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A COMPARISON OF THE AMINO ACID COMPOSITION OF FIFTEEN SPECIES OF WHOLE FISH

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ABSTRACT

With the object of obtaining information on the nutritive value of whole fish as feed for fur animals and in fish farming 47 samples of 15 species of fish were analysed for the amino acid contents. The samples were analysed for nitrogen, ash, TMAO, TMA and total volatile nitrogen and prepared for amino acid analysis by freeze-drying followed by extraction with hexane. In 23 cases both wet samples and hexane extracted dry samples were analysed, establishing that the latter were representative of the whole fish as received. For two species, saithe and blue whiting, both whole and gutted fish were analysed giving quite comparable results. The amino acid contents between species were remarkably similar. The noteworthy exceptions were a high content of glycine in saithe and a high content of histidine in pelagic species, especially in mackerel.

INTRODUCTION

A project on the analysis of nutrients in Norwegian fish species and fish products was sponsored by the Norwegian Council for Fisheries Research for the years 1973-1975. Results were published at intervals in «Fiskets Gang» (UTNE, 1976). The amino acid analyses of 15 species of fish are compiled and discussed in the present paper. Data on the fatty acid composition of the fish lipids were published by LAMBERTSEN (1978) and data on mineral contents by JULSHAMN et al. (1978).

Most samples consisted of whole fish, but in a few cases samples of gutted fish were analysed. Values for whole fish were relevant as the anticipated use of the data was for the evaluation of such fish as feed for fur animals and in fish farming. Amino acid analyses of fish off-fall products have been published previously (NJAA, 1978).

SAMPLES

The samples were obtained during the years 1973-1975 and brought to the institute fresh, frozen or in ice. They were in good condition as indicated by

Table 1. Mean values and standard deviations for ash, TMAO-N, TMA-N and total volative N in the fish species analysed for amino acids.

	Ash (g/kg dry weight)	TMAO-N	TMA-N (mg/100 wet weight)	Total vol. N
Saithe, whole	(3)*112± 3	25.0± 2.0	18.7± 5.7	37.0± 6.6
Saithe, gutted	(3) 146± 5	35.7± 4.6	6.7± 3.2	22.0± 3.5
Blue whiting, whole	(3) 125±16	59.7± 1.5	8.7± 3.5	30.3± 8.1
Blue whiting, gutted	(2) 146± 7	74.7± 2.1	7.5± 3.5	24.5± 9.2
Norway pout	(4) 133±44	35.8± 8.6	8.8± 3.8	34.0± 8.3
Polar cod	(2) 90± 4	72.0± 7.1	29.5± 3.5	48.0± 2.8
Capelin	(4) 73±15	65.3± 7.0	2.0± 1.8	16.5± 3.0
Herring, local stock	(3) 58±10	38.0± 3.2	0.7± 0.5	16.0± 3.6
Herring, North Sea	(3) 70±23	47.6±13.0	2.7± 1.1	16.7± 4.0
Sprat	(3) 95± 7	19.3± 5.5	0.5±0.1	13.3± 3.2
Mackerel	(2) 54±15	18.5± 0.7	2.5±0.7	22.5± 3.5
Horse mackerel	(1) 75	31.0	1.0	16.0
Sandeel	(1) 92	12.0	1.0	29.0
Great Silver Smelt	(3) 89±13	60.0±12.8	9.4± 9.9	27.3±16.6
Müller's pearlsides	(4) 86±24	36.0±11.5	0.6± 0.2	20.8± 2.1
Ballan Wrasse	(2) 161±17	42.0± 2.8	0.6± 0.1	13.5± 0.7
Lumpfish (female)	(2) 144± 6	28.0± 8.5	0.1± 0.0	5.0± 0.0
Lumpfish (male)	(2) 141±48	28.0±12.7	9.6±13.2	6.0± 4.2

* Number of samples analysed.

low values of trimethylamine and high values of trimethylamine oxide (Table 1). The samples were homogenised by several passes through a meat grinder at low temperatures and representative portions were freeze-dried. After drying most of the fat was extracted with hexane and the residue was milled in a Tecator mill. The extracted freeze-dried samples were stored for analysis.

