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Comparative study on dipeptidase activities in fish tissues

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Comparative study on dipeptidase activities in fish tissues

By

A. SCHMITT, G. SIEBERT and I. BOTTKE

With 9 Tables

(Received October 25, 1965)

A. Introduction

Muscle and organ tissues of fish, compared to the corresponding tissues in mammals, have a high content of proteolytic enzymes (1); the dipeptide-cleaving enzymes are markedly more active than the other enzymes of protein and amino acid metabolism (1,2). This study compares the enzymatic decomposition of numerous dipeptides by muscle and organ extracts of various fish with the decomposition by the tissues of several mammals. The multitude of data provides an answer to the question to what extent peptidases of known specificity contribute to the decomposition of dipeptides

along with still unidentified peptidases. This study makes the existence of dipeptidases of new specificity seem probable.

B. Methods

The enzymes for our tests were taken from cod freshly caught at sea whose muscle tissues and organs were stored in a deep-frozen state until the time of testing. For carp and trout, the tissues were taken from live fresh fish, and for mammals, too, fresh tissues only were used.

Depending on the intensity of the prevailing activity, 51
the tissues to be tested were homogenized in an ice-bath with 1% KCl solution in the ratios 1:5 and 1:10, respectively, then were allowed to stand for 20 minutes and afterwards centrifuged for 15 minutes at 25,000 xg.

The dipeptidase activity was mainly determined by spectrophotometry (3), in a few cases also by measuring the increase of ninhydrin-positive material according to MOORE and STEIN (4). Protein was determined according to LOWRY (5).

C. Results and Discussion

The results of our tests have been summarized in Tables 1-4. If in Table 1 the activities of spleen tissues of different origins

are compared, it becomes clear that the cod spleen is more intensely active than any other tissue. In a comparison with the activity of renal tissue of mammals (rat, pig), the "classic" enzyme cell for dipeptidases, the intense activity of the cod spleen is again striking. Even in the series of other examined cod organs (Table 3), the spleen shows the highest total activities; the enzymatic decomposition of comparable dipeptides by cod spleen extracts exceeds even decomposition by intestinal extracts. Surprisingly high are also the activities of heart muscles while the cleavage rates of the cod spleen are low. The total activities of dipeptide hydrolysis by carp and trout spleen extracts are only half as intense as in the cod spleen, but still considerably higher than the cleavage rates for rat and cattle spleens.

Table 2 contains the dipeptidase activities for muscle tissues of cod, carp and trout; the total activities of cattle and pig muscles have been added for purposes of comparison. Among the muscle tissues of fish, trout muscles show the highest total activities, followed by cod and carp muscles. Compared with mammalian muscle tissues (cattle, pig), fish muscles have several times more capacity to break down dipeptides than the muscles of warm-blooded organisms. This finding is corroborated by the data in Table 4 on various organs of carp and trout, where only the various portions of carp intestine are remarkably active.

The multitude of substrates broken down by the examined tissues raises the question as to the possible number of participating dipeptidases. Attempts to trace the high cleavage rates of the various dipeptides back to the action of known dipeptidases have met with considerable difficulties. On the one hand, the number of hitherto well-known dipeptidases is low, on the other hand, the substrate specificity of these enzymes has in parts not been examined systematically to the extent required by the data of this study. Of the known dipeptidases, prolidase and prolinase can be excluded from the enzymes responsible for the decomposition of most dipeptides, for they have the specific function of breaking down proline-containing dipeptides (6,7). Carnosinase and Anserinase are also out of the question (except for Gly-L-His) because they can break down only dipeptides which contain C-terminal L-histidine. Neither can the enzyme glycylglycine dipeptidase be made responsible for breaking down the great number of dipeptides; its activity in the examined tissues is too low to furnish an explanation for the high cleavage rates of the examined dipeptides. The only remaining well-known dipeptidase is glycyl-L-leucine dipeptidase the substrate specificity of which has, however, not yet been thoroughly studied. Leucine-amino-peptidase, an amino-polypeptidase, which can break down also leucyl-dipeptide (substrate: e.g. L-leucylglycine), is not sufficiently active in the examined tissues 52

to provide an explanation for the high cleavage rates of most of the dipeptides. There is also the fact that this enzyme is only very moderately capable of catalyzing the hydrolysis of dipeptides which contain glycine N-terminally. If we restrict ourselves to the break-down of aliphatic dipeptides which contain glycin N-terminally, the only known dipeptidase in question is glycyl-L-leucine dipeptidase. Doubtlessly we may expect that this enzyme will break down at approximately the same rate any dipeptide homologous in structure to glycyl-L-leucine (e.g. glycyl-L-valine).

In order to estimate the possible participation of already known enzymes in the cleavage of homologous substrates, the relative cleavage rates of various tissues of different origins, related to the decomposition of standard substrates (glycyl-L-leucine, L-leucyl-glycine and L-alanyl-glycine), have been summarized in Tables 5-9. The comparison of data in Table 5 shows that glycyl-L-valine, the closest homolog to glycyl-L-leucine, is broken down at strikingly similar rates in the two tissues of four different origins. The same applies to glycyl-L-phenylalanine and glycyl-L-serine. This finding speaks against a different species specificity of glycyl-L-leucine dipeptidase as well as against a different organ specificity. Apparently, glycyl-L-leucine, glycyl-L-phenylalanine and glycyl-L-valine are good substrates for one and the same dipeptidase which, in spite of a different origin, possesses the same specificity

for these substrates. If these findings are extended to the other homologs of glycyl-L-leucine, we find partly considerable differences in the relative activities (e.g. glycyl-L-alanine: 0.27-1.0; glycyl-D,L-norvaline: 0.26-0.76; glycyl-L-methionine: 0.68-1.56). Therefore the decomposition of these substrates cannot be due only to the glycyl-L-leucine dipeptidase, as in such a case approximately the same cleavage rates would have had to be observed, as in the case of glycyl-L-valine above. It must be assumed therefore that in addition to glycyl-L-leucine dipeptidase at least one other dipeptidase is active in the examined tissues which is also capable of breaking down glycyl dipeptides, or glycyl-L-leucine dipeptidase, as an expression of a certain organ or species specificity, proves to be slightly variable, depending on the enzyme cell, in the rigidity with which its substrate specificity has developed. At present it is impossible to decide which of these two alternatives is correct.

Examining the relative data of dipeptide hydrolysis, related to the cleavage of L-leucyl-glycine (Table 6), we find even more pronounced differences. L-leucyl-glycin is a substrate of leucine-amino-peptidase; but highly purified leucine-amino-peptidase can break down L-alanyl-glycine only to a very moderate extent (8). This substrate is broken down more rapidly, however, by cod spleen extracts - 11 times more rapidly than L-leucyl-glycine, i.e. cod

spleen contains a dipeptidase which has a preference for breaking down L-alanine peptides; apparently L-seryl-glycine is a substrate of this enzyme, too.

Contrary to glycyl-L-leucine dipeptidase which affects numerous homologs of glycyl-L-leucine, the specificity range of the L-alanyl-glycine-cleaving enzyme seems to be narrower. The decomposition of aliphatic homologs of L-alanyl-glycine in cod spleen is less than 10% of that of the standard substrate (Table 7); a branching of the aliphatic lateral chain of the N-terminal amino acid reduces the rate of hydrolysis substantially. Only the non-branched L-seryl-glycine, which has a similar three-dimensional structure, is broken down at a higher rate.

Table 9 contains the relative activities determined for fish muscles and related to the cleavage of glycyl-L-leucine and L-alanyl-glycine. The comparison between cod and trout muscles shows similar cleavage rates for glycyl-L-phenylalanine, glycyl-L-threonine, glycyl-L-isoleucine and glycyl-L-norvaline; it is therefore fairly certain that the decomposition of these substrates is caused by the glycyl-L-leucine dipeptidase. Here again the decomposition of L-seryl-glycine is due to the action of the L-alanyl-glycine dipeptidase; the relative cleavage rates of this substrate are of approximately the same magnitude for muscle tissue (0.44 and 0.45) as those for cod spleen (0.41). In carp muscles which are remarkable

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for their low content of dipeptidases (Table 2), hardly any cleavage rates analogous to those for cod and trout muscles have been observed; the decomposition of the examined dipeptides is no longer governed predominantly by glycyl-L-leucine dipeptidase and L-alanyl-glycine dipeptidase. As the leucine amino peptidase (substrate: L-leucyl-glycine) is very moderately active in this tissue, too, other peptidases must be active in addition to those already mentioned.

