ANNAL. BIOL. TIHANY	33	217—231	HUNGARIA 1966

ON pH CONDITIONS OF THE ALIMENTARY CANALS OF SOME CRUSTACEANS

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Received: March 18th 1966

Except for some practically most important groups of Insects very few literary data are found concerning the pH of the gastric juice of animals of 1 cm or lower order of magnitude. Particularly few are the literary data on Crustaceans of small size. The pH of the gastric juice of *Daphnia magna* and that of the various parts of the digestive tract were examined by KRÜGER (1925), von DEHN (1930) and HASLER (1935) but rather differing results have been obtained. RANKIN (1929) found in *Simocephalus vetulus* at the beginning of the alimentary canal 6.8, at its end 8.0 pH. BOND (1934) investigating *Calanus finmarchicus* could establish only slightly alkaline pH without a definite value. NICHOLLS (1931) using the method of WIGGLESWORTH obtained for the pH of the alimentary canal of *Ligia oceanica* the following results: foregut 6.3; hepatopancreas 6.0; intestine 6.5; rectum 6. 2. From the literary data of recent years the works of DE GIUSTI et al. (1962) and AGRAWAL (1963) are worth mentioning. Both authors examine the pH conditions of the juices of the alimentary canal of Amphipoda with various methods and different results.

In a previous work (PONYI AND P. ZÁNKAI 1966) the pH-optimum of the proteolytic enzymes of the digestive system of some domestic Crustaceans *(Astacus leptodactylus, Asellus aquaticus, Gammarus roeseli, Dicerogammarus haematobaphes balatonicus, Limnomysis benedeni)* was examined. In the present examinations the pH conditions of the juices in the alimentary canal of these animals were studied also under natural conditions and compared with our data obtained up to now. The importance of the examinations of similar character is stressed by KRISHNA and SAXENA (1963) who investigating the pH conditions of *Tribolium castaneum* found that the pH of the intestinal content agrees with the pH optimum of the various enzymes contained.

Material and method

I. Animals examined and places of collection:

Limnomysis benedeni CZERN, *Dicerogammarus haematobaphes balatonicus* PONYI and *Dicerogammarus villosus bispinosus* MART. were collected from various sites of the Balaton, Gammarus *(Rivulogammarus roeseli* var. *triacanthus*

SCHÄFERNA and *Asellus aquaticus L.)* from the Aszófő creek. For comparison and to reproduce the literary data also the species *Astacus leptodactylus* ESCH. was examined.

II. *The pH conditions of the gastric juices are generally examined with the following methods:*

1. Feeding method (DAY and POWNING (1949), SINHA (1959), SRIVASTAVA (1960), DE GIUSTI and co-workers (1962), KRISHNA and SAXENA (1963).

2. pH determination with indicator paper SINHA (1959), RASTOGI and DATTA GUPTA (1962), AGRAWAL (1963).

3. So-called dilution method RASTOGI and DATTA GUPTA (1962).

In our experiments we endeavoured to determine the pH of the gastric juice of the animals as far as possible without lesion of the alimentary canal, under natural conditions, therefore we used in the first place the feeding method supplemented with two control methods (modified WIGGLESWORTH method and determination with BECKMAN'S pH meter).

1. The feeding method was employed as follows: animals starved for 5—24—48 hours were placed in a solution containing proper feed and indicator or only indicator respectively, then the change of colour in the intestinal canal after lifting out the digestive tract *(Amphipoda, Asellus)* or without *(Limnomysis)* obwserved after 5—24—48—72 hours under the binocular microscope at a white light. In each experimental series 25—30 animals were used up, as far as possible of larger body, distributed in groups of 5. In the various groups 2—3 animals gave evaluable results on the average.

After a number of preliminary experiments we succeeded in finding for *Amphipoda* such readily consumed feed which well binds the indicator and does not release it even in water. This stuff is agar from which we measured out 1 g in dry condition, soaked for 24 hours in distilled water and adding 10 mg indicator powder boiled down in 5 ccm of distilled water. After cooling down this was supplied as food cut into small cubes. We tried also casein (HAMMARSTEIN) which, however, was not willingly consumed by the animals. With yeast recommended by DE GIUSTI (1962) we could not obtain good results either, because the cells of the yeast used by us did not bind the indicator at all and on the other hand they have their own colour which makes reading off of the values difficult, beside this was not readily consumed by the animals either.

As an indicator the 0.1 per cent aqueous solution of the indicators of the sulphonphtalein series was used because in these the pH deviation caused by salt and proteins is relatively low and they are not toxic (DAY and POWNING, 1949). The series consisting of bromphenol blue (pK = 3.8), chlorphenol red (pK = 6.0), bromcresol red (pK = 6.12), bromthymol blue (pK = 7.1), neutral red (pK = 7.4), phenol red (pK = 7.8), cresol red (pK = 6.25) reaching from the 4.8 to 8.8 pH domain was completed in given cases with methyl red (pK = 5.0).

For *Asellus* and *Limnomysis* no such stuff was found which were readily consumed by these so from some indicators and water of the Lake Balaton a 0.1 per cent solution was made and the animals were kept in this solution.

2. To control this method we used the methodics of WIGGLESWORTH (1927) with some modification. We adopted the use of the slide with paraffin so that we made such small holes in the still tepid paraffin in which about 0.002

ml of the solution found place. Then we brought together from a pH series of M/15 KH_2PO_4-Na_2HPO_4 buffer and the corresponding indicator 0.001 ml in these little holes and subsequently covered the whole with a slide. These were the comparative solutions of known pH. In another hole instead of the buffer of known pH the material to be examined was placed. Determination of pH was supplied by the agreement of colour shades. This method was only used in *Amphipoda.* The juice to be examined which originated in most cases from the stomach and the end of the medium intestine was sucked out by a microburetta. As the neutral red indicator does not dissolve readily in water, here we dispensed with its use. The great many data obtained from the use of this method were statistically evaluated.

3. pH conditions of the hepatopancreas of *Amphipoda* and *Asellus* and in many cases also those of the gastric juice are difficult to determine as the colour of the indicators which may enter into consideration is yellow-red or yellowish-blue which shades may be covered by the colour of the juices. Therefore we attempted to dilute these juices and to determine their pH with BECKMAN'S pH-meter. Since here small quantities of liquids have to be measured it was necessary to control these. For this purpose from the above described phosphate buffer of known pH 0.3—0.5 ml were dropped on a slide then drawn away in a narrow stripe and the pH repeatedly determined. Subsequently the hepatopancreas or sucked out gastric juice of 15—27 animals was collected on a cooled slide, then 2 × distilled water on glass added and similarly prepared for the measurement as described above. When more than 0.5 ml distilled water was added the gastric juices were often no more able to buffer the solution. In some cases when a comparatively greater amount of juice was available we measured the pH without adding distilled water. The difference between the two types of measurement was not greater than the deviation of the pH values between the groups.

Before measurement the small tubes of the *Amphipoda* and *Asellus* hepatopancreas were dissected out and cut off before the entry of the intestine. After placing on the slide we cut them through once more to facilitate the flow out of the juices. The gastric juice was sucked out according to the method described in point 2.

At every measurement the pH of the juice from 20—25—30 animals was determined.

Of *Astacus* the pH of the hepatopancreas and gastric juice of 5 animals was measured, the result obtained is the mean value of these measurements.

Results

1. Limnomysis benedeni

The animal is quite transparent and although the juice of the hepatopancreas tubes is coloured, the colour is very pale and therefore the pH can be readily determined. On account of the anatomical conditions (5 pairs of hepatopancreas) and small size of the animal only the feeding method could be employed here. The medium intestine can be sometimes broken up in two parts on the basis of the pH conditions. These limits, however, are not constant and not definite *(Fig. 1).*

Table 1.

The pH conditions of the gastric juices of *Limnomysis benedeni*

Number of measurements	Indicator	Stomach	Hepatopancreas	Beginning of medium intestine	End of medium intestine
13	Chlorphenol red	11 c > 6.0 2 c ~ 6.0	5 c > 6.0 8 c ~ 6.0	> 6.0	> 6.0
16	Bromcresol red	> 6.1	10 c ~ 6.1 6 c < 6.1	> 6.1	> 6.1
9	Bromthymol blue	< 7.1	< 7.1	> 7.1	> 7.1
11	Neutral red	< 7.4	< 7.4	7 c > 7.4 4 c ~ 7.4	> 7.4
15	Phenol red	< 7.8	< 7.8	< 7.8	6 c > 7.8 9 c ~ 7.8
14	Cresol red	< 8.2	< 8.2	< 8.2	6 c ~ 8.2 8 c < 8.2

c = number of cases

1. táblázat

Limnomysis benedeni emésztőnedveinek pH-viszonyai

Mérések száma	Indikátor	Gyomor	Hepatopancreas	Középbél eleje	Középbél vége
13	klórfenol vörös	11 e > 6.0 2 e ~ 6,0	5 e > 6,0 8 e ~ 6,0	> 6,0	> 6,0
16	Brómkresol vörös	> 6,1	10 e ~ 6,1 6 e < 6,1	> 6,1	> 6,1
9	Brómtimolkék	< 7,1	< 7,1	< 7,1	< 7,1
11	Neutrál vörös	< 7,4	< 7,4	7 e > 7,4 4 e ~ 7,4	> 7,4
15	Fenol vörös	< 7,8	< 7,8	< 7,8	6 e > 7,8 9 e ~ 7,8
14	Kresol vörös	< 8,2	< 8,2	< 8,2	6 e ~ 8,2 8 e < 8,2

e = esetek száma.

As it appears from the *Table 1* the pH of the gastric juice is >6.0 or 6.1 and <7.1; in the case of the hepatopancreas the pH falls for the most part between 6.0—6.1. Although from these measurements no precise values can be read off, it may be established that the pH of the hepatopancreas falls between 6.0—6.2 since the transition points of 2 indicators are just near these values.

2. In *Amphipoda,* as it appears from *Fig. 2,* the 4 hepatopancreas tubes and the stomach as well as the anterior dorsal coecum and the posterior dorsal coeca are anatomical units readily separating from the intestine. The medium intestine extending from the stomach to the entry of the posterior coeca is anatomically uniform, but can be divided on the basis of pH values established with feeding experiments into 2 or 3 parts.

The pH conditions of part 1 perfectly agree with the pH of the hepatopancreas (therefore not indicated on the *Tables*), the pH conditions of the shorter or longer part of sector 2 lasting about to the end of the posterior dorsal coeca and often readily recognizable, in other cases disappearing are under the influence of the hepatopancreas juice present even there sometimes neutral

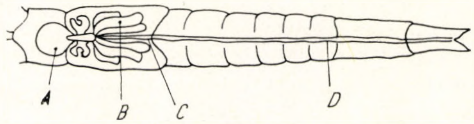

Fig. 1. Schematic drawing of the alimentary tract of *Limnomysis benedeni* CZERN. A = stomach, B = hepatopancreas, C = beginning of medium intestine, D = end of medium intestine. The pH at the site C is frequently lower than at D.

1. ábra: Limnomysis benedeni CZERN. emésztőtraktusának vázlatos rajza. A = gyomor, B = hepatopancreas, C = középbél eleje, D = középbél vége, A pH C helyen gyakran alacsonyabb, mint D -n

sometimes more alkaline, in conformity with the pH conditions prevailing in the last third of the intestine. In the last third of the intestine the pH is always alkaline *(Tables 2.* and *3.)*.

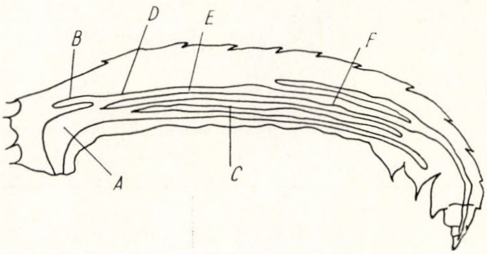

Fig. 2. Schematic drawing of the alimentary canal of *Amphipoda* A = stomach, B = anterior dorsal coeca, C = hepatopancreas, D = beginning of medium intestine, E = median, from the viewpoint of pH transitory part of medium intestine, F = end of medium intestine, posterior dorsal coeca

2. ábra: Amphipoda emésztőcsatorna vázlatos rajza. A = gyomor, B = elülső dorsalis coeca, C = hepatopancreas, D = középbél eleje, E = = középbél középső, pH szempontból átmeneti része, F = középbél vége, hátulsó dorsalis coeca

Between *Dicerogammarus villosus bispinosus* and *Dicerogammarus haematobaphes balatonicus* no essential difference exists either as regards the mode of nutrition or the quality of the feed consumed or in the pH values obtained; so on the Table the two species were drawn together.

Gammarus roeseli were continuously examined over the whole year but no seasonal differences found.

On the basis of the results from the feeding experiments we established that there is no essential difference between the pH conditions of the gastric juices of the 3 *Amphipoda* species. The results in *Tables 2.* and *3.* were controlled with WIGGLESWORTH'S method *(Table 4.)*.

Table 2.

The pH conditions of the gastric juices of *Dicerogammarus villosus bispinosus* and *Dicerogammarus haematobaphes balatonicus*

Number of measurements	Indicator	Stomach	Hepatopancreas	Med. intest.* 2nd third	Med. intest. 3rd. third
17	Chlorphenol red	13 c > 6.0 4 c < 6.0	5 c > 6.0 5 c ~ 6.0 7 c < 6.0	> 6.0	> 6.0
29	Bromcresol red	18 c > 6.1 3 c ~ 6.1 8 c < 6.1	10 c ~ 6.1 19 c < 6.1	> 6.1	> 6.1
26	Bromthymol blue	1 c ~ 7.1 25 c < 7.1	< 7.1	> 7.1	> 7.1
17	Neutral red	< 7.4	< 7.4	4 c > 7.4 6 c ~ 7.4 7 c < 7.4	> 7.4
21	Phenol red	< 7.8	< 7.8	< 7.8	12 c > 7.8 6 c ~ 7.8 3 c < 7.8
14	Cresol red	< 8.2	< 8.2	< 8.2	10 c < 8.2 4 c ~ 8.2

c = number of cases
Med. intest. = medium intestine

2. táblázat

Dicerogammarus villosus bispinosus és *Dicerogammarus haematobaphes* balatonicus emésztőnedveinek pH-viszonyai

Mérések száma	Indikátor	Gyomor	Hepatopancreas	Középbél 2. harmad	Középbél 3. harmad
17	Klórfenol vörös	13 e > 6,0 4 e < 6,0	5 e > 6,0 5 e ~ 6,0 7 e < 6,0	> 6,0	> 6,0
29	Brómkresolvörös	18 e > 6,1 3 e ~ 6,1 8 e < 6,1	10 e ~ 6,1 19 e < 6,1	> 6,1	> 6,1
26	Brómtimolkék	1 e ~ 7,1 25 e < 7,1	< 7,1	> 7,1	> 7,1
17	Neutrálvörös	< 7,4	< 7,4	4 e > 7,4 6 e > 7,4 7 e < 7,4	> 7,4
21	Fenolvörös	< 7,8	< 7,8	< 7,8	12 e > 7,8 6 e ~ 7,8 3 e < 7,8
14	Kresolvörös	< 8,2	< 8,2	< 8,2	10 e < 8,2 4 e ~ 8,2

Accordingly, the pH of the gastric juice of *Dicerogammarus villosus bispinosus* varies between 5.88—6.37; that of *Dicerogammarus haematobaphes balatonicus* between 5.82—6.37 and of *Gammarus roeseli* between the limits of 5.97 and 6.63, while the pH of the intestinal juice in the last third of the

Table 3

The pH conditions of the gastric juices of *Gammarus roeseli*

Number of measurements	Indicator	Stomach	Hepatopancreas	Med. intest. 2nd third	Med. intest 3rd third
30	Chlorphenol red	19 c > 6.0	19 c > 6.0	> 6.0	> 6.0
		6 c ~ 6.0	11 c < 6.0		
		5 c < 6.0			
25	Bromcresol red	19 c > 6.1	10 c > 6.1		
		4 c ~ 6.1	4 c ~ 6.1	> 6.1	> 6.1
		2 c < 6.1	11 c < 6.1		
37	Bromthymol blue	2 c ~ 7.1	< 7.1	> 7.1	> 7.1
		35 c < 7.1			
36	Neutral red	< 7.4	< 7.4	19 c > 7.4	
				9 c ~ 7.4	> 7.4
				8 c < 7.4	
54	Phenol red	< 7.8	< 7.8	18 c ~ 7.8	15 c > 7.8
				36 c < 7.8	9 c ~ 7.8
					30 c < 7.8
43	Cresol red	< 8.2	< 8.2	8.2	25 c ~ 8.2
					18 c < 8.2

3 táblázat

Gammarus roeseli emésztőnedveinek pH-viszonyai

Mérések száma	Indikátor	Gyomor	Hepatopancreas	Középbél 2. harmad	Középbél 3. harmad
30	Klórfenolvörös	19 e > 6,0	19 e > 6,0		
		6 e ~ 6,0	11 e < 6,0	> 6,0	> 6,0
		5 e < 6,0			
25	Brómkresolvörös	19 e > 6,1	10 e > 6,1		
		4 e ~ 6,1	4 e ~ 6,1	> 6,1	> 6,1
		2 e < 6,1	11 e < 6,1		
37	Brómtimolkék	2 e ~ 7,1	< 7,1	> 7,1	> 7,1
		35 e < 7,1			
36	Neutrál vörös	< 7,4	< 7,4	19 e > 7,4	
				9 e ~ 7,4	> 7,4
				8 e < 7,4	
54	Fenolvörös	< 7,8	< 7,8	18 e ~ 7,8	15 e > 7,8
				36 e < 7,8	9 e ~ 7,8
					30 e < 7,8
43	Kresolvörös	< 8,2	< 8,2	< 8,2	25 e ~ 8,2
					18 e < 8,2

medium intestine fell in the case of *villosus* between 7.72—8.06 in *haematobaphes* between 7.59—8.07 and in *roeseli* between 7.61—7.99.

The pH of the hepatopancreas or gastric juice respectively of 322 *Amphipoda* was measured with BECKMAN's pH-meter. The pH of the hepatopancreas juice of *Gammarus roeseli* was 6.16 on the average; in the case of *Dicerogammarus villosus bispinosus* it was 6.12 while in *Dicerogammarus haematobaphes*

Table 4.

Determination of the pH of the digestive systems of *Amphipoda* by WIGGLESWORTH's method

Animal	Juice	Indicator	Measurements	x̄	s ±
Dicerogammarus villosus bispinosus	Stomach	Chlorphenol red	51	6.18	0.18
	,,	Bromcresol red	60	6.18	0.19
	,,	Bromthymol blue	44	6.19	0.21
	Medium intestine 3rd third	Phenol red	32	7.89	0.17
		Cresol red	27	7.95	0.11
Dicerogammarus haematobaphes balatonicus	Stomach	Chlorphenol red	40	6.19	0.18
	,,	Bromcresol red	24	6.0	0.18
	,,	Bromthymol blue	13	6.1	0.16
	Medium intestine 3rd third	Phenol red	37	7.83	0.24
		Cresol red	14	7.80	0.18
Gammarus roeseli	Stomach	Chlorphenol red	20	6.17	0.20
		Bromcresol red	17	6.19	0.21
		Bromthymol blue	55	6.32	0.31
	Medium intestine 3rd third	Phenol red	17	7.80	0.19
		Cresol red	39	7.79	0.12

4. táblázat

Az *Amphipodák* emésztőrendszerei pH-jának meghatározása Wigglesworth-módszerrel

Állat neve	Nedv	Indikátor	Mérések	$\bar{x}$	s ±
Dicerogammarus villosus bispinosus	gyomor	klórfenolvörös	51	6,18	0,18
	,,	brómkresolvörös	60	6,18	0,19
	,,	brómtimolkék	44	6,19	0,21
	középbél 3. harmad	fenolvörös	32	7,89	0,17
	középbél 3. harmad	kresolvörös	27	7,95	0,11
Dicerogammarus haematobaphes balatonicus	gyomor	klórfenolvörös	40	6,19	0,18
	,,	brómkresolvörös	24	6,0	0,18
	,,	brómtimolkék	13	6,1	0,16
	középbél 3. harmad	fenolvörös	37	7,83	0,24
	középbél 3. harmad	kresolvörös	14	7,80	0,18
Gammarus roeseli	gyomor	klórfenolvörös	20	6,17	0,20
	,,	brómkresolvörös	17	6,19	0,21
	,,	brómtimolkék	55	6,32	0,31
	középbél 3. harmad	fenolvörös	17	7,80	0,19
	középbél 3. harmad	kresolvörös	39	7,72	0,12

balatonicus 6.10. The gastric juice gave for all three species higher values i. e. in the above order of species 6.37:, 6.31 and 6.25.

3. The digestive canal of *Asellus (Fig. 3)* was divided in feeding experiments on the basis of the pH of the juices found in them into 2 parts *(Table 5)*. To the first part belong the hepatopancreas tubes while the second part is determined by the pH of the juices in the gastric and intestinal tract. The 4 hepatopancreas tubes under the influence of various indicators (mainly chlorphenol red and bromcresol red) often stained in two ways: the secretion at the end of the tubes proved to be more acid than in the vicinity of the entry.

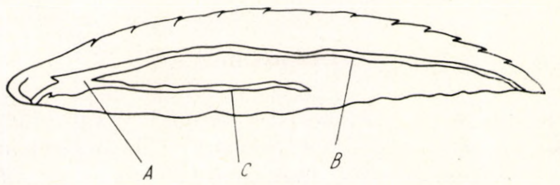

Fig. 3. Schematic drawing of the alimentary canal of *Asellus aquaticus*
A = stomach, B = medium intestine, C = hepatopancreas

3. ábra: Asellus aquaticus emésztőcsatorna vázlatos rajza.
A = gyomor, B = középbél, C = hepatopancreas

Table 5.

The pH conditions of the digestive juices of *Asellus aquaticus*

Number of measurements	Indicator	Hepatopancreas	Stomach + intestine
15	Chlorphenol red	~ 6.0	> 6.0
9	Bromcresol red	3 c ~ 6.1	
		6 c < 6.1	> 6.1
11	Bromthymol blue	< 7.1	3 c > 7.1
			8 c ~ 7.1
12	Neutral red	< 7.4	< 7.4
12	Phenol red	< 7.8	< 7.8
10	Cresol red	< 8.2	< 8.2

5. táblázat

Asellus a uqaticus emésztőnedveinek pH-viszonyai

Mérések száma	Indikátor	Hepatopancreas	Gyomor + bél
15	Klórfenolvörös . .	~ 6,0	> 6,0
9	Brómkresolvörös .	3 e ~ 6,1	
		6 e < 6,1	> 6,1
11	Brómtimolkék . . .	< 7,1	3 e > 7,1
			8 e ~ 7,1
12	Neutrálvörös	< 7,4	< 7,4
12	Fenolvörös	< 7,8	< 7,8
10	Kresolvörös	< 8,2	< 8,2

The pH values of the hepatopancreas of *Asellus aquaticus*, after having been prepared according to the methodics described were measured also with BECKMAN'S pH meter. In the case of 96 animals a mean value of 6.08 was found.

Of the indicators enumerated in the methodical part we did not use bromphenol blue and methyl red because we found in the course of preliminary experiments that their pK falls outside the area of the pH of the digestive juices of the animals examined.

