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On the Hydrogen-Ion Concentration in the Alimentary Canal of the Coleoptera

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Introduction

In an earlier paper on the hydrogen-ion concentration of certain Orthopteroid insects, the authors (Srivastava & Srivastava, 1956) had concluded that within a particular group of insects, the hydrogen-ion concentration of the different parts of the alimentary canal shows a limited range within which the variation observed from insect to insect may be related to the feeding habit. It was also shown that while the difference in the hydrogen-ion concentration of the various kinds of food may affect the hydrogen-ion concentration of the fore-gut and the hind-gut of an insect, it does not influence the hydrogen-ion concentration of the mid-gut which shows a great deal of constancy. These conclusions were based on a study of the hydrogen-ion concentration of 15 species of relatively primitive groups, and it appears necessary to check their validity by observations in some other order, preferably a highly evolved one. In the present paper, therefore, the authors have given the hydrogen-ion concentration of the different parts of the alimentary canal of 16 species of *Coleoptera* belonging to 12 families and with diverse food habits. In some cases, both larvae and adults of the same species were examined.

Material and technique

The names of the insects examined, along with their families and food habits, have been given in Table 1. The method of determining the pH was broadly the same as described before (Srivastava & Srivastava, 1956). But in certain cases, efforts to feed the insects on bits of pH paper have succeeded. In these cases, the alimentary

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canal was cut open and the pH of the different regions was noted by comparing the colour of the paper inside with those of the chart The results thus obtained were checked by the method of direct contact of the gut contents with the pH paper. The pH of blood of these insects was also recorded.

The results given are the mean of at least five experiments

Table 1

	Names of insects	Food habits
1	*Hydrophilus* sp (*Hydrophilidae*)	Free feeder
2.	*Sternolophus decens* Zaitzev (*Hydrophilidae*)	Free feeder.
3	*Dorcus parallelopipedus* L (*Lucanidae*)	Phytophagous, feeds upon wood in which it bores
4	*Elater rufipennis* Stephens (*Elateridae*)	Phytophagous, feeds upon wood in which it bores
5	*Pheropsophus lineiformis* Chaud (*Carabidae*)	Carnivorous
6	*Coccinella septempunctata* L (*Coccinellidae*)	Carnivorous, predator upon aphids
7.	*Epilachna* 28-*punctata* Fabr (*Coccinellidae*)	Phytophagous, leaf-eating
8	*Aulacophora foveicollis* Fabr (*Chrysomelidae*)	Phytophagous, leaf eating
9	*Phaedon cochleariae* Fabr (*Chrysomelidae*)	Phytophagous, eats cruciferous leaves
10	*Cylas formicarius* Fabr (*Curculionidae*)	Phytophagous, eats leaves and tubers
11	*Mylabris phalerata* Pall (*Meloidae*)	Phytophagous, flower eating
12	*Bruchus analis* Fabr (*Bruchidae*)	Phytophagous, eats stored pulses
13	*Tenebrio molitor* L (*Tenebrionidae*)	Phytophagous, eats flour
14	*Tribolium castaneum* Herbst (*Tenebrionidae*)	Phytophagous, eats flour
15	*Dermestes maculatus* Degeer (*Dermestidae*)	Saprophagous (zoosaprophagous), feeds upon wool
16	*Onitis distinctus* Lansb (*Scarabaeidae*)	Saprophagous (scatophagous), eats excrement

Observation

The hydrogen-ion concentration of the fore-gut, mid-gut, hind-gut and blood of the different beetles examined has been given in Table 2.

It is remarkable that the total range of pH in the different parts of the alimentary canal of any beetle is not very large. The maximum difference between the lowest and the highest pH is noted in *Elater rufipennis* (5.2 in the fore-gut and 6.4 in the mid-gut), while in *Phaedon cochleariae*, it is 6.0 in the fore-gut and 7.0 in the hind-gut with the mid-gut pH being 6.4 to 6.6. The minimum range is seen in the adult of *Cylas formicarius* in which it is 6.4 to 6.7 with 6 4 in the mid-gut and 6.7 in the fore-gut, and in *Onitis distinctus* in which it is 6.2 to 6.5 with 6.2 in the hind-gut and 6.5 in the mid-gut.

The range of variation of the pH in the different parts of the gut in different insect varies. In the fore-gut, it is 5.2 (*Elater rufipennis* adult) to 6.8 (*Coccinella septempunctata* and *Epilachna* 28-*punctata* grubs); in the

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mid-gut it is 5.4 (*Sternolophus decens* adult) to 6.8 (*Tribolium castaneum* grubs) with a near maximum pH of 6.6 to 6.7 in the mid-gut of *Phaedon cochlerariae*, *Cylas formicarius* and *Tenebrio molitor*; and in the hind-gut it is 5.3 (*Pheropsophus lineifrons*) to 7.0 (*Phaedon cochlerariae* and *Tenebrio molitor* grubs).

It will also be noted that the range of pH of blood in the different beetles is 6.2 to 6.8 and in several cases there is a close correspondence between the pH of mid-gut and blood. But in *Sternolophus decens*, there is a considerable difference between the two, i. e. 1.2.

Table 2. Hydrogen-ion concentration

Insect		Fore-gut	Mid-gut	Hind-gut	Blood	Remarks
1. *Hydrophilus* sp.	a[1])	6.2	6.4	6.4—6.6	6.4	
2. *Sternolophus decens*	a	5.6	5.4	6.4	6.6	Lowest mid-gut pH and max. difference in mid-gut and blood pH.
3. *Dorcus parallelopipedus*	a	6.4—6.6	6.6	6.6—6.8	6.6	
4. *Elater rufipennis*	a	5.2	6.4	6.0—6.2	6.4	
5. *Pheropsophus lineifrons*	a	5.4	6.2	5.3	6.8	
6. *Coccinella septempunctata*	a	6.0—6.2	6.2	6.4	6.2	
—	g[1])	6.4—6.8	6.4	6.4	6.4	
7. *Epilachna 28-punctata*	a	6.2	6.0	5.4—5.7	6.4	
—	g	6.4—6.8	6.0	6.0	6.4	
8. *Aulacophora foveicollis*	a	6.0	6.2—6.4	6.2	6.4	
9. *Phaedon cochlerariae*	g	6.0—6.2	6.4—6.6	6.8—7.0	6.5	Highest mid-gut pH
10. *Cylas formicarius*	a	6.4	6.7	6.7	6.4	
11. *Mylabris phalerata*	a	6.2	6.2—6.4	6.0	6.6	
12. *Bruchus analis*	a	6.6	6.4	6.2	6.2	
13. *Tenebrio molitor*	a	6.2—6.4	6.4	6.6	6.5	
—	g	6.2—6.3	6.6	6.6—7.0	6.5	
14. *Tribolium castaneum*	g	6.4	6.6—6.8	6.4	6.4	
15. *Dermestes maculatus*	a	6.4—6.6	6.0—6.2	6.0	6.2	
16. *Onitis distinctus*	a	6.4	6.5	6.2	6.8	

[1]) 'a' stands for adult; 'g' for grub.

Discussion

Swingle (1931 a) examined the hydrogen-ion concentration of 21 species of beetles (including both adults and larvae of several species) and of these the range of pH of the fore-gut of 16 species was within the range noted by us, but the remaining had a higher pH going up to 8.6. Similary in 14 cases, the range of the pH of the mid-gut fell within the range recorded here, viz. 5.4 to 6.8, while the remaining had a much higher pH reaching up to 9.5, the highest being recorded in *Passalus cornutus* adult, *Popillia japonica* larva and *Pelidnota punctata*. In the hind-gut also, the pH of 15 insects fell within the range noted by us whereas the remaining even had a higher pH reaching up to a maximum of 8.12 in the *Cerambycidae*. Srivastava's observation in *Epilachna vigintiopunctata* (1957), on the other

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hand, is completely in line with our present observations. It may also be mentioned that, on the basis of his observations in *Coleoptera* and other orders, SWINGLE (1931 a) had concluded that the alimentary canal of insects is slightly acidic. Our results in the *Coleoptera* are in conformity with these conclusions, although SWINGLE himself had noted an alkaline medium in several beetles and in the *Lepidoptera*. The range of pH noted by us is 5.2 to 6.8. SHINODA (1930) and STAUDENMEYER (1940) had noted that the mid-gut content of the wood-eating beetles is alkaline, but in *Elater* and *Dorcus*, which also feed upon wood, we do not find this condition. In fact, if we take into account the diversity of the food of the beetles examined and the comparatively small pH range, we are led to conclude that the nature of food or feeding habit does not have any significant bearing upon the pH of the alimentary canal. SWINGLE (1931 a and b) also could not establish any correlation between the pH value of the gut and the type of food of an insect. He fed larvae of *Popillia japonica* on soil samples of very different pH values and found that this did not alter the pH of the gut to any considerable degree. These facts are, however, in contradiction of the views of WIGGLESWORTH (1927) who does not think that the pH of gut is a physiological constant of an insect, because he found difference in the pH of exclusively protein-fed and exclusively carbohydrate-fed *Blattella germanica* L. However, the difference under these two conditions was very slight (6.4 and 6.3), and, therefore, he also thought that there existed a relative constancy in the pH of the stomach. In the larvae of the fruit-fly, *Dacus cucurbitae* COQUILLETT, the authors (SRIVASTAVA & SRIVASTAVA, 1957) have noted that with the decay of the fruit pulp and the consequent change in the pH, the insects move deeper into the fruit. This may not be entirely due to the pH, but it is clear that the food of the larvae does not have the same pH. Nevertheless, the pH of the gut does show a constancy. These facts lead to the only conclusion that a buffer mechanism exists in the mid-gut of insects and this mechanism may differ from species to species.