So far the discussion has been limited to the relative activity data for dipeptides containing glycine. Dipeptides which do not contain glycine show an apparently irregular dispersion of their relative activities. Here apparently the activities of the two above-mentioned dipeptidases are superimposed upon each other; there is also the possibility of other dipeptidases of absolutely new specificities participating. The question whether dipeptidases of different origin (organ, animal species) also differ in their specificities, can in the light of the available data be investigated only with glycycl-L-leucine dipeptidase as example. Glycyl-L-phenylalanine, glycyl-L-valine and glycyl-L-threonine are substrates the hydrolysis of which is catalyzed by this enzyme. A comparison of the relative cleavage rates of these substrates between different enzyme cells shows their far-reaching analogy to the rates for glycyl-L-leucine. The majority of data for glycyl-L-phenyl-alanine, in spite of different animal species, lies between 0.65

and 0.85 for the various enzyme sources, some between 0.69 and 0.70. The accumulation of data between 0.65 and 0.85 and the remarkably close values at 0.69-0.70 cannot be regarded as accidental, but are to be interpreted as follows: the glycyl-L-leucine dipeptidase from different organs of different animal species possesses the same specificity towards glycyl-L-henylalanine, that is to say, the specificity of the glycyl-L-leucine dipeptidase depends neither on the organ nor on the species from which that organ originates.

Independently of the organ and species specificity discussed here, however, the results of this study show the qualitative and quantitative variety of dipeptidases in fish tissues. At the present time there is no saying as to what consequences this abundance of enzymes might have for the protein metabolism in fish tissues, unless explanations are given by working hypotheses with regard to biological life cycles (9). The findings of this study are further explanation of the readiness with which protein in fish tissues breaks down post mortem as far as the amino acids (10).

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E. Summary

1. Dipeptidase activities of various fish tissues were compared with those of some mammalian tissues, using 27 different dipeptides as substrates. In the average, the activities of dipeptidases are several times higher in fish than in mammalian tissues. Cod spleen possesses the highest activity which is 5 to 10 times higher than in mammalian spleen. Cod and trout muscles are also remarkably more active than mammalian muscles.

2. Of all known dipeptidases, glycyl-L-leucine dipeptidase is the only enzyme with high activity in the tissues under investigation. The specificity of this enzyme is apparently rather broad; the cleavage of numerous homologs of glycyl-L-leucine must be ascribed to this enzyme. There is no clear-cut tissue or species dependence of the substrate specificity of glycyl-L-leucine dipeptidase.

3. A second enzyme of rather narrow specific nature and high activity prefers L-alanylglycine as a substrate. Homologs of this substrate are cleaved to a much lesser extent. The enzyme does not exhibit a species or a tissue specificity. Apparently, this is a new dipeptidase which preferentially cleaves L-alanyl peptides.

4. In addition, a comparison of the experimental data leads to the conclusion of the existence of a series of yet unknown dipeptidases in fish tissues, all of which participate in the rapid degradation of protein in fish muscles.

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Table 1. Decomposition of dipeptides by organ extracts of different origin