In no species did we determine the pH of the rectum because this is covered by chitin cuticle and, except for *Asellus*, it never showed staining.

Discussion

The Crustaceans examined can be ranged taxonomically in 4 groups (ordo): *Mysidacea (Limnomysis* b) *Amphipoda (Dicerogammarus and Gammarus* r.*)*, *Isopoda (Asellus* a.) and *Decapoda (Astacus l.)*. Our results were compared with the data of other authors in the case of 3 ordines *(Amphipoda, Isopoda, Decapoda)* as in the available literature data were found only for the representatives of these 3 orders.

Our data obtained for the pH conditions of the digestive juices of the species belonging to *Amphipoda* can be well compared with the works of AGRAWAL (1963) and DE GIUSTI and co-workers (1962), although these authors obtained their results with the use of one method (indicator paper or feeding method). Comparison of these results is presented in *Table 6*.

From the Table it appears that our results are nearer to the values found by AGRAWAL and rather differ from the data of DE GIUSTI and co-workers. This is particularly remarkable in the case of the stomach and of the hepatopancreas where regarding the extreme values the deviation is almost 2.0 pH whereas in the 3. third of the medium intestine we obtained values similar to the results of DE GIUSTI.

Table 6.

Comparison of the pH conditions in the digestive tract of the species belonging to the ordo *Amphipoda*

Name of species	Author	Stomach	Hepatopancreas	Medium intestine[1]	End of medium intestine[2]
Corophium volutator	AGRAWAL	6.7	6.2	6.6	—
Hyalella azteca	DE GIUSTI	4.1—4.7	3.8—4.7	6.8—7.2	7.2—7.9
Gammarus limnaeus	DE GIUSTI	4.1—6.3	3.8—4.8	6.4—7.2	7.2—7.9
Dic. vill. bispinosus	P. ZÁNKAI	5.9—6.4	5.8—6.1	7.1—7.4	7.7—8.1
Dic. haem. balatonicus	P. ZÁNKAI	5.8—6.4	5.8—6.1	7.1—7.4	7.6—8.1
Gammarus roeseli	P. ZÁNKAI	6.0—6.6	5.8—6.2	7.1—7.8	7.6—8.0

[1] Medium intestine: results measured in the 2nd third of the medium intestine were ranged here.

[2] End of medium intestine: data of pH conditions found in the 3rd third of the medium intestine were presented here.

6. *táblázat*

Az *Amphipoda* csoporthoz tartozó fajok emésztőtraktusa pH viszonyainak összehasonlítása

Faj neve	Szerző	Gyomor	Hepatopancreas	Középbél[1]	Középbél vége[2]
Corophium volutator	AGRAWAL	6,7	6,2	6,6	—
Hyalella azteca	DE GIUSTI	4,1—4,7	3,8—4,7	6,8—7,2	7,2—7,9
Gammarus limnaeus	DE GIUSTI	4,1—6,3	3,8—4,8	6,4—7,2	7,2—7,9
Dic. vill. bispinosus	P ZÁNKAI	5,9—6,4	5,8—6,1	7,1—7,4	7,7—8,1
Dic. haem. balatonicus	P. ZÁNKAI	5,8—6,4	5,8—6,1	7,1—7,4	7,6—8,1
Gammarus roeseli	P. ZÁNKAI	6,0—6,6	5,8—6,2	7,1—7,8	7,6—8,0

Középbél[1] = a középbél 2. harmadában mért eredményeket soroltuk ide.
Középbél vége[2] = a középbél 3. harmadában talált pH viszonyok adatait tüntettük itt fel.

These deviations can not be motivated with the difference in the nutrients used in the feeding experiments alone (the above mentioned authors used yeast, rice starch, gelatin etc. as feed). On the basis of a number of authors (SRIVASTAVA, RASTOGI and DATTA GUPTA, WATERHOUSE) and of our own experiments we may state with certainty that the pH of the feed is in no connection with the pH of the digestive tract. It may be assumed that the differences are brought about by specific and geographic dissimilarities, by the different environmental conditions and by the conditions of other types of nutrition together. Both *Gammarus limnaeus* and *Hyalella azteca* are characteristic *Amphipoda* of the American continent, on the nutritional conditions of which PENNAK (1953, p. 436) states: Like the decapods, the scuds are omnivorous, general scavangers. As a contrast, the *Amphipoda* examined by us are in the first place herbivorous *(Dicerogammarus)* and only to a small part carnivorous *(Gammarus* r.).

Between *Asellus aquaticus* and the littoral *Ligia oceanica* pertaining also to this group — inspite of the difference in the methods used for the determination of pH — there is much similarity. The pH of the hepatopancreas is 6.0. in *Ligia*, 6.1 in *Asellus* and in the pH of the intestinal juice there are no such great differences *(Asellus* ~7. 1, *Ligia* 6.5) as could be expected.

We found the pH of the gastric juice of *Astacus leptodactylus* to be 5.2 while VONK (1935) refers to a value of 5.0.

Results obtained from the examination of the pH conditions of the digestive tract of the 6 species point out that between the pH of the gastric juice of *Astacus*, *Amphipoda* and *Asellus* there are great differences whereas the pH conditions of the hepatopancreas of the 6 species examined almost agree (6.1 — 6.3). The last third of the medium intestine (*Amphipoda)* or second part respectively *(Limnomysis)* closely agree while in *Asellus* almost neutral pH was measured from stomach to rectum.

It has been established that between beginning and medial part of the medium intestine of *Limnomysis* and *Amphipoda* and its end substantial differences prevailed from the point of view of pH while at the same time in *Asellus* the whole medium intestine exhibited a uniform value.

The phenomenon that the intestinal tract of the species referred to above could be devided or drawn together *(Asellus)* beside the anatomically separated foregut and medium intestine into further parts, can be explained by the expansion of the juices impouring into the intestine. The pH of the whole intestinal tract ought to be determined by the juice of the unique gland producing digestive enzyme, the hepatopancreas of about 6 pH. In the development of the somewhat higher pH of the gastric juice — in our opinion — the anterior dorsal coecum may be involved which occurs in all Crustaceans examined and the physiological role and significance of which is not elucidated so far. In the course of our experiments we found that the nutrient particles get into the anterior dorsal coecum the pH of which is nearly neutral. The beginning or first third of the medium intestine in *Amphipoda* agrees with the pH of the hepatopancreas; subsequently the medium intestine readily tracebly gets alkalized to about 8 pH. This alkalinization is brought about by the posterior dorsal coeca. These are indicated as a secretory organ (KAESTNER 1959) which introduces its secretion into the intestine at the limit of medium intestine and rectum.

According to our examinations the pH conditions of the digestive canals are between certain rather constant limits. They are not essentially influenced by the various seasons, the condition of the animal (starving, repletion). As it was shown, between the orders of Crustaceans there are first of all important differences in the pH of the gastric juice. It is very interesting that the greatest differences can be found exactly between the animals most distant from the aspect of phylogenetic relationship e. g. between *Astacus* and *Asellus* $\sim$ 2.0 pH, between *Amphipoda* and *Astacus* $\sim$ 1. 0. pH. In the first case the degree of relationship is more distant than in the latter.

In our earlier work (PONYI and P. ZÁNKAI 1966) the pH — optimum of the endopeptidase in the hepatopancreas digestive juice of the animals enumerated in the Introduction was examined (substrate: denaturated hemoglobin). It has been established that in *Astacus* the optimum is at 5.2 pH which perfectly coincides with the value obtained at the determination of the pH of the gastric juice. In *Amphipoda* we obtained as pH optimum 6.6—7.1. which essentially does not greatly differ from the natural pH conditions. This is particularly valid in the case of *Gammarus roeseli* where the upper limit of the pH of the gastric juice is 6.6. The pH optimum of the hepatopancreas juice of *Asellus* is marked by the values 5.5—6.0 while the natural pH of the hepatopancreas juice is 6. 1. In the case of *Limnomysis* no similar agreement could be demonstrated. These results seem to verify the assumption of KRISHNA and SAXENA (1963) inasmuch as the later examinations corroborate the presence of several enzymes in the digestive juice and the pH optimum of the signle enzymes coincides with the pH optimum of the enzyme-mixtures constituting the gastric juice.

Summary

The pH conditions of the juices in the alimentary canal of 6 Crustaceans *(Limnomysis benedeni, Dicerogammarus haematobaphes balatonicus, Dicerogammarus villosus bispinosus, Gammarus roeseli, Asellus aquaticus, Astacus leptodactylus* were examined with the aid of 3 methods.

In the case of *Limnomysis* the pH of the stomach $>$ 6.0 or 6.1 respectively and $<$7.1, of the hepatopancreas 6.0 — 6.1 The beginning and the end of the medium intestine can often be separated on the basis of the pH differences. The intestinal juice indicates values of 7.4—7.8 pH.

In *Amphipoda* the anatomically unitary medium intestine can be divided according to the pH conditions of its juice in 3 parts: the pH of part 1 coincides with the pH of the hepatopancreas. Section 2 lasts about to the end of the posterior dorsal coeca, it is often readily recognizable, in other cases indistinct, its pH is sometimes acid (hepatopancreatic effect) in other cases neutral (upon the action of the juice of the posterior dorsal coeca). In the last third of the intestine the pH is always alkaline. The pH conditions of the digestive juices of *Dicerogammarus* are as follows: stomach 5.8 – 6.4, hepatopancreas 5.8–6.1, medium intestine 2nd third 7.1–7.4, medium intestine 3rd third 7.6–8.1. In the case of *Gammarus roeseli*: stomach 6.0–6.6, hepatopancreas 5.8–6.2, medium intestine 2nd third 7.1–7.8, 3rd third 7.6–8.0.

In the case of *Asellus aquaticus* the anatomically readily separating stomach and medium intestine on the basis of the pH of their juices must be drawn together, so the pH of the hepatopancreas is 6.1, that of the stomach and medium intestine nearly neutral.

It has been further established that seasons and starving do not essentially influence the pH of the digestive juices.

Author establishes a parallel between the pH optimum obtained with biochemical methods of the gastric juice of some species and the natural pH conditions.

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NÉHÁNY RÁKFAJ EMÉSZTŐCSATORNÁJÁNAK pH-VISZONYAIRÓL

P.-Zánkai Nóra

Összefoglalás

A szerző;6 rákfaj *(Limnomysis benedeni, Dicerogammarus haematobaphes balatonicus Dicerogammarus villosus bispinosus, Gammarus roeseli, Asellus aquaticus, Astacus leptodactylus)* emésztőcsatornájában levő nedvek pH viszonyait vizsgálta 3 módszer segítségével.

A *Limnomysis* esetében a gyomor pH-ja > 6,0 ill. 6,1 és < 7,1, a hepatopancreas 6,0–6,1. A középbél eleje és vége gyakran szétválasztható a pH különbségek alapján. A bélnedv 7,4–7,8 pH értékeket mutat.

Az *Amphipodáknál* az anatómiailag egységes középbél a benne levő nedv pH viszonyai alapján 3 részre osztható: 1 rész pH-ja megegyezik a hepatop. pH-jával. A 2. szakasz kb. a hátulsó dorsális coeca-k végéig tart, gyakran jól felismerhető, máskor elmosódik, pH-ja némelykor savas (hepatop. hatás), máskor semleges (hátulsó dorsalis coeca-k nedvének hatására). A bél utolsó harmadában a pH mindig lúgos. A *Dicerogammarusok* emésztőnedveinek pH viszonyai a következőképpen alakulnak: gyomor 5,8–6,4, hepatop. 5,8–6,1, középbél 2. harmad 7,1–7,4, középbél 3. harmad 7,6–8,1. A *Gammarus roeseli* esetében: gyomor 6,0–6,6, hepatop. 5,8–6,2, középbél 2. harmad 7,1–7,8, 3. harmad 7,6–8,0.

Az *Asellus aquat.* esetében az anatómiailag jól elkülönülő gyomrot és közepbelet nedveik pH-ja alapján össze kell vonni, így a hepatop. pH-ja 6,1, a gyomor + középbél közel semleges.

Megállapítást nyert továbbá, hogy az évszakok, az éhezés nem befolyásolja jelentősen az emésztőnedvek pH-ját.

A szerző párhuzamba állítja egyes fajok emésztőnedvének biokémiai módszerekkel kapott pH optimumát és a természetes pH viszonyokat.

ОБ УСЛОВИЯХ pH В ПИЩЕВАРИТЕЛЬНОМ ТРАКТЕ НЕКОТОРЫХ ВИДОВ РАЧКОВ

Нора Р.-Занкаи

Изучали pH тремя методами в пищеварительном тракте 6 видов рачков *(Limnosys benedeni, Dicerogammarus haematobaphes balatonicus, Dicerogammarus vielosus bispinosus, Gammarus, roeseli, Asellus aquaticus.*

У *Lymnomysis* pH желудка 6,0 или 6,1 и 7,1, гепатопанкреас 6,0–6,1. По различию pH часто можно выделить в кишке переднюю и заднюю части. pH кишечного сока 7,4–7,8.

У амфипод среднюю кишку, несмотря на ее анатомическую однородность, можно разделить на три части: pH первой части соответствует pH гепатопанкреаса; pH средней части кислый или нейтральный, а задней всегда основной. pH пищеварительных соков *Dicerogammarus:* желудок 5,8—6,4, гепатопанкреас 5,8—6,1, 2-ая часть средней кишки 7,1—7,4, 3-ья часть средней кишки 7,6—8,1. У *Gammarus roeseli:* желудок 6,0—6,6, гепатопанкреас 5,8—6,2, 2-ая часть средней кишки 7,1—7,8, 3-ья часъ средней кишки 7,6—8,0.

У *Asellus aquaticus* pH гепатопанкреаса 6,1, а желудка и средней кишки почти нейтрален, хотя анатомически желудок и средняя кишка представляют хорошо различимые отделы.

Сезоны и голодание не влияют на pH пищеварительных соков.

Определенный биохимически оптимум pH для пищеварительных соков сопоставляли с естественным pH соответствующих отделов.