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# The Rate of Passage of Foodstuffs through the Alimentary Tracts of Certain *Microtidae* Under Laboratory Conditions

## Szybkość przechodzenia treści przez przewód pokarmowy niektórych *Microtidae* w warunkach laboratoryjnych

[With 5 Tables & 3 Figs.]



## I. INTRODUCTION

The rate of passage of foodstuffs through the alimentary tract has long since aroused the interest of research workers, primarily on account of the importance of this problem in the rearing of animals and also in research on metabolism. A very considerable amount of data is available in literature on the rate of passage of different foodstuffs through the alimentary tract of domestic animals and those intended for industrial purposes (Lenkeit & Habeck, 1930; Lenkeit, 1931; Balch, 1950; Mangold & Behm, 1954; Neseni, Lecht & Schewen, 1955; Castle, 1956; Castle & Castle, 1956, 1957; Neseni & Piatkowski, 1958; Koźniewski, 1961; Horszczaruk, 1962; Sławiński, Bednarz & Sławoń, 1962; Sławiński, Sławoń & Bednarz, 1962). A few authors have investigated this problem in relation to wild animals (Honigman, 1956; Gill, 1957, 1959,

1960), in particular rodents (Velitshko & Mokejeva, 1949; Velitshko, 1956; Pravdina, 1958; Gill & Bieguszewski, 1960). A better knowledge of the course taken by this process in *Rodentia* is interesting on account of the specific structure of the alimentary tract in these mammals and the relative ease with which the rapid evolution connected with the transition from the feeding on protein food to cellulose food can be traced in these animals (Vorontsov, 1962).

Our work was therefore aimed at investigating and comparing the rate of passage of foodstuffs through the alimentary tract of certain *Microtidae* differing as to the kind of food they eat (seeds, green plants) and as to the structure of the alimentary system. It was also decided to trace the course taken by this process in both sexes of these rodents. The investigations were made on *Clethrionomys glareolus* (Schreber, 1780), *Microtus agrestis* Linnaeus, 1761, *Microtus arvalis* (Pallas, 1779) and *Microtus nivalis* Martins, 1842, which belong to two well distinguished genera of *Microtidae* (Table 1).

Harder (1950) divided rodents into those feeding on seed food and those on the green parts of plants, while Voronov (1954) distinguished yet another group of *Rodentia,* the omnivorous group. *C. glareolus* represents the group of which the basic food is formed by seeds (Naumov, 1948; Miller, 1954; Vorontsov, 1961; Górecki & Gębczyńska, 1962), and *M. arvalis* is a typical representative of the rodents which feed on the green parts of plants (Naumov, 1948; Golenistschev, 1952; Kagantsova, 1954; Voronov, 1954; Bashenina, 1962). *M. agrestis* feeds on both grain and the green parts of plants, with a slight preference for grain according to Naumov (1948), and according to Nasarova (1958). a preference for green plants. We know from literature that *M. nivalis* feeds chiefly on the green parts of plants (Bauman, 1949; Ognev, 1950; Zimmermann, 1959; Kowalski, 1964), but there are no detailed data on the composition of the food of this species.

The different food relations of the species of rodents referred to are reflected in the structure of their digestive systems. Numerous authors maintain that *Rodentia*, the basic food of which is formed by green plants, have a very strongly developed caecum and large intestine (Naumov, 1948; Harder, 1950; Schwarz, 1960; Vorontsov, 1962), in which the digestion of cellulose, with the participation of specific microflora, takes place (Velitshko & Mokejeva, 1949; Golley, 1960). Rodents feeding on seed foods, on the other hand, have a shorter posterior part of the intestine, and longer small intestine, in which starch and protein are digested (Naumov, 1948; Kulajeva, 1958; Vorontsov, 1962). Of the animals examined *M. arvalis* has the most strongly developed caecum and large intestine, and a relatively short small intestine; in the case of *M. agrestis* the small intestine is slightly longer and the posterior part of the digestive system shorter (Nasarova, 1958); in *C. glareolus* the relative lengths of each section of the intestines form the opposite of the above — the small intestine is the longest, and the caecum and large intestine shortest (Naumov, 1948; Kulajeva, 1958).

## II. INVESTIGATION METHODS

Use was made in our experiments of the stained food method worked out by Lenkeit & Habeck (1930) and Mangold (1950), improved by Castle (1956) and modified by Gill (1957), using basic fuchsin as the colouring agent. In the

experiments concerned with the passage of the green parts of plants, *M. arvalis*, *M. agrestis* and *M. nivalis* were fed with *Arrhenatherum elatius* L., *Trifolium* sp. and *Taraxacum officinale* Web., and *C. glareolus* received *Viola silvestris* Rchb., *Oxalis acetosella* L., *Pulmonaria obscura* Dum. — defined by Górecki & Gębczyńska (1962) as some of the species of plants most readily eaten by this rodent, and also 1 g. of wheat grain. The addition of grain proved essential, as *C. glareolus* was found to lose weight and die when kept on an exclusively green diet. This was the cause of the limited number of animals in this experiment. During the experiments on the rate of passage of grain through the alimentary tract in all four species of *Microtidae* examined, the animals were fed with wheat grain. Since under natural conditions acorns form one of the basic components of the food of *C. glareolus* (Górecki & Gębczyńska, 1962), their rate of passage through the alimentary system of these animals was also examined for purposes of comparison with the rate of passage of wheat. The indicator of the passage of foodstuffs through the alimentary tract was always the stained portion of the food with which the animals were fed during the experiment. They were given the stained food at 10 a.m., and this was followed after one hour by a similar, but not stained, portion of food.

**Table 1.**

Number of individuals examined.

| Species / Kind of food | M. arvalis | | M. agrestis | | C. glareolus | | M. nivalis | |
|---|---|---|---|---|---|---|---|---|
| | ♂♂ | ♀♀ | ♂♂ | ♀♀ | ♂♂ | ♀♀ | ♂♂ | ♀♀ |
| Green parts of plants | 15 | 15 | 15 | 15 | 6 | 3 | 5 | 2 |
| Wheat grains | 15 | 15 | 15 | 15 | 15 | 15 | 4 | 2 |
| Acorns | – | – | – | – | 4 | 3 | – | – |
| Total | 60 | | 60 | | 46 | | 13 | |

Excrement was collected at intervals of one hour, then dried at a temperature of about 60°C, and each portion weighed on a torsion balance with accuracy of up to 0.5 mg., then diluted with 0.02 ml. of water to each mg., and thoroughly mixed. The stained food was calculated in each sample in five fields of vision of the microscope, magnified 150 times, using the Fuchs-Rosenthal camera ensuring that layers of uniform thickness were obtained. A total of 8000 samples of excrement were examined. The total amount of stained food calculated in all the samples coming from one animal were taken as 100%, then calculation was made of the percentage of test food excreted in each hour of the experiment. Taking these data as a basis, curves were drawn according to Balch (1950) illustrating the course taken by the passage of food through the alimentary tract of the animals examined in each of the experiments. *R* values (Castle, 1956), being the mean time of retention of food in the digestive system of the animals and enabling a comparison of the curves throughout their entire length to be made, were determined, and calculation made of the times of excretion of 5%, 50%, 90% and 100% of the stained food in each of the experiments. All these values were compared by the *t*-Student test for the difference in the mean values for two independent groups, and calculation made for them of the divisions of confidence based on the variable *t*.

The animals were placed singly in wooden cages measuring 40 × 15.5 × 17.5 cm., from 4 to 7 days before the beginning of the experiment. Each cage contained

a wooden six-sided house, each side measuring 9 cm. in width, filled with paper shavings. These houses served as nests during the preparatory period. During the actual experiment the houses were taken out of the cages. A metal net was placed at a height of 1.5 cm. above the bottom of each cage, which permitted of the frequent collection of excrement without disturbing the rodents. The animals were fed on the same kind of food both during the preparatory period and during the experiment.

During the experiments endeavour was made to maintain uniform temperature and humidity conditions in the places in which the rodents under examination were kept (temperature about 20°C, humidity about 80%).

## III. RESULTS

### 1. Passage of the green parts of plants (Tables 2, 4; Fig. 1)

The process of excretion of the indicator began in all the species examined in the first hour of the experiment, and was completely finished after the lapse of 17—18 hours. *C. glareolus* excreted 50% of the indicator most rapidly (34.80%/hour), *M. agrestis* more slowly (25.20%/hour) and *M. arvalis* (18.60%/hour) and *M. nivalis* (14.40%/hour) the slowest. With this distribution of passage rate the main mass of the test food also passes through the alimentary tract of *C. glareolus* most rapidly, that is, after 3—3.5 hours. In the case of *M. agrestis* this process takes slightly longer (3.5—4 hours), while it is slowest in the case of *M. arvalis* (4—4.5 hours) and *M. nivalis* (5—6 hours). After the passage of the main mass of the indicator the rate of excretion gradually decreased in all the species and the lowest value was attained with the excretion of the final 10% of stained food (about 1%/hour). The differences discussed between the species of animal examined, occurring in the rate of excretion of the test food, are reflected in the *R* values, which are lower in *M. agrestis* and *C. glareolus* in comparison with *M. arvalis* and *M. nivalis* (Table 2).

Comparison of *R* values and excretion times of 5%, 50%, 90% and 100% of the indicator revealed statistically significant differences in many cases (Table 3). The statistical analysis made shows that excretion of the first 50% of test food takes a similar course in the case of *C. glareolus* as it does in that of *M. agrestis*, and of *M. arvalis* as in that of *M. nivalis*. On the other hand, the course taken by the passage of the remainder of the indicator is similar in representatives of the genus *Microtus*, thus differing from *C. glareolus*. In general, however, the excretion of the green parts of plants is very similar in all the species examined (Fig. 1).

**Table 2.**

Description of the course taken by excretion of the green parts of plants.

| No. | Sex | Excretion time of stained food /hours and minutes/ | | | | R values |
|---|---|---|---|---|---|---|
| | | 5% | 50% | 90% | 100% | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Microtus arvalis | | | | | | |
| 1 | MALES | 1.04 | 2.56 | 7.03 | 21.00 | 3.08 |
| 2 | | 0.31 | 2.48 | 6.50 | 17.00 | 3.25 |
| 3 | | 1.06 | 2.14 | 5.55 | 16.00 | 3.12 |
| 4 | | 0.42 | 2.54 | 6.49 | 19.00 | 3.33 |
| 5 | | 1.08 | 2.23 | 4.41 | 17.00 | 2.40 |
| 6 | | 0.14 | 2.15 | 7.15 | 15.00 | 2.58 |
| 7 | | 1.04 | 2.45 | 6.00 | 18.00 | 3.18 |
| 8 | | 1.13 | 4.07 | 7.36 | 17.00 | 4.13 |
| 9 | | 0.28 | 2.46 | 7.46 | 19.00 | 3.34 |
| 10 | | 0.19 | 2.06 | 5.39 | 16.00 | 2.38 |
| 11 | | 0.45 | 3.01 | 6.49 | 17.00 | 3.28 |
| 12 | | 1.00 | 2.28 | 5.58 | 15.00 | 2.59 |
| 13 | | 1.08 | 2.33 | 6.10 | 18.00 | 3.10 |
| 14 | | 0.25 | 2.34 | 5.33 | 18.00 | 3.07 |
| 15 | | 0.16 | 2.36 | 7.25 | 17.00 | 3.17 |
| $\bar{X}_{♂♂}$ | | 0.46 ± 0.11 | 2.42 ± 0.15 | 6.30 ± 0.29 | 17.18 ± 1.00 | 3.15 ± 0.09 |
| 16 | FEMALES | 1.08 | 2.32 | 7.23 | 20.00 | 3.22 |
| 17 | | 0.42 | 1.55 | 5.17 | 20.00 | 2.40 |
| 18 | | 1.05 | 3.05 | 6.32 | 17.00 | 3.36 |
| 19 | | 0.36 | 2.14 | 5.06 | 21.00 | 2.39 |
| 20 | | 0.31 | 2.38 | 6.09 | 16.00 | 2.59 |
| 21 | | 0.28 | 2.23 | 7.32 | 20.00 | 3.14 |
| 22 | | 0.26 | 2.34 | 7.28 | 17.00 | 3.22 |
| 23 | | 1.10 | 2.58 | 6.56 | 18.00 | 3.50 |
| 24 | | 1.02 | 2.33 | 5.01 | 19.00 | 2.58 |
| 25 | | 0.20 | 2.55 | 5.55 | 16.00 | 3.19 |
| 26 | | 1.13 | 2.43 | 7.01 | 17.00 | 1.57 |
| 27 | | 0.42 | 2.27 | 6.35 | 16.00 | 3.07 |
| 28 | | 1.08 | 3.12 | 7.10 | 17.00 | 3.50 |
| 29 | | 0.18 | 2.36 | 4.40 | 14.00 | 2.40 |
| 30 | | 0.55 | 3.17 | 6.19 | 16.00 | 3.34 |
| $\bar{X}_{♀♀}$ | | 0.44 ± 0.14 | 2.40 ± 0.14 | 6.20 ± 0.16 | 17.36 ± 1.06 | 3.08 ± 0.19 |
| $\bar{X}_{♂♂+♀♀}$ | | 0.45 ± 0.09 | 2.41 ± 0.09 | 6.25 ± 0.15 | 17.27 ± 0.43 | 3.11 ± 0.10 |
| Microtus agrestis | | | | | | |
| 1 | MALES | 0.26 | 1.58 | 4.47 | 14.00 | 2.25 |
| 2 | | 0.32 | 2.16 | 5.56 | 15.00 | 3.07 |
| 3 | | 1.03 | 1.58 | 4.33 | 15.00 | 2.30 |
| 4 | | 0.08 | 1.15 | 2.47 | 13.00 | 1.26 |
| 5 | | 0.38 | 1.45 | 4.48 | 14.00 | 2.27 |
| 6 | | 1.05 | 2.39 | 6.47 | 18.00 | 3.37 |
| 7 | | 0.07 | 1.09 | 4.19 | 19.00 | 1.41 |
| 8 | | 0.07 | 1.17 | 3.45 | 20.00 | 1.42 |
| 9 | | 0.10 | 1.34 | 4.37 | 19.00 | 2.13 |
| 10 | | 0.07 | 1.06 | 2.52 | 19.00 | 1.36 |
| 11 | | 1.00 | 1.48 | 3.56 | 17.00 | 2.38 |
| 12 | | 0.09 | 1.37 | 9.24 | 19.00 | 2.55 |
| 13 | | 0.11 | 1.33 | 5.32 | 18.00 | 2.22 |
| 14 | | 0.08 | 1.17 | 4.13 | 19.00 | 1.49 |
| 15 | | 0.07 | 1.19 | 8.00 | 17.00 | 2.43 |
| $\bar{X}_{♂♂}$ | | 0.24 ± 0.12 | 1.38 ± 0.15 | 5.02 ± 0.66 | 17.04 ± 1.24 | 2.21 ± 0.25 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 16 | | 0.36 | 1.51 | 5.15 | 14.00 | 2.24 |
| 17 | | 1.05 | 2.21 | 5.37 | 17.00 | 2.59 |
| 18 | | 2.03 | 4.03 | 10.25 | 16.00 | 4.43 |
| 19 | | 0.31 | 2.50 | 5.57 | 23.00 | 3.01 |
| 20 | | 0.12 | 1.35 | 5.23 | 17.00 | 2.17 |
| 21 | | 0.20 | 2.41 | 10.24 | 17.00 | 3.54 |
| 22 | | 0.26 | 2.46 | 11.41 | 17.00 | 4.31 |
| 23 | | 0.30 | 2.17 | 8.01 | 18.00 | 3.34 |
| 24 | | 0.08 | 1.28 | 4.08 | 17.00 | 1.55 |
| 25 | | 1.16 | 5.00 | 9.35 | 17.00 | 4.57 |
| 26 | | 0.38 | 2.06 | 9.24 | 18.00 | 4.05 |
| 27 | | 0.06 | 1.06 | 5.27 | 17.00 | 2.10 |
| 28 | | 0.26 | 1.47 | 7.56 | 18.00 | 3.07 |
| 29 | | 0.25 | 2.10 | 9.00 | 18.00 | 3.26 |
| 30 | | 0.07 | 1.09 | 2.48 | 19.00 | 1.21 |
| $\bar{x}$ ♀♀ ♀♀ | | 0.35 ± 0.18 | 2.21 ± 0.35 | 7.17 ± 1.40 | 17.32 ± 1.10 | 3.16 ± 0.32 |
| $\bar{x}$ ♂♂+♀♀ ♀♀ | | 0.30 ± 0.10 | 1.59 ± 0.18 | 6.09 ± 0.56 | 17.18 ± 0.51 | 2.48 ± 0.19 |
| Microtus nivalis | | | | | | |
| 1 | o | 0.45 | 3.24 | 10.00 | 20.00 | 4.31 |
| 2 | o | 0.17 | 2.39 | 6.57 | 17.00 | 3.16 |
| 3 | o | 0.36 | 1.58 | 5.25 | 16.00 | 2.27 |
| 4 | o | 0.14 | 4.11 | 6.50 | 20.00 | 4.16 |
| 5 | o | 1.54 | 5.16 | 7.57 | 16.00 | 5.22 |
| 6 | ♀ | 0.31 | 2.36 | 10.28 | 17.00 | 3.50 |
| 7 | ♀ | 0.29 | 3.47 | 7.20 | 19.00 | 3.54 |
| | $\bar{x}$ | 0.41 ± 0.28 | 3.25 ± 1.00 | 7.51 ± 1.40 | 17.52 ± 2.00 | 3.57 ± 0.50 |
| Clethrionomys glareolus | | | | | | |
| 1 | o | 1.04 | 1.44 | 14.53 | 19.00 | 4.53 |
| 2 | o | 0.08 | 1.28 | 5.20 | 18.00 | 2.18 |
| 3 | o | 0.12 | 1.44 | 8.08 | 15.00 | 2.48 |
| 4 | o | 0.10 | 1.30 | 11.01 | 16.00 | 3.04 |
| 5 | o | 0.06 | 0.57 | 7.23 | 16.00 | 2.40 |
| 6 | o | 0.06 | 0.59 | 10.24 | 18.00 | 3.44 |
| 7 | ♀ | 0.06 | 0.57 | 5.20 | 21.00 | 1.58 |
| 8 | ♀ | 0.08 | 2.28 | 9.06 | 13.00 | 3.08 |
| 9 | ♀ | 0.06 | 1.05 | 11.31 | 19.00 | 3.23 |
| | $\bar{x}$ | 0.14 ± 0.14 | 1.26 ± 0.23 | 9.14 ± 2.23 | 17.13 ± 2.00 | 3.06 ± 0.40 |