The 1973-samples were also analysed after homogenisation without drying. This was done to establish whether freeze-dried samples were representative of the original fish.

METHODS

Protein (N x 6,25) was determined essentially as described by CROOKE and SIMPSON (1971) after digestion in a Tecator block digestor at above 370°. Ash, TMAO, TMA and volatile N were determined with conventional methods. Amino acids were determined firstly in a Technicon Amino Acid Analyser Model NC-1 and later in a Model NC-2-P. In the former case the samples were hydrolysed with 6M HCl under reflux in a N_2 atmosphere, in the latter

Table 2. Comparison of amino acid analyses on 23 wet and 23 freeze-dried samples of fish. (Means ±-standard deviations).

	Wet samples	Freeze dried samples	
	g/kg protein		
Aspartic acid	93.0± 6.4	96.3± 7.6	($p<0.05$)
Threonine	42.4± 2.6	44.6± 3.5	
Serine	44.3± 4.0	44.8± 5.7	
Glutamic acid	130.9± 9.1	131.7± 7.5	
Proline	41.6± 5.1	42.2± 5.8	
Glycine	66.4±10.0	64.9±10.6	
Alanine	60.8± 4.0	60.8± 2.5	
Valine	47.8± 1.9	47.7± 3.1	
Cystine (n=20)	6.4± 2.0	7.1± 1.3	($p<0.01$)
Methionine	29.8± 4.4	28.1± 3.6	
Isoleucine	42.0± 2.1	41.7± 1.7	
Leucine	72.7± 3.0	72.8± 3.4	
Tyrosine	33.8± 2.4	33.0± 2.1	
Phenylalanine (n=22)	38.1± 2.2	38.6± 1.7	
Lysine	89.3± 8.7	88.3± 5.9	
Histidine	22.1± 3.6	21.3± 3.2	
Arginine	62.7± 4.3	60.8± 5.9	

case with 6M HC1 in closed screw cap test tubes with $TiCl_3$ added to protect methionine (MOORHOUSE et al., 1976). However, the methionine analyses were erratic, and the tables therefore contain further values obtained colorimetrically by the metod described by NJAA (1980) for total methionine.

RESULTS

Comparisons of results obtained on wet samples and on samples after freeze-drying and fat extraction are given in table 2. Most differences were small and insignificant, only aspartic acid ($p<0.05$) and cystine ($p<0.01$) showed values slightly higher in the freeze-dried samples. In our hands values for these amino acids tend to vary between analyses of the same sample at different times. We therefore concluded that analyses of extracted freeze-dried samples were representative for the original samples and in the two later years only extracted dry samples were used for analysis. The amino acid composition for four species of the Gadidae family are given in table 3. The samples of saithe and blue whiting were analysed whole and gutted. For practically all

Table 3. Amino acid contents (g/kg protein) in four species of cod fishes, (Gadidae).

