

## Food Preference and Feeding Behavior of the German Cockroach, *Blattella germanica* (Linnaeus)

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**ABSTRACT:** The purpose of this experiment was to study the food that male and female German cockroaches preferred and their feeding behavior. These 48-h-starved cockroaches were given choices among eight food items (four carbohydrate-rich foods: bread, sugar, banana, and potato; and four protein-rich foods: peanut, cheese, pork, and cat food). Modified eight-chamber olfactometers were used for this food preference experiment. Each kind of food was placed in each chamber of the olfactometer with 15 of each sex of the starving cockroaches placed at the center. The olfactometers were observed for 48 hours in the laboratory. The cockroaches were checked at 1, 4, 16, 24, 28, 40, and 48 hours; the amount of food eaten was recorded and the Rodgers's index was used for inferring the food preference of the cockroaches. Moreover, the differences between sexes and among food items were analyzed by the *Mann-Whitney U*-test. The results showed that the male cockroaches preferred banana and potato significantly whereas the female cockroaches significantly preferred banana. Additionally, the female cockroaches also significantly preferred peanut, sugar, and cat food more than the males at  $p < 0.05$ . Furthermore, the feeding behavior of these cockroaches occurred during the hours between 07.00-10.00 pm and 04.00-05.00 am. The feeding behavior started with swinging their antenna followed by touching the food.

**Key words:** food preference, olfactometer, feeding behavior, *Blattella germanica*

### INTRODUCTION

For most insects, nutrition affects survivorship of adults and their reproductive outputs. Generally, female fecundity depends on the ingestion of proteins which are necessary for egg development whereas male fertility does not highly depend on proteins. Moreover, insects generally are unable to convert lipids to monosaccharides by themselves and carbohydrates are one nutrient that both sexes use as a primary energy source.<sup>(1)</sup> Nutritional factors reportedly had profound short-term and long-term effects on the development and reproduction of insects.<sup>(2)</sup> Even though the nutritional requirements of most insects are relatively similar, the optimal sources, types, and proportions of nutrients widely vary among species and reproductive stages.<sup>(2)</sup>

Recent studies revealed that insects significantly show sex-specific differences in feeding behaviors and adult nutritional requirements. For example, young female tephritid fruit flies, *Bactrocera dorsalis*, (Diptera: Tephritidae) are attracted to the odors of protein food baits more than to the odors of host fruit.<sup>(3)</sup> Female peacock butterflies, *Inachis io* Linn. and Adonis blue butterflies, *Lysandra bellagrus* Linn. preferred amino acid-rich floral nectars, whereas males preferred sugar-rich floral nectars.<sup>(4,5)</sup> Moreover, male Madagascar hissing cockroaches *Gromphadorhina portentosa* (Dictyoptera: Blaberidae) preferred carbohydrate-rich foods whereas females preferred protein-rich foods.<sup>(1)</sup>

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Entomologists have been interested in studying cockroach food preference and feeding behavior because cockroaches are one of the most prevalent household pests. The range of food substances that they utilize is greater than any other insect.<sup>(6)</sup> The German cockroach, *Blattella germanica* Linn., has been used as a model organism for the study of insect neurobiology, digestion and physiology.<sup>(6)</sup> However, the documentation of food preference and feeding behavior of the German cockroach has been limited.

We hypothesized that the adult German cockroach might show sex-differences in food choices due to reproductive investment needs. Therefore, the objectives of this research were to study the attractiveness of various foods to the male and female German cockroaches. We also looked at their feeding behavior. Laboratory olfactometer assays and behavior observation were used in this experiment. In addition, this research would determine the attractiveness of some non-chemical baits for trapping the German cockroach in the field.

## MATERIALS AND METHODS

### Insect mass rearing

Colonies of the German cockroach were established from field-collected adults. All colonies were maintained in the laboratory under an approximately 12:12-hour light: dark natural photoperiod at about 30°C and 50-60% relative humidity. Wide-mouth glass jars were used as containers. The upper two-fifths of the inner surface of the jar was coated with petroleum jelly to ensure the cockroaches were unable to climb out, and a cardboard roll was placed for their shelter. The cockroaches were fed with cat food (Me-O<sup>®</sup>, S.W.T. Company, Samutprakarn, Thailand) once a week and water was monitored twice a week. The newly molted adults were separated by sex and placed in separate containers.

### Test for food preference

Adult male and female German cockroaches (N=300) were used in our experiment. Modified eight-chamber-olfactometers (Figure 1) were used for this food preference experiment. Each kind of food (0.2 g) was placed filled randomly in each chamber of the olfactometer. Foods consisted of carbohydrate-rich foods: bread, sugar, banana, *Musa sapientum* Linn., and potato, *Solanum tuberosum* Linn. and protein-rich foods: peanut, cheese, pork, and cat food. And fifteen of each sex of the starving cockroaches (to be evaluated the effect of hunger on food choice, the cockroaches were starved for 3 days before conducting the test) were placed at the center. The olfactometers were placed on a laboratory bench under red light illumination in a room with fully covered windows. The cockroaches were checked at 1, 4, 16, 24, 28, 40, and 48 hours and the experiment

was replicated 10 times (each replication used a new group of insects).

### Study for feeding behavior

Adult male and female cockroaches (N=100, for each sex) were used in this feeding behavior experiment. Twenty of each sex of the German cockroach were placed in an arena (15 x 30 x 18 cm) with a rolled cardboard for their shelter. The cockroaches were fed with cat food and water. The arena was placed on a laboratory bench under red light illumination in a room with fully covered windows. The behavior of insects were observed for 24 hours and replicated 5 times (each replication used a new group of insects).

### Data analysis

The amount of food eaten (in the test for food preference) was recorded and calculated to proportion eaten (in this experiment, the proportion eaten = X/0.2 g). In addition, the Rodgers's index for inferring the food preference was used as following:

The Rodgers's index ( $R_i$ )<sup>(7)</sup>

$$R_i = \frac{A_i}{\max(A_i)}$$

When:

$R_i$  = Rodgers's index of preference for food item i

$A_i$  = Area under the cumulative proportion eaten curve for food item i

$\max A_i$  = the largest value of the  $A_i$

The homogeneities of variances were tested and the significant differences between sexes and among the food items were analyzed by *Mann-Whitney U-test*.



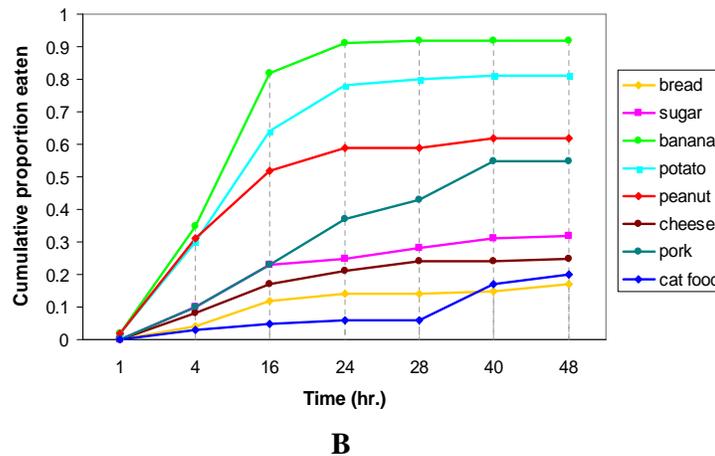
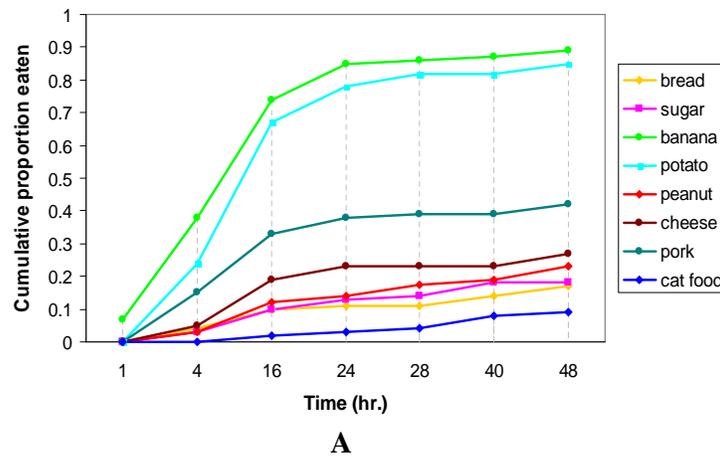
**Figure 1. A modified eight-chamber-olfactometer used for the food preference experiment. Cockroