
Ch. gunnari	68·3	12·9	17·2	0·7	—	—
Stomach:						
N. neglecta	79·7	16·0	2·6	1·6	0·9	—
N. gibberifrons	80·1	15·4	2·6	1·7	1·0	—
Ch. aceratus	83·8	11·5	3·1	1·3	0·9	—
Ch. gunnari	80·1	14·6	4·3	1·4	0·9	—
Heart:						
N. neglecta	78·4	17·3	1·8	1·7	—	—
N. gibberifrons	80·5	14·4	2·1	1·3	—	—
Ch. aceratus	80·8	13·2	2·9	1·6	—	—
Ch. gunnari	80·5	14·6	3·5	1·3	—	—
Spleen:						
N. neglecta	77·6	18·6	1·8	1·7	—	—
N. gibberifrons	77·1	16·3	3·9	1·6	—	—
Ch. aceratus	77·8	13·2	6·9	1·3	—	—
Ch. gunnari	73·5	13·5	13·0	1·2	—	—
Pyloric caeca:						
N. neglecta	76·8	15·7	4·7	1·7	—	—
N. gibberifrons	73·5	13·5	9·2	2·2	—	—
Ch. aceratus	78·1	13·5	6·1	1·5	—	—
Ch. gunnari	67·2	14·3	15·3	1·5	—	—
Liver:						
N. neglecta	64·8	15·3	16·3	1·8	—	4·6
N. gibberifrons	64·5	13·4	14·4	2·7	—	8·2
Ch. aceratus	78·0	13·7	4·8	1·4	—	3·6
Ch. gunnari	75·0	17·4	5·6	2·1	—	2·1
Gonads:						
N. neglecta	83·2	14·9	1·3	1·9	—	—
N. gibberifrons	79·0	16·6	2·2	1·7	—	—
Ch. aceratus	84·3	11·4	2·3	1·3	—	—
Ch. gunnari	68·9	23·7	5·0	1·3	—	—

composition of gonads differed widely. An extremely low protein content was found in the gonads of female *Ch. aceratus*, and an extremely high protein content in that of female *Ch. gunnari.* Unfortunately the actual stages of maturity were not determined on board.

The fluoride content of Antarctic fish species was investigated earlier (Oehlenschläger & Manthey, 1982), showing that fluoride is stored in calcified tissue like scales and vertebrae (approx. 1000 mg/kg wet weight), while muscle tissue and internal organs contain this halogen at a level of approx. 3 mg/kg wet weight.

The livers of *Ch. aceratus* were heavily infested with the parasitic nematode *Contracaecum* spec. while that of *Notothenia neglecta* was somewhat less so. Single livers of the ice-fish had a burden of 50–150 nematodes making up to 20% of liver fresh weight. Details are given in Table 6.

TABLE 6
Infestation of Livers of Ten Individuals of *Chaenocephalus aceratus* (Ch1–Ch10) and Three Individuals of *Notothenia neglecta* (N1–N3) with the Nematode *Contracaecum* spec.

	Weight of liver (g)	*Number of nematodes*	*Weight of nematodes (g)*	*Weight (%)*
Sample				
Ch1	30·9	151	6·2	20·1
Ch2	25·5	52	1·5	5·9
Ch3	39·1	115	3·5	9·0
Ch4	26·2	90	3·9	14·9
Ch5	26·4	130	4·7	17·8
Ch6	46·4	111	3·8	8·2
Ch7	41·5	99	3·8	9·2
Ch8	31·0	77	2·7	8·7
Ch9	40·9	116	4·3	10·5
Ch10	29·2	54	1·7	5·8
Mean	33·7	100	3·5	11·0
SD	7·6	32	1·4	4·9
N1	14·5	7	0·3	2·1
N2	22·1	34	0·8	3·6
N3	11·4	3	0·1	0·9
Mean	16·0	15	0·4	2·2
SD	5·5	—	—	1·3

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