	Saithe		Blue whiting		Norway pout	Polar cod
	Whole	Gutted	Whole	Gutted	Whole	Whole
	(3)*	(3)	(3)	(2)	(4)	(2)
Aspartic acid	100.3±1.7	93.7±2.3	96.7±2.1	93.5±2.1	105.2±11.9	89.0±0.0
Threonine	45.0±1.0	43.0±1.0	41.3±0.6	47.5±9.2	47.5± 4.0	50.0±4.2
Serine	48.7±1.5	46.0±1.0	44.7±5.7	33.0±9.9	45.0± 3.7	48.0±1.4
Glutamic acid	139.0±8.5	135.7±2.1	103.3±4.2	127.0±2.8	138.7± 8.4	113.5±9.2
Proline	44.3±5.5	45.7±1.5	38.0±3.0	38.0±4.2	40.7± 3.0	39
Glyçine	75.3±4.2	73.3±1.5	57.3±5.7	58.0±1.4	62.7± 5.8	50.0±5.6
Alanine	61.7±2.5	60.3±2.3	59.0±3.7	60.0±1.4	63.2± 4.0	62.5±2.1
Valine	48.7±1.5	46.3±1.1	45.3±2.1	48.5±3.5	45.5± 3.3	41.5±2.1
Cystine	7.7±1.1	6.7±1.1	6.3±0.6	7.5±0.7	8.3± 2.1	10.5±2.1
Methionine (chrom.)	29.3±4.7	28.0±2.6	30.0±1.0	29.5±2.1	26.7± 2.7	29
Methionine (color.)	33.3±0.6	31.3±0.6	32.0±1.0	32.0±1.4	32.7± 1.2	31.0±0.0
Isoleucine	43.0±0.0	41.0±1.0	42.3±0.6	41.0±2.8	41.0± 2.2	34.0±5.6
Leucine	73.3±1.5	71.3±1.5	72.7±1.5	73.0±2.8	73.2± 2.6	65.5±0.7
Tyrosine	32.3±1.5	32.7±0.6	33.0±1.0	31.0±2.8	32.7± 4.2	28.5±2.1
Phenylalanine	38.0±0.0	37.0±2.0	38.7±0.6	37.5±2.1	39.5± 3.3	35.5±2.1
Lysine	91.3±6.0	92.3±3.8	90.7±2.3	90.5±3.5	87.2± 5.6	66.0±4.2
Histidine	22.0±1.0	21.3±0.6	20.0±0.0	20.0±0.0	19.2± 0.5	17.5±0.7
Arginine	65.0±2.0	64.0±1.7	61.7±0.6	59.0±4.2	61.5± 3.0	57.0±2.8
Tryptophan	10.0±0.0	9.3±0.6	11.0±1.0	9.5±0.7	9.5± 1.0	9.5±0.7

* Number of samples analysed.

Table 4. Amino acid contents (g/kg protein) in seven species of pelagic fish used for the production of fish meal and oil.

	Capelin (4)*	Herring North Sea (3)	Herring Local stock (3)	Sprat (3)	Mackerel (2)	Horse mackerel (1)	Sand-eel (1)
Aspartic acid	97.2±14.8	90.3± 8.6	90.0± 8.5	89.3± 5.0	88.0± 4.2	84	105
Threonine	46.5± 1.9	48.0± 4.6	40.7± 2.1	43.0± 0.0	45.5± 2.1	41	48
Serine	43.5± 4.5	45.0± 0.0	38.7± 0.6	43.3± 1.1	44.0± 0.0	39	45
Glutamic acid	124.2± 3.2	100.7±12.6	126.7±12.5	120.3±10.6	120.0± 8.5	121	131
Proline	43.7± 2.1	—	38.5± 0.7	34.0± 1.7	41	37	37
Glycine	58.2± 1.5	54.7± 4.9	59.0± 5.3	54.0± 4.6	59.0± 5.6	58	59
Alanine	58.5± 3.4	61.7± 1.5	57.0±10.0	58.3± 4.0	59.0± 1.4	48	63
Valine	50.0± 3.0	43.3± 2.5	43.0±11.3	43.3± 6.6	47.0± 1.4	44	52
Cystine	6.5± 1.3	—	6	7.0± 0.0	7	6	5
Methionine (chrom.)	29.5± 1.3	—	31.0± 2.8	26.3± 3.2	32	23	20
Methionine (color.)	30.2± 1.7	32.0± 1.0	32.0± 1.0	29.3± 3.2	31.0± 0.0	27	31
Isoleucine	42.0± 2.6	40.0± 1.7	38.3± 6.4	36.0± 5.2	42.0± 4.2	38	44
Leucine	76.7± 3.9	73.7± 5.5	75.0± 1.7	71.3± 1.1	75.0± 5.6	65	75
Tyrosine	36.0± 1.6	28.0± 3.6	32.3± 2.5	30.3± 2.5	33.0± 4.2	29	32
Phenylalanine	39.5± 1.3	37.0± 3.5	37.7± 3.2	37.0± 1.7	38.0± 2.8	33	38
Lysine	85.0± 3.6	81.0± 5.0	90.3± 0.6	83.7± 7.2	84.5±12.0	71	84
Histidine	20.7± 1.7	24.7± 5.5	27.0± 2.6	26.3± 5.8	30.0± 1.4	31	27
Arginine	60.7± 2.4	52.3± 6.4	55.0± 6.5	57.3± 3.2	58.0± 2.8	56	62
Tryptophan	10.0± 0.8	9.3± 1.2	9.5± 0.7	8.3± 1.5	11.0± 1.4	9	10