**2. Passage of seeds (Tables 4, 5; Fig. 2)**

Stained particles appeared in the excretions of all the species during the first hour of the experiment. 50% of the test food is most rapidly excreted by *C. glareolus* (6%/hour), and most slowly by *M. arvalis* (4.29%) *M. agrestis* occupies an intermediate position (5%/hour), also *M. nivalis* (5.40%/hour). The main mass of the test food also passes most rapidly through the alimentary tract of *C. glareolus* (16 hours), more slowly in the case of *M. nivalis* and *M. agrestis* (17.5 hours), and most slowly with *M. arvalis* (19 hours). After 75% of the indicator has been excreted, excretion gradually slows down and the final 10% was excreted by the

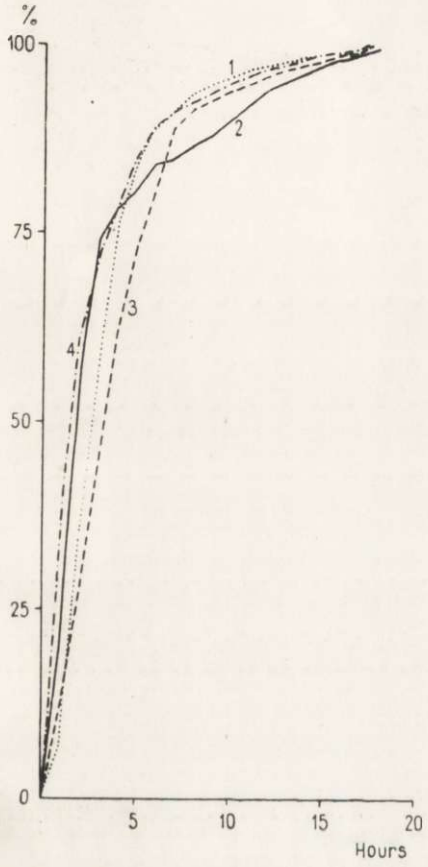


Fig. 1. Average course taken by excretion of the red stained green parts of plants.

1 — *M. arvalis*, 2 — *M. agrestis*, 3 — *M. nivalis*, 4 — *C. glareolus*.

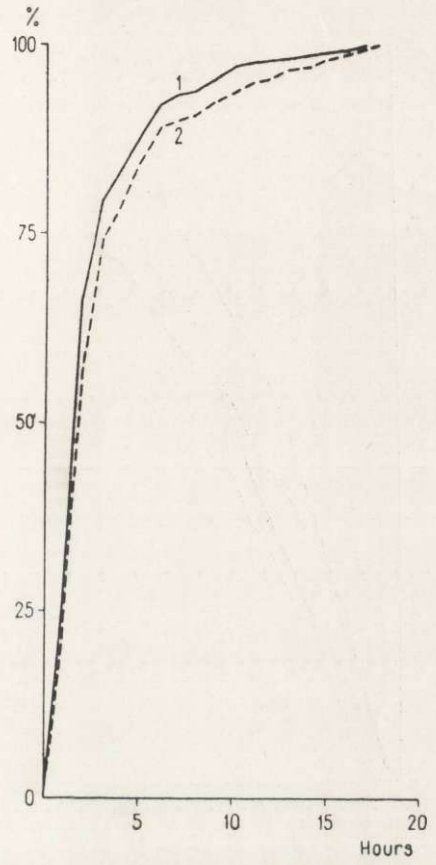


Fig. 3. Average course taken by excretion of indicator in males and females of *Microtus agrestis* fed on the green parts of plants.

1 — Males, 2 — Females.

rodents examined at a rate of 0.60%/hour. The lowest $R$ value was obtained for *C. glareolus*, the highest for *M. arvalis*, and intermediate values for *M. nivalis* and *M. agrestis*. As can be seen, these values are distributed parallel to the rate of excretion of the test food. Comparison of the times of excretion of 5%, 50%, 90% and 100% of the indicator by *C. glareolus* and *M. agrestis* did not reveal statistically significant differences, such differences being obtained only from a comparison of $R$ values. Statistically significant differences are obtained when comparing all the above mentioned values calculated for *C. glareolus* with analogical data for *M. arvalis*. In analysing the process of excretion of wheat by *M. arvalis* and *M. agrestis*, significant differences were found only when