	µMol/min/g Gewebe; 25 °C						µMol/min/mg Protein; 25 °C					
		Milz			Niere			Milz			Niere	
	Dorsch	Ratte	Schwein	Rind	Ratte	Schwein	Dorsch	Ratte	Schwein	Rind	Ratte	Schwein
Glycyl-L-alanine	258	11	158	21	185	374	3,03	0,13	2,0	0,31	2,10	5,50
Glycyl-D,L-norleucine	365	11	100	23	84	500	4,20	0,13	1,30	0,34	0,96	7,35
Glycyl-D,L-norvaline	297	16	125	20	90	490	3,45	0,20	1,63	0,30	1,02	7,20
Glycyl-L-leucine	501	40	210	77	186	647	5,9	0,49	2,73	1,15	2,15	9,5
Glycyl-L-valine	320	41	245	125	186	620	3,75	0,50	3,20	1,88	2,15	9,1
Glycyl-D,L-isoleucine	272	17	238	44	103	476	3,20	0,20	3,10	0,66	1,17	7,0
Glycyl-L-serine	105	5	39	5	33	104	1,24	0,06	0,51	0,07	0,37	1,53
Glycyl-L-threonine	332	25	262	36	142	470	3,90	0,30	3,40	0,54	1,61	6,9
Glycyl-L-asparaginsäure	12	<1	10	<1	<1	28	0,14	<0,02	0,13	0,02	<0,02	0,41
Glycyl-L-glutaminsäure	20	2	45	1	13	66	0,24	0,02	0,58	0,02	0,15	0,97
Glycyl-L-methionine	340	35	125	120	198	815	3,95	0,41	1,63	1,80	2,26	12,0
Glycyl-L-phenylalanine	310	28	145	71	128	455	3,6	0,34	1,88	1,07	1,46	6,7
Glycyl-L-proline	8	<1	<1	<1	—	—	0,09	<0,02	<0,02	<0,02	—	—
Glycyl-L-histidine	14	2	<1	<1	5	10	0,16	0,02	<0,02	<0,02	0,06	0,15
Glycyl-L-lysine	62	<1	39	<1	21	—	0,72	<0,02	0,50	<0,02	0,24	—
L-Alanyl-glycine	233	17	118	17	110	220	2,73	0,21	1,53	0,25	1,24	3,23
L-Leucyl-glycine	20	3	50	10	37	137	0,24	0,04	0,65	0,15	0,42	2,00
D,L-Isoleucyl-glycine	10	3	20	<1	17	42	0,12	0,04	0,26	<0,02	0,20	0,62
L-Valyl-glycine	22	4	45	3	21	74	0,25	0,05	0,58	0,04	0,24	1,01
L-Seryl-glycine	95	<1	73	10	43	60	1,12	<0,02	0,95	0,15	0,50	0,88
L-Prolyl-glycine	4	3	<1	5	30	22	0,05	0,03	<0,02	0,07	0,34	0,32
L-Lysyl-glycine	9	2	<1	—	15	15	0,11	0,02	<0,02	—	0,17	0,22
L-Alanyl-L-alanine	166	32	315	103	210	970	1,92	0,39	4,10	1,55	2,40	14,3
L-Alanyl-L-leucine	170	29	143	20	86	—	2,00	0,36	1,86	0,30	0,98	—
L-Leucyl-L-alanine	41	16	132	16	83	476	0,48	0,19	1,72	0,24	0,94	7,0
D,L-Leucyl-L-leucine	122	23	110	26	115	375	1,42	0,28	1,44	0,39	1,30	5,5
L-Valyl-L-valine	66	31	210	47	179	595	0,77	0,38	2,73	0,70	2,05	8,7

Table 2. Dipeptidase activities of fish and mammalian muscles

	µMol/min/g Gewebe tissue				
	Cod Dorsch	25 °C carp Karpfen	Trout Forelle	Cattle Rind	37 °C Pig Schwein
Glycyl-L-alanine	—	1,2	15,5	—	—
Glycyl-D,L-norleucine	14,2	1,2	13,5	—	—
Glycyl-D,L-norvaline	11,0	1,9	19,2	—	—
Glycyl-L-leucine	19,2	6,7	27,5	2,3	2,5
Glycyl-L-valine	11,3	7,5	25,0	2,8	7,7
Glycyl-D,L-isoleucine	16,0	4,4	21,0	—	—
Glycyl-L-serine	7,9	—	5,2	1,8	2,4
Glycyl-L-threonine	17,5	1,2	23,5	4,8	10,6
Glycyl-L-asparaginsäure aspartic acid	—	—	<1	—	—
Glycyl-L-glutaminsäure glutamic acid	—	—	2,5	3,0	2,3
Glycyl-L-methionine	18,3	6,9	17,0	—	—
Glycyl-L-phenylalanine	15,0	2,5	19,2	—	—
Glycyl-L-proline	<1	<1	—	<1	—
Glycyl-L-histidine	—	—	1,8	0,7	1,3
Glycyl-L-lysine	—	—	2,5	<1	—
L-Alanyl-glycine	11,0	5,0	12,2	—	—
L-Leucyl-glycine	4,7	<1	<1	—	7,0
D,L-Isoleucyl-glycine	—	—	<1	—	—
L-Valyl-glycine	3,3	<1	<1	<1	—
L-Seryl-glycine	4,9	<1	5,5	1,2	1,0
L-Prolyl-glycine	6,0	<1	2	2,6	—
L-Lysyl-glycine	—	—	<1	1,5	2,9
L-Alanyl-L-alanine	—	2,5	6,2	—	—
L-Alanyl-L-leucine	—	—	7,0	—	—
L-Leucyl-L-alanine	—	<1	<1	—	—
D,L-Leucyl-L-leucine	—	1,2	3,0	—	—
L-Valyl-L-valine	4,9	<1	3,5	—	—