* Number of samples analysed.

Table 5. Amino acid contents (g/kg protein) in four miscellaneous fish species.

	Great silver smelt (3)*	Müller's pearlsides (4)	Ballan wrasse (2)	Lumpfish female (2)	Lumpfish male (2)
Aspartic acid	94.0± 5.0	90.0± 7.1	92.5± 3.5	83.5± 7.8	68.0± 7.1
Threonine	45.0± 8.5	46.0± 1.4	41.0± 2.8	35.5± 4.9	37.0± 9.9
Serine	44.3± 4.2	36.2±17.5	43.5± 4.9	46.0± 2.8	37.0±14.1
Glutamic acid	135.7±15.0	106.7±25.4	131.5±12.0	99.5± 2.1	105.0± 0.0
Proline	37.5± 3.5	55	51.0± 5.6	56	53
Glycine	60.3± 5.5	59.0±21.0	83.5± 3.5	110.5± 6.4	95.0± 1.4
Alanine	59.3± 2.5	54.2±10.0	64.0± 0.0	52.0± 7.1	52.5± 3.5
Valine	47.2± 5.7	40.7± 8.8	45.5± 0.7	30.5± 3.5	26.0± 1.4
Cystine	—	8.7± 0.6	6	5.5± 2.1	—
Methionine (chrom.)	30	32	28.0± 5.6	22	23
Methionine (color.)	31.0± 1.7	31.2± 0.9	31.5± 0.7	24.5± 3.5	24.0± 4.2
Isoleucine	39.7± 4.2	37.0± 2.9	40.0± 1.4	28.0± 4.2	23.5± 7.8
Leucine	71.3± 4.9	69.3± 4.0	71.5± 3.5	60.0±15.5	65.0±22.6
Tyrosine	32.0± 2.0	31.7± 0.5	29.5± 2.1	21.5± 3.5	21.5± 0.7
Phenylalanine	39.0± 2.8	37.7± 1.2	39.0± 2.8	28.5± 2.1	20.0± 7.1
Lysine	87.0± 5.0	73.0±11.1	81.5± 2.1	54.5± 9.2	58.0± 8.5
Histidine	21.0± 1.0	23.2± 6.0	20.0± 1.4	16.0± 1.4	15.0± 1.4
Arginine	59.7± 1.1	48.3±10.3	63.5± 2.1	56.5± 3.5	57.5±10.6
Tryptophan	10.3± 2.3	11.0± 3.5	7.0± 1.4	6	6

* Number of samples analysed.

amino acids the values were strikingly similar between species, and also between whole and gutted fish. Only glycine showed somewhat divergent values in saithe as compared to the other species.

The amino acid composition in samples from seven species of pelagic fish is given in table 4. These fish species are exploited for the production of fish meal and oil. Again the results were strikingly similar between species, the only exception being the high value for histidine in mackerel.

The amino acid composition of four species of miscellaneous fish species are given in table 5. Ballan wrasse and lump-fish (female and male) showed high values for glycine. Besides, some of the amino acid values differed greatly between samples within the same species (glutamic acid for great silver smelt and for Müller's pearlsides, glycine for Müller's pearlsides and leucine for lumpfish).