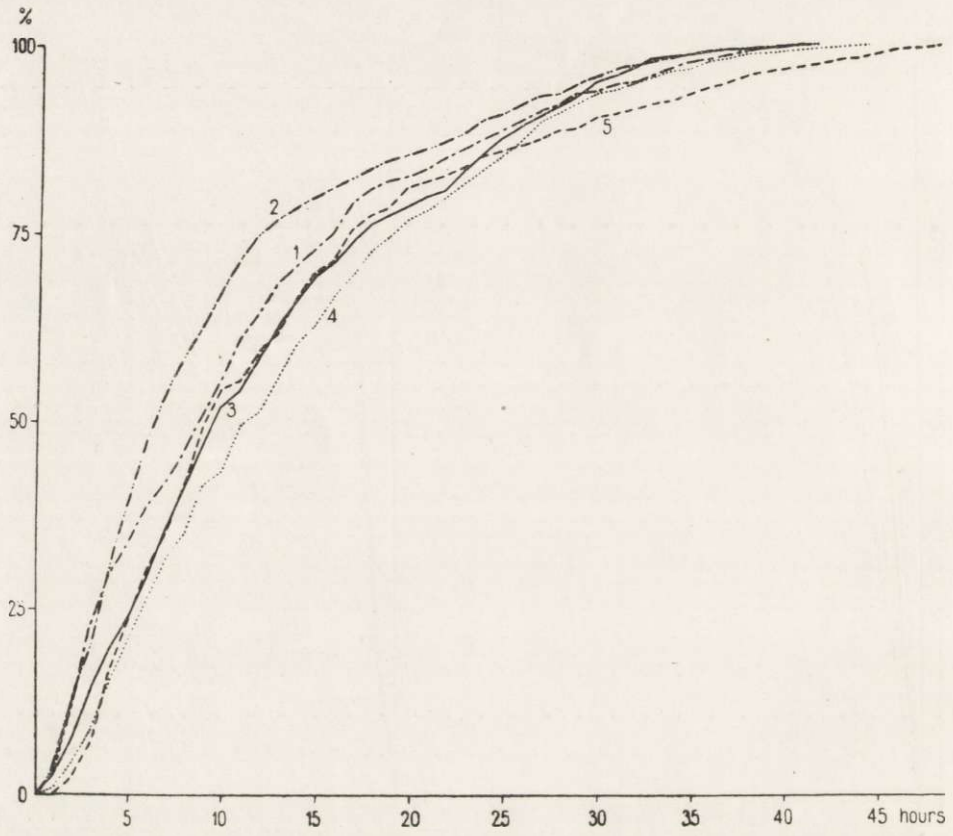


Fig. 2. Average course taken by excretion of red stained seeds.

1 — *C. glareolus* — wheat; 2 — *C. glareolus* — acorns; 3 — *M. agrestis;* 4 — *M. arvalis*, 5 — *nivalis* — wheat.

the times of excretion of 50% and 100% of the indicator are compared The excretion of grain food by *M. nivalis* is similar to the course taken by this process in *M. agrestis* (statistically non-significant difference between *R* values and times of excretion of 5% and 50% of the test food). The excretion times of 50% and 100% of the indicator in *M. arvalis* and *M. nivalis* differ in a statistically different way.

The passage of acorns through the alimentary tract of *C. glareolus* (Table 5) is the same as the passage of wheat (differences statistically non-significant).

Despite the above-mentioned differences, the course taken by the passage of seeds in all the species of *Microtidae* examined is in general outlines similar (Fig. 2).

**Table 3.**

Significance of differences between values describing the passage of the green parts of plants. The significance of differences between ♂♂ and ♀♀ of these species is marked on the intersections of *M. agrestis* with *M. agrestis* and *M. arvalis* with *M. arvalis*.

| | | M. agrestis | | | | | C. glareolus | | | | | M. arvalis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5% | 50% | 90% | 100% | R | 5% | 50% | 90% | 100% | R | 5% | 50% | 90% | 100% | R |
| M. agrestis | 5% | — | | | | | — | | | | | | | | | |
| | 50% | | — | | | | | — | | | | | | | | |
| | 90% | | | + | | | | | + | | | | | | | |
| | 100% | | | | — | | | | | — | | | | | | |
| | R | | | | | + | | | | | — | | | | | |
| M. nivalis | 5% | — | | | | | + | | | | | — | | | | |
| | 50% | | + | | | | | + | | | | | + | | | |
| | 90% | | | — | | | | | — | | | | | + | | |
| | 100% | | | | — | | | | | — | | | | | — | |
| | R | | | | | + | | | | | — | | | | | + |
| M. arvalis | 5% | + | | | | | + | | | | | — | | | | |
| | 50% | | + | | | | | + | | | | | — | | | |
| | 90% | | | — | | | | | + | | | | | — | | |
| | 100% | | | | — | | | | | — | | | | | — | |
| | R | | | | | + | | | | | — | | | | | — |

### 3. Comparison of the rate of passage of the green parts of plants with the rate of passage of seeds

The process of excreting both kinds of food always began during the first hour following the time at which the animals were given the test food. The main mass of the stained green parts of plants passes 4—5 times more quickly through the alimentary tract than the main mass of the stained seed food. The rate of excretion of the remainder of the indicator