Table 3. Dipeptidase activities of various cod organs

	Leber Liver	Magen Stomach	Darm Intestine	Pylorus Tissue Pylorus	Rogen Roe	Herz Heart
	µMol/min/g Gewebe; 25°					
Glycyl-L-leucine	6	32	128	118	114	70
Glycyl-L-threonine	6	28	128	56	88	72
Glycyl-L-methionine	20	34	124	112	100	92
Glycyl-L-phenylalanine	5	25	94	78	80	64
L-Alanyl-glycine	5	20	82	80	72	45
L-Leucyl-glycine	2	11	16	41	18	18
L-Seryl-glycine	2	22	52	82	44	26
	µMol/min/mg Protein					
Glycyl-L-leucine	0,05	0,65	1,63	2,60	3,65	0,88
Glycyl-L-threonine	0,05	0,57	1,63	1,24	2,40	0,90
Glycyl-L-methionine	0,15	0,69	1,59	2,50	2,70	1,15
Glycyl-L-phenylalanine	0,04	0,52	1,20	1,72	2,15	0,80
L-Alanyl-glycine	0,04	0,42	1,05	1,78	1,92	0,56
L-Leucyl-glycine	0,02	0,22	0,25	0,91	0,52	0,22
L-Seryl-glycine	—	0,45	0,66	1,83	1,19	0,32

Table 4. Dipeptidase activities in various carp and trout organs

	Milz Spleen	Leber+ Pankreas Liver + pancreas	Karpfen Carp Darm A*) Intestine	Darm B*)	Darm C*)	Milz Spleen	Forelle Trout Leber Liver	Pylorus Pylorus
	µMol/min/g Gewebe Tissue							
Glycyl-L-leucine	175	90	340	340	290	159	44	31
Glycyl-L-valine	—	—	—	—	—	155	35	32
Glycyl-D,L-isoleucine	—	—	—	—	—	84	23	12
Glycyl-L-threonine	—	41	109	129	104	—	—	—
L-Alanyl-glycine	72	72	134	112	106	—	—	—
L-Leucyl-glycine	62	41	81	60	64	60	4	14
L-Seryl-glycine	50	45	53	41	49	—	—	—
	µMol/min/mg Protein							
Glycyl-L-leucine	0,90	1,24	5,1	4,8	4,6	1,06	0,42	0,43
Glycyl-L-valine	—	—	—	—	—	1,03	0,33	0,44
Glycyl-D,L-isoleucine	—	—	—	—	—	0,56	0,22	0,16
Glycyl-L-threonine	—	0,50	1,33	1,50	1,53	—	—	—
L-Alanyl-glycine	0,38	1,04	2,00	1,75	1,60	—	—	—
L-Leucyl-glycine	0,50	0,66	1,10	0,88	0,95	0,40	0,04	0,19
L-Seryl-glycine	0,28	0,68	0,83	0,78	0,85	—	—	—

* Portions of intestine: A = beginning of intestine, B = middle intestine, C = terminal intestine

Table 5. Relative dipeptidase activities, related to the cleavage of glycyl-L-leucine = 1