DISCUSSION

Most data reported previously on the amino acid composition of different fish species refer either to the edible part of the fish (CONNELL and HOWGATE, 1959; BRÆKKAN and BOGE, 1962) or to fish meals (NJAA et al. 1968; OPSTVEDT et al. 1970). ARNESEN(1969) reported data on codfish organs, flesh, bones and stomach contents, but not on whole cod. The samples analysed in the present study were probably best comparable with whole fish meals, assuming that the production processes do not seriously affect the amino acid composition. Data given by BOGE (1960) indicate that this is the case at least in a comparison between whole herring and whole herring meal. Our finding of surprisingly small differences between the amino acid contents of different fish species should also be judged on the basis of the variation seen between fish meals produced from one species. Thus menhaden meals (KIFER et al. 1968), Norwegian herring meals (KIFER et al. 1969) and Canadian Atlantic herring meals (POWER et al. 1969) showed coefficients of variation below 10% for most of the amino acids, and quite similar amino acid contents. Likewise, data on the amino acid contents reported by OPSTVEDT et al., (1970) for fish meals from five species of pelagic fish were very similar and the coefficients of variation for most amino acids were less than 10%. In contrast, the amino acid contents of fish off-fall from cod varied much more with coefficients of variation ranging from 14 to 66%. Also, the contents of most of the essential amino acids were lower than in whole fish (NJAA, 1978).

The higher content of glycine in saithe than in the other Gadidae may be due to the relative amounts of flesh to bones, skin, etc. (ARNESEN, 1969.) In fact, in our material there was a positive correlation between the glycine content and the amount of ash on a dry matter basis. In an earlier study we found a rather high level of glycine in horse mackerel (scad) together with a high ash content (NJAA et al., 1968). In the present study one sample of horse mackerel had a rather low ash content and was not especially rich in glycine (Tables 1 and 4). Ballan wrasse and lumpfish showed high contents of glycine as well as of ash (Tables 1 and 5). The former is a bony fish with thick skin, the latter apparently contains much cartilage. The high content of histidine in mackerel is a consequence of this species containing high levels of free histidine in the muscle. SAKAGUCHI and SHIMIZU (1965), BRÆKKAN and BOGE (1962) and KJOSBAKKEN and LARSEN (1981) reported high levels of total histidine in the edible part of mackerel. The free histidine content in mackerel and herring varies with the season (SAKAGUCHI and SHIMIZU, 1965; HUGHES, 1959), the high content in herring meals reported by POWER et al. (1969) may be a reflection of this. Species with high levels of free histidine should be stored with care as adverse storing conditions may result in the formation of histamine (TAKAGI et al. 1969).

Among the fish species analysed only lumpfish seems to have significantly lower levels of most of the essential amino acids compared to those in other species. Mean values for the amino acid contents found in 12 analyses of whole fish of the Gadidae family and in 17 analyses of whole pelagic fish are compared in table 6. The only noteworthy difference was found for the contents of histidine ($p<0.001$). Capelin, which is a salmoid species showed values nearer to the Gadidae than did the other pelagic species.

Table 6. Comparisons between the mean contents of amino acids (g/kg protein) in 12 samples of whole fish from the Gadidae family and in 17 samples of whole pelagic fish.