**Table 4.**
Description of the course taken by excretion of wheat grains.

| No. | Sex | Excretion time of stained food /hours and minutes/ | | | | R values |
|---|---|---|---|---|---|---|
| | | 5% | 50% | 90% | 100% | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Clethrionomys glareolus | | | | | | |
| 1 | MALES | 1.00 | 4.49 | 22.41 | 37.00 | 8.23 |
| 2 | | 1.36 | 8.36 | 20.13 | 39.00 | 9.39 |
| 3 | | 1.22 | 8.36 | 14.19 | 39.00 | 9.21 |
| 4 | | 1.32 | 6.46 | 24.23 | 39.00 | 8.57 |
| 5 | | 1.23 | 8.30 | 24.42 | 41.00 | 10.24 |
| 6 | | 3.06 | 12.19 | 29.47 | 42.00 | 14.27 |
| 7 | | 1.15 | 9.34 | 23.43 | 43.00 | 10.53 |
| 8 | | 1.17 | 17.41 | 33.42 | 43.00 | 16.07 |
| 9 | | 0.47 | 12.07 | 23.30 | 40.00 | 12.00 |
| 10 | | 0.33 | 3.22 | 28.13 | 42.00 | 8.35 |
| 11 | | 1.18 | 8.40 | 25.54 | 38.00 | 10.51 |
| 12 | | 1.12 | 8.44 | 20.03 | 41.00 | 10.38 |
| 13 | | 3.05 | 6.49 | 31.04 | 42.00 | 12.21 |
| 14 | | 0.57 | 7.58 | 21.44 | 40.00 | 10.22 |
| 15 | | 1.42 | 8.40 | 25.17 | 40.00 | 10.22 |
| $\bar{X}_{♂♂}$ | | 1.28 ± 0.25 | 8.53 ± 1.53 | 24.39 ± 2.35 | 40.24 ± 1.00 | 10.53 ± 1.12 |
| 16 | FEMALES | 1.07 | 2.21 | 17.59 | 38.00 | 5.52 |
| 17 | | 5.07 | 12.34 | 35.53 | 41.00 | 15.58 |
| 18 | | 6.26 | 13.11 | 27.59 | 40.00 | 15.30 |
| 19 | | 1.52 | 5.55 | 25.31 | 41.00 | 10.00 |
| 20 | | 2.17 | 8.48 | 23.30 | 40.00 | 10.50 |
| 21 | | 1.51 | 5.37 | 16.12 | 45.00 | 9.52 |
| 22 | | 1.10 | 9.48 | 27.08 | 44.00 | 11.25 |
| 23 | | 1.19 | 12.00 | 28.08 | 38.00 | 13.45 |
| 24 | | 1.32 | 5.34 | 25.41 | 38.00 | 9.39 |
| 25 | | 0.27 | 10.11 | 26.41 | 41.00 | 10.44 |
| 26 | | 1.38 | 12.05 | 22.43 | 39.00 | 12.34 |
| 27 | | 0.49 | 6.42 | 26.48 | 41.00 | 9.57 |
| 28 | | 1.06 | 7.50 | 35.25 | 43.00 | 13.52 |
| 29 | | 0.37 | 4.32 | 22.33 | 38.00 | 9.23 |
| 30 | | 2.32 | 7.02 | 20.32 | 39.00 | 9.13 |
| $\bar{X}_{♀♀}$ | | 1.59 ± 0.56 | 8.15 ± 1.53 | 25.31 ± 3.02 | 40.24 ± 1.18 | 11.14 ± 1.30 |
| $\bar{X}_{♂♂+♀♀}$ | | 1.43 ± 0.28 | 8.34 ± 1.14 | 25.05 ± 1.51 | 40.24 ± 0.46 | 11.03 ± 0.54 |
| Microtus agrestis | | | | | | |
| 1 | MALES | 4.17 | 8.28 | 27.33 | 42.00 | 13.20 |
| 2 | | 2.35 | 10.46 | 25.48 | 40.00 | 13.28 |
| 3 | | 9.12 | 12.06 | 13.57 | 41.00 | 12.34 |
| 4 | | 2.25 | 8.53 | 28.07 | 38.00 | 11.25 |
| 5 | | 3.12 | 9.08 | 29.00 | 37.00 | 13.10 |
| 6 | | 2.29 | 11.41 | 32.31 | 40.00 | 14.57 |
| 7 | | 1.44 | 12.23 | 28.43 | 45.00 | 14.15 |
| 8 | | 2.22 | 15.25 | 30.12 | 39.00 | 15.45 |
| 9 | | 1.31 | 16.41 | 29.57 | 43.00 | 15.46 |
| 10 | | 1.14 | 9.33 | 24.35 | 40.00 | 11.49 |
| 11 | | 1.17 | 9.30 | 26.42 | 45.00 | 12.38 |
| 12 | | 1.19 | 7.51 | 23.26 | 44.00 | 10.14 |
| 13 | | 1.22 | 11.06 | 25.04 | 43.00 | 11.22 |
| 14 | | 2.26 | 9.02 | 24.00 | 39.00 | 12.09 |
| 15 | | 2.29 | 13.44 | 26.10 | 42.00 | 14.40 |
| $\bar{X}_{♂♂}$ | | 2.40 ± 1.06 | 11.05 ± 1.28 | 26.23 ± 3.27 | 41.12 ± 1.25 | 13.10 ± 0.56 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 16 | | 0.45 | 5.42 | 24.29 | 41.00 | 8.30 |
| 17 | | 1.24 | 9.41 | 30.27 | 40.00 | 12.51 |
| 18 | | 0.28 | 9.48 | 25.52 | 40.00 | 10.50 |
| 19 | | 1.13 | 9.19 | 27.52 | 39.00 | 10.56 |
| 20 | | 0.30 | 7.06 | 21.33 | 41.00 | 8.45 |
| 21 | | 5.24 | 12.38 | 28.48 | 38.00 | 15.22 |
| 22 | | 0.59 | 9.46 | 23.57 | 40.00 | 12.27 |
| 23 | | 3.15 | 8.40 | 24.13 | 37.00 | 11.51 |
| 24 | | 1.34 | 9.12 | 28.22 | 43.00 | 12.03 |
| 25 | | 1.33 | 9.23 | 26.00 | 42.00 | 11.49 |
| 26 | | 0.26 | 8.19 | 24.00 | 42.00 | 10.52 |
| 27 | | 0.38 | 7.03 | 26.47 | 38.00 | 10.31 |
| 28 | | 2.23 | 6.19 | 25.53 | 41.00 | 10.12 |
| 29 | | 1.54 | 11.18 | 26.13 | 39.00 | 12.57 |
| 30 | | 0.36 | 8.12 | 26.00 | 40.00 | 11.13 |
| $\bar{X}_{♀♀}$ | | 1.32 ± 0.45 | 8.50 ± 1.00 | 26.02 ± 1.07 | 40.04 ± 0.49 | 11.25 ± 0.55 |
| $\bar{X}_{♂♂+♀♀}$ | | 2.06 ± 0.38 | 9.58 ± 0.54 | 26.12 ± 1.14 | 40.38 ± 0.46 | 12.17 ± 0.44 |
| Microtus arvalis | | | | | | |
| 1 | | 2.36 | 10.22 | 29.36 | 45.00 | 13.27 |
| 2 | | 2.07 | 10.35 | 25.45 | 51.00 | 12.57 |
| 3 | | 1.20 | 10.56 | 27.15 | 46.00 | 12.40 |
| 4 | | 3.00 | 10.26 | 27.04 | 44.00 | 13.03 |
| 5 | | 1.15 | 7.25 | 27.04 | 51.00 | 11.29 |
| 6 | | 2.06 | 8.30 | 26.06 | 42.00 | 11.22 |
| 7 | | 1.34 | 12.33 | 27.47 | 49.00 | 14.19 |
| 8 | | 3.18 | 12.35 | 27.20 | 42.00 | 13.39 |
| 9 | | 2.15 | 14.16 | 28.43 | 46.00 | 14.04 |
| 10 | | 2.36 | 10.20 | 27.54 | 46.00 | 13.53 |
| 11 | | 4.23 | 14.35 | 28.49 | 39.00 | 16.56 |
| 12 | | 1.41 | 11.40 | 24.49 | 45.00 | 12.17 |
| 13 | | 2.03 | 15.29 | 30.10 | 44.00 | 15.55 |
| 14 | | 8.27 | 15.44 | 19.52 | 42.00 | 15.34 |
| 15 | | 2.30 | 10.16 | 27.12 | 42.00 | 12.42 |
| $\bar{X}_{♂♂}$ | | 2.45 ± 1.00 | 11.43 ± 1.22 | 27.02 ± 1.20 | 44.56 ± 1.54 | 13.37 ± 0.54 |
| 16 | | 2.03 | 8.52 | 33.08 | 49.00 | 13.24 |
| 17 | | 2.09 | 12.23 | 26.21 | 46.00 | 12.27 |
| 18 | | 1.28 | 12.51 | 28.10 | 47.00 | 13.25 |
| 19 | | 3.18 | 10.23 | 26.38 | 45.00 | 12.53 |
| 20 | | 2.16 | 10.19 | 26.07 | 46.00 | 12.32 |
| 21 | | 2.11 | 10.57 | 25.03 | 42.00 | 12.27 |
| 22 | | 3.11 | 8.23 | 24.34 | 43.00 | 11.04 |
| 23 | | 1.15 | 6.03 | 25.30 | 37.00 | 10.16 |
| 24 | | 2.25 | 13.36 | 30.55 | 44.00 | 15.45 |
| 25 | | 1.33 | 11.43 | 26.00 | 40.00 | 13.04 |
| 26 | | 2.26 | 10.43 | 29.34 | 46.00 | 14.00 |
| 27 | | 2.51 | 12.44 | 29.51 | 45.00 | 15.25 |
| 28 | | 1.52 | 11.46 | 33.00 | 44.00 | 14.53 |
| 29 | | 2.23 | 13.02 | 25.50 | 43.00 | 13.56 |
| 30 | | 3.17 | 9.56 | 27.00 | 44.00 | 13.46 |
| $\bar{X}_{♀♀}$ | | 2.20 ± 0.20 | 10.55 ± 1.08 | 27.50 ± 1.33 | 44.04 ± 1.38 | 13.17 ± 0.51 |
| $\bar{X}_{♂♂+♀♀}$ | | 2.32 ± 0.30 | 11.19 ± 0.50 | 27.26 ± 1.00 | 44.30 ± 1.12 | 13.27 ± 0.34 |
| Microtus nivalis | | | | | | |
| 1 | ♂ | 3.09 | 7.11 | 31.48 | 47.00 | 12.15 |
| 2 | ♂ | 2.50 | 9.00 | 27.47 | 46.00 | 13.04 |
| 3 | ♂ | 2.22 | 12.46 | 37.04 | 53.00 | 15.07 |
| 4 | ♂ | 3.23 | 7.45 | 23.48 | 45.00 | 11.05 |
| 5 | ♀ | 1.33 | 7.50 | 31.38 | 46.00 | 12.15 |
| 6 | ♀ | 2.28 | 9.58 | 29.30 | 53.00 | 13.13 |
| $\bar{X}$ | | 2.37 ± 0.43 | 9.05 ± 2.53 | 30.16 ± 4.39 | 48.20 ± 4.18 | 12.50 ± 1.23 |