	Milz Spleen				Niere Kidney	
	Dorsch Cod	Ratte Rat	Schwein Pig	Rind Cattle	Ratte Rat	Schwein Pig
Glycyl-L-leucine	1,0	1,0	1,0	1,0	1,0	1,0
Glycyl-L-alanine	0,51	0,27	0,75	0,27	1,0	0,58
Glycyl-D,L-norleucine	0,73	0,27	0,48	0,30	0,45	0,77
Glycyl-D,L-norvaline	0,59	0,41	0,59	0,26	0,49	0,76
Glycyl-L-valine	0,63	1,03	1,16	1,63	1,00	0,96
Glycyl-D,L-isoleucine	0,54	0,42	1,12	0,57	0,55	0,74
Glycyl-L-serine	0,21	0,13	0,19	0,06	0,18	0,16
Glycyl-L-threonine	0,66	0,62	1,24	0,47	0,77	0,72
Glycyl-L-asparaginsäure (aspartic acid)	0,02	<0,02	0,05	<0,01	<0,01	0,04
Glycyl-L-glutaminsäure (glutamic acid)	0,04	0,05	0,21	0,01	0,07	0,10
Glycyl-L-methionine	0,68	0,87	0,59	1,56	1,06	1,37
Glycyl-L-phenylalanine	0,62	0,70	0,69	0,92	0,69	0,70
Glycyl-L-proline	0,01	<0,02	<0,01	<0,01	—	—
Glycyl-L-histidine	0,03	0,05	<0,01	<0,01	0,03	0,05
Glycyl-L-lysine	0,12	<0,02	0,19	<0,01	0,11	—
L-Alanyl-glycine	0,47	0,43	0,56	0,23	0,60	0,34
L-Leucyl-glycine	0,05	0,07	0,24	0,13	0,20	0,21
D,L-Isoleucyl-glycine	0,02	0,07	0,10	<0,01	0,09	0,06
L-Valyl-glycine	0,05	0,11	0,21	0,03	0,11	0,11
L-Seryl-glycine	0,19	<0,02	0,35	0,13	0,23	0,09
L-Prolyl-glycine	0,01	0,07	<0,01	0,06	0,16	0,03
L-Lysyl-glycine	0,02	0,05	<0,01	—	0,08	0,02
L-Alanyl-L-alanine	0,31	0,80	1,50	1,34	1,13	1,50
L-Alanyl-L-leucine	0,34	0,73	0,68	0,26	0,46	—
L-Leucyl-L-alanine	0,08	0,41	0,63	0,21	0,45	0,74
D,L-Leucyl-L-leucine	0,24	0,58	0,52	0,34	0,62	0,58
L-Valyl-L-valine	0,13	0,78	1,00	0,61	0,97	0,92

Table 6. Relative dipeptidase activities, related to the cleavage of L-leucylglycine = 1

	Milz Spleen				Niere Kidney	
	Dorsch Cod	Ratte Rat	Schwein Pig	Rind Cattle	Ratte Rat	Schwein Pig
L-Leucyl-glycine	1,00	1,00	1,00	1,00	1,00	1,00
L-Alanyl-glycine	11,65	5,60	2,36	1,70	2,97	1,61
D,L-Isoleucyl-glycine	0,50	1,00	0,40	0,1	0,46	0,31
L-Valyl-glycine	1,10	1,32	0,90	0,30	0,57	0,54
L-Seryl-glycine	4,75	0,3	1,43	1,00	1,16	0,44
L-Prolyl-glycine	0,20	1,00	0,1	0,50	0,81	0,16
L-Lysyl-glycine	0,45	0,66	0,1	—	0,40	0,11
L-Alanyl-L-alanine	8,30	10,56	6,30	10,30	5,67	7,08
L-Alanyl-L-leucine	8,50	9,57	2,86	2,00	2,32	—
L-Leucyl-L-alanine	2,05	5,28	2,64	1,60	2,24	3,47
D,L-Leucyl-L-leucine	6,10	7,59	2,20	2,60	3,10	2,74
L-Valyl-L-valine	3,30	10,23	4,20	4,70	4,83	4,34

Table 7. Relative dipeptidase activities, related to the cleavage of L-alanyl-glycine = 1