It may be possible, however, that although change in the nature of food of a certain insect may not bring about any change in the pH of its mid-gut, adaptation to a particular type of feeding habit might have led to different pH in different insects. Perhaps no group of insects shows a greater diversity of feeding habits than the *Coleoptera*, with its members feeding upon wood, fruits, flowers, leaves, humus, leather, animal tissue, etc., but the range of pH is still not large and in the insects examined by us we find the range of mid-gut pH to be only 5.4 to 6.8. Similarly in the *Hymenoptera*, SWINGLE (1931 a) found it to be 6.48 to 7.28. In the *Orthoptera*, it is 6.15 to 7.28. In the *Lepidoptera*, the work of WATERHOUSE (1949), GRAYSON (1951) and others shows this range to be small and clearly alkaline. This confirms our earlier view that the pH range of the mid-gut of majority of insects is determined primarily by the group to which they

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belong, and this, in turn, depends upon the existence of some kind of a buffer mechanism. Since the range of pH in different groups itself differs, it also follows that the different groups possess different kinds of buffer mechanisms.

From the data now available, we may also state that in the majority of insects, the medium in the mid-gut is more or less neutral, and this may tend towards slight acidity; but this cannot be considered a rule since there are whole groups of insects, like the *Lepidoptera* and *Trichoptera*, in which the pH is distinctly high and in the alkaline range.

Summary

1. The hydrogen-ion concentration of the fore-gut, mid-gut, and hind-gut and blood of sixteen species of *Coleoptera*, belonging to 12 families has been determined. It ranges from 5.2 to 6.8, 5.4 to 6.8, and 5.3 to 7.0 in the fore-gut, mid-gut and hind-gut respectively.

2. The total range of pH in the different parts of the alimentary canal is very small, the difference between the maximum and minimum being only 1.2.

3. On the whole, the alimentary canal may be said to be slightly acidic.

4. In most cases, there is a close correspondence between the pH of mid-gut and blood.

5. There does not appear to be any relationship between the feeding habit and pH of the alimentary canal. On the other hand, the pH seems to be related to the group to which an insect belongs.

6. The existence of different kinds of buffer mechanisms in groups of insects with different pH ranges is inferred.

Zusammenfassung

1. Die Wasserstoffionenkonzentration des Vorder-, Mittel- und Enddarmes sowie des Blutes von 16 Coleopteren-Arten (zu 12 verschiedenen Familien gehörig) wurde bestimmt. Sie beträgt zwischen 5,2 und 6,8 im Vorderdarm, 5,4 und 6,8 im Mitteldarm und zwischen 5,3 und 7,0 im Enddarm.

2. Der Gesamtbereich des pH-Wertes in den verschiedenen Teilen des Verdauungskanals ist sehr gering. Die Differenz zwischen Maximum und Minimum beträgt nur 1,2.

3. Insgesamt kann man den Verdauungskanal als schwach sauer bezeichnen.

4. In den meisten Fällen zeigt sich eine enge Beziehung zwischen dem pH-Wert des Mitteldarmes und dem des Blutes.

5. Offenbar besteht keine Beziehung zwischen der Ernährungsweise und dem pH-Wert des Verdauungskanals. Andererseits scheint der pH-Wert charakteristisch für gewisse Insektengruppen zu sein.

6. Das Vorhandensein von verschiedenen Puffer-Mechanismen bei Insektengruppen mit verschiedenen pH-Bereichen wird vermutet.

Резюме

1. Определялась концентрация ионов водорода передней, средней и прямой кишки, а также крови 16 видов *Coleoptera* (принадлежащех к 12 различным семействам). Она составляет 5,2 до 6,8 в передней кишке, 5,4 до 6,8 в средней кишке и 5,3 до 7,0 в прямой кишке.

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2. Общий предел величины pH в различных частях пищеварительного тракта очень невелик. Разница между максимумом и минимумом составляет только 1,2.

3. В общем можно обозначить пищеварительный тракт слабо кислым.

4. В большинстве случаев проявляется тесная связь между величиной pH средней кишки и крови.

5. Очевидно нет никакой связи между способом питания и величиной pH пищеварительного тракта. С другой стороны величина pH повидимому характерна для известных групп насекомых.

6. Наличие различных буферных механизмов у групп насекомых с неодинаковыми пределами pH предполагается.

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