	Gadidae	Pelagic	Significance of difference
Aspartic acid	99.1± 8.6	91.9± 9.5	$p < 0.05$
Threonine	45.7± 4.0	44.8± 3.5	N.S.
Serine	46.3± 3.7	42.8± 3.1	$p < 0.01$
Glutamic acid	132.5±11.7	119.5±12.2	$p < 0.01$
Proline	(10)* 40.8± 4.2	(12) 39.2± 4.5	N.S.
Glycine	62.4±10.1	57.1± 4.0	N.S.
Alanine	61.7± 3.3	58.5± 5.3	N.S.
Valine	45.6± 3.2	45.9± 6.0	N.S.
Cystine	(11) 8.0± 1.9	(12) 6.5± 0.9	$p < 0.05$
Methionine (chrom.)	(11) 28.5± 3.0	(12) 27.8± 4.0	N.S.
Methionine (color.)	32.4± 1.2	30.6± 2.0	$p < 0.05$
Isoleucine	40.7± 3.8	39.8± 4.2	N.S.
Leucine	71.8± 3.4	73.9± 4.2	N.S.
Tyrosine	32.0± 2.9	31.9± 3.6	N.S.
Phenylalanine	38.2± 2.3	37.6± 2.5	N.S.
Lysine	85.6±10.2	84.1± 6.4	N.S.
Histidine	19.8± 1.6	26.5± 6.0	$p < 0.001$
Arginine	61.7± 3.3	57.1± 4.8	$p < 0.05$
Tryptophan	10.0± 0.9	9.9± 2.1	N.S.

* Samples analysed when less than 12, resp. 17.
N.S.: not significant.

REFERENCES

ARNESEN, G., 1969, J. Sci. Fd. Agric. *20* 218-220.

BOGE, G., 1960. J. Sci. Fd. Agric. *11* 362-365.

BRÆKKAN, O. R. and BOGE, G., 1962. Fisk. Dir. Skr., Ser. Teknol. Unders. *4*: No 3 19 pp.

CONNELL, J.J. and HOWGATE, P.F., 1959. J. Sci. Fd. Agric. *10* 241-244.

CROOKE, W.W. and SIMPSON, W.E., 1971. J. Sci. Fd. Agric. *22* 9-10.

HUGHES. R. B., 1959, J. Sci. Fd. Agric. *10* 558-564.

JULSHAMN, K., HAUGSNES, J. and UTNE., F., 1978. Fisk. Dir. Skr., Ser. Ernæring *1*: No 4 117–135.

KIFER, R. R., PAYNE, W. L., MILLER, D. and AMBROSE, M. E., 1968. Feedstuffs May 18, 36-37.

KIFER, R. R., PAYNE, W. L. and AMBROSE, M. E., 1969. Feedstuffs April 26, 18-19.

KJOSBAKKEN, J. and LARSEN, H. 1981. Fisk. Dir. Skr., Ser. Ernæring *2*: No 1, 7–24.

LAMBERTSEN, G., 1978. Fisk. Dir. Skr., Ser. Ernæring *1*: No. 4, 105–116.

MOORHOUSE, C. O., LAW, A. R. and MADDIX, C., 1976. Adv. in Automated Chemistry. 7th Technicon International Congress Vol 2, Mediad Inc. New York pp. 182-189.

NJAA, L. R., 1978. Norges offentlige utredninger *23* 136-139.

NJAA, L. R., 1980. Br. J. Nutr. *43* 339-348.

NJAA, L. R., UTNE, F., BOGE, G and BRÆKKAN, O. R., 1968. Fisk. Dir. Skr., Ser. Teknol. Unders. *5*: No 5 12 pp.

OPSTVEDT, J., OLSEN, S. URDAHL, N., LAKSESVELA, B and BJØRNSTAD, J., 1970. Meldinger fra SSF nr. 4. 168 pp.

POWER, H. E., SAVAGAON, K. A., MARCH, B. E. and BIELY, J., 1969. Fish. Res. Bd. Can. Techn. Rep. No 114 14 pp.

UTNE, F., 1976. Fiskets Gang, Fiskeridirektoratet, Bergen, No 31 495-497 and further nos.

SAKAGUCHI, M. and SHIMIZU, W., 1965. Nippon Suisan Gakkaishi *31* 72–75, cited after Chem. Abstr. *66* 62915 y (1967).

TAKAGI, M., JIDA, A. and MURAYAMA, H., 1969. Bull Fac. Fisheries, Hokkaido Univ. *22* 227-234.