			Milz Spleen		Niere Kidney	
	Dorsch Cod	Ratte Rat	Schwein Pig	Rind Cattle	Ratte Rat	Schwein Pig
L-Alanyl-glycine	1,00	1,00	1,00	1,00	1,00	1,00
L-Leucyl-glycine	0,09	0,18	0,42	0,59	0,34	0,62
D,L-Isoleucyl-glycine	0,04	0,18	0,17	—	0,15	0,19
L-Valyl-glycine	0,09	0,24	0,38	0,18	0,19	0,33
L-Seryl-glycine	0,41	—	0,62	0,59	0,39	0,27
L-Prolyl-glycine	0,02	0,18	—	0,29	0,27	0,10
L-Lysyl-glycine	0,04	—	—	—	0,14	0,07
L-Alanyl-L-alanine	0,71	1,89	2,68	6,08	1,91	4,36
L-Alanyl-L-leucine	0,73	1,71	1,21	1,18	0,78	—
L-Leucyl-L-alanine	0,18	0,94	1,22	0,94	0,75	2,14
D,L-Leucyl-L-leucine	0,52	1,36	0,93	1,53	1,05	1,69
L-Valyl-L-valine	0,28	1,83	1,78	2,77	1,62	2,68

Table 8. Relative dipeptidase activities of cod organs, related to the cleavages of glycyl-L-leucine and L-alanyl-glycine, respectively, = 1

	Milz Spleen	Leber Liver	Magen Stomach	Darm Intestine	Pylorus	Rogen Roe	Herz Heart
Glycyl-L-leucine	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Glycyl-L-threonine	0,66	1,00	0,87	1,00	0,48	0,62	1,03
Glycyl-L-methionine	0,68	3,30	1,06	0,97	0,95	0,71	1,31
Glycyl-L-phenylalanine	0,62	0,83	0,79	0,73	0,66	0,57	0,91
L-Alanyl-glycine	0,47	0,83	0,64	0,64	0,68	0,51	0,64
L-Leucyl-glycine	0,05	0,33	0,34	0,12	0,35	0,13	0,26
L-Seryl-glycine	0,19	0,33	0,69	0,40	0,70	0,31	0,37
L-Alanyl-glycine	1,00	1,00	1,00	1,00	1,00	1,00	1,00
L-Leucyl-glycine	0,09	0,40	0,54	0,19	0,51	0,25	0,40
L-Seryl-glycine	0,41	0,40	1,08	0,62	1,02	0,61	0,58

Table 9. Relative dipeptidase activities in muscle tissues of fish, related to glycyl-L-leucine and L-alanyl-glycine, respectively, = 1

	Dorsch Cod	Karpfen Carp	Forelle Trout
Glycyl-L-leucine	1,00	1,00	1,00
Glycyl-L-alanine	—	0,18	0,56
Glycyl-D,L-norleucine	0,74	0,18	0,49
Glycyl-D,L-norvaline	0,57	0,28	0,69
Glycyl-L-valine	0,59	1,12	0,90
Glycyl-D,L-isoleucine	0,83	0,66	0,75
Glycyl-L-serine	0,41	—	0,19
Glycyl-L-threonine	0,91	0,18	0,85
Glycyl-L-methionine	0,95	1,04	0,61
Glycyl-L-phenylalanine	0,78	0,37	0,69
L-Alanyl-glycine	0,57	0,75	0,44
L-Leucyl-glycine	0,25	<0,15	<0,10
D,L-Isoleucyl-glycine	—	—	<0,10
L-Valyl-glycine	0,17	<0,15	<0,10
L-Seryl-glycine	0,25	—	0,20
L-Alanyl-L-alanine	—	0,37	0,22
L-Valyl-L-valine	0,25	<0,15	0,12
D,L-Leucyl-L-leucine	—	0,18	0,11
L-Alanyl-glycine	1,00	1,00	1,00
L-Leucyl-glycine	0,43	<0,20	<0,10
L-Valyl-glycine	0,30	<0,20	<0,10
L-Seryl-glycine	0,44	—	0,45
L-Alanyl-L-alanine	—	0,50	0,51
L-Valyl-L-valine	0,44	<0,20	0,29
D,L-Leucyl-L-leucine	—	0,24	0,25