in both cases increases gradually and becomes similar to each other in the final phase. The end of excretion of the green food takes place 2.5 — 3 times earlier than in the case of seed food. It is obvious from the above that after the main mass of the indicator has been excreted, the rate of excreting the green parts of plants decreases far more considerably than the rate of excreting seeds, as can be seen by comparing the curves of excretion (Fig. 1, 2). These differences are expressed in the *R* values, which are about four times greater in the case of seeds, as compared with the *R* value for the passage of green food. The main mass of the indicator of the passage of both kinds of food is most rapidly excreted by *C. glareolus*, more slowly by *M. agrestis*, and most slowly by *M. arvalis*. The course taken by the excretion of the green parts of plants in *M. nivalis* is similar to this process in *M. arvalis*, while excretion of the remainder of

**Table 5.**

Description of the course taken by excretion of acorns in *C. glareolus*.

| No. | Sex | Excretion time of stained food /hours and minutes/ | | | | R values |
|---|---|---|---|---|---|---|
| | | 5% | 50% | 90% | 100% | |
| 1 | ♂ | 2.33 | 8.42 | 25.55 | 43.00 | 11.35 |
| 2 | ♂ | 2.25 | 9.54 | 23.18 | 41.00 | 11.04 |
| 3 | ♂ | 1.08 | 4.18 | 26.03 | 40.00 | 8.33 |
| 4 | ♂ | 3.10 | 9.38 | 26.56 | 45.00 | 12.59 |
| 5 | ♀ | 1.17 | 6.45 | 23.03 | 41.00 | 9.31 |
| 6 | ♀ | 0.27 | 4.05 | 19.33 | 41.00 | 6.45 |
| 7 | ♀ | 1.03 | 5.16 | 15.30 | 44.00 | 6.57 |
| $\bar{x}$ | | 1.43 ± 0.56 | 6.57 ± 3.12 | 22.49 ± 4.16 | 42.08 ± 2.00 | 9.38 ± 2.11 |

the wheat takes place in the case of this species in a similar way to that in *M. agrestis*.

The data obtained show that despite the occurrence of differences between the species of *Microtidae* examined in the rate of passage of food, this rate depends primarily on the kind of food, and to a far lesser degree on the species of rodents.

#### 4. Sex dimorphism in the rate of passage of foodstuffs

The passage of seeds follows a uniform course in both sexes of *C. glareolus*, *M. agrestis* and *M. arvalis*. Comparison of *R* values and excretion times of 5%, 50%, 90% and 100% of the indicator reveals statistically non-significant differences. The rate of passage of the green parts of plants through the alimenary tract of males and females of *M. arvalis* is also uniform (statistically non-significant differences). This process differs slightly in both sexes in the case of *M. agrestis*, for which a sta-

tistically significant difference was obtained when comparing the excretion time of 90% of the stained food, and also when comparing *R* values (Fig. 3).

## IV. DISCUSSION

Experiments made on species feeding on different kinds of food and possessing differently built digestive systems made it possible to establish, in the case of the *Microtidae* examined, the degree to which the rate of passage of foodstuffs is dependent on the kind of food and species of animal.

The rate of excretion of the main mass of the test food by *C. glareolus*, more rapid than in the other species discussed, is conditioned by the long small intestine and the relatively short caecum and large intestine. The cause of reduction in the rapidity of excretion of the final amounts of the indicator in the rodents examined was the retention of the stained food in their caecum and large intestine. A similar decrease in the excretion rate in the final phase of excretion was observed in nutria also (Gill & Bieguszewski, 1960). Velitshko & Mokejeva (1949) found that food remains longest in the posterior section of the rodents' intestines. Pravdina (1958) showed that the green parts of plants pass more rapidly through the alimentary tract of *Rodentia* than seed food. Our data agree with these observations, but more exact comparison of results is impossible on account of the different investigation methods used by the above-mentioned authors.

The differences between the species of *Microtidae* examined in the rate of passage of the same kind of food are slight. When comparing *R* values and excretion times of 5%, 50%, 90% and 100% of the indicator of any two of the species examined, statistically significant results were never obtained simultaneously in all of the cases.

In all the *Microtidae* examined the curves describing the passage of the same kind of food are very similar, while in the same species the passage of different kinds of food takes an entirely different course. This proves that in the *Microtidae* examined the rate of passage of foodstuffs depends on the kind of food, and only to a very slight degree on the species of animal.

The statistically significant differences obtained between males and females of *M. agrestis* when comparing *R* values and excretion time of 90% of the remainder of the green parts of plants are probably fortuitous and are not of any importance. It may therefore be said that there is no sex dimorphism in the rate of passage of food through the alimentary system of the *Microtidae* examined.

## V. SUMMARY

Passage of the green parts of plants and of seeds through the alimentary tract was examined in 179 individuals belonging to four species of the family *Microtidae*. The method worked out by Castle (1956) and modified by Gill (1957) was used in the experiments. The part of the food stained with basic fuchsin was used as an indicator.

The rate of passage of food through the digestive system in the species examined depends on the kind of food. Passage of green food takes place 2.5—3.0 times faster than the passage of seeds.

The first stained food appears in the excrement within the first hour of all the experiments. The main mass of the indicator of the passage of green food was excreted after 3—6 hours, and the main mass of stained seeds after 16—19 hours, *C. glareolus* excreting most rapidly and *M. arvalis* most slowly in both cases. A considerable decrease in the rate of passage of the final 10% of the indicator was observed in all the experiments.

The course taken by the passage of the same kind of food is similar in general outline in all the species examined. Statistically significant differences were, however, found when comparing certain *R* values and excretion times of 5%, 50%, 90% and 100% of the indicator. The greatest similarity in the passage of the green parts of plants occurs in *C. glareolus* and *M. agrestis*, and in *M. arvalis* and *M. nivalis* The passage of seeds takes place similarly in *M. agrestis* and *M. nivalis*. Statistically significant differences in the rate of passage of wheat grains and acorns in *C. glareolus* were not obtained.

The rate of passage of foodstuffs through the alimentary system of the *Microtidae* examined does not depend on sex. Statistically significant differences were obtained only for *R* values and the excretion time of 90% of the indicator for males and females of *M. agrestis* fed on the green parts of plants.

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STRESZCZENIE

Transport wegetatywnych części roślin i nasion przebadano u 179 osobników należących do czterech gatunków z rodziny *Microtidae* (Tabela 1). W eksperymentach zastosowano metodę opracowaną przez Castle (1956) i zmodyfikowaną przez Gilla (1957). Jako wskaźnika użyto części pożywienia zabarwionej fuksyną zasadową. Pokarm testowy podawano zwierzętom raz dziennie. Barwne resztki liczono w pięciu polach widzenia mikroskopu w próbkach kału zbieranych w odstępach jednogodzinnych i odpowiednio rozcieńczanych. Następnie obliczono procent barwnych resztek wydalonych w poszczególnych godzinach doświadczeń i wykreślono krzywe w/g Balcha (1950). Wyznaczono także wartości *R* (Castle, 1956), obliczono czasy wydalania 5%, 50%, 90% i 100% pożywienia testowego i otrzymane wyniki poddano analizie statystycznej (test t-Studenta).

Szybkość przechodzenia pokarmu przez przewód trawienny badanych gatunków zależy od rodzaju pożywienia. Transport pokarmu zielonego odbywa się z szybkością 2,5—3 razy większą od transportu nasion.

Pierwsze barwne resztki pojawiały się w kale już w pierwszej godzinie wszystkich eksperymentów. Główna masa wskaźnika transportu pokarmu zielonego zostaje usunięta po 3—6 godzinach, a główna masa barwionych nasion po 16—19 godzinach, przy czym najszybciej w obu wypadkach wydala ją *C. glareolus*, a najwolniej *M. arvalis* (Ryc. 1, 2). We wszystkich doświadczeniach zaobserwowano duży spadek prędkości transportu ostatnich 10% wskaźnika. Koniec wydalania wegetatywnych części roślin następował po 17—18 godzinach, a nasion po 40—48 godzinach (Tabela 2, 4, 5).

Przebieg transportu tego samego rodzaju pokarmu jest w ogólnych zarysach podobny u wszystkich badanych gatunków (Ryc. 1, 2). Stwierdzono jednak różnice statystycznie istotne przy porównaniu niektórych wartości *R* oraz czasów wydalenia 5%, 50%, 90% i 100% wskaźnika. Największe podobieństwo w transporcie wegetatywnych części roślin występuje u *C. glareolus* i *M. agrestis* oraz u *M. arvalis* i *M. nivalis* (Tabela 3). Transport nasion u *M. agrestis* przebiega podobnie jak u *M. nivalis*. Nie otrzymano różnic istotnych statystycznie w tempie przechodzenia nasion pszenicy i żołędzi u *C. glareolus* (Tabela 5).

Szybkość przechodzenia treści przez przewód pokarmowy badanych *Microtidae* nie zależy od płci. Różnice statystycznie istotne otrzymano jedynie dla wartości *R* i czasu wydalenia 90% wskaźnika dla samców i samic *M. agrestis* karmionych zielonymi częściami roślin (Ryc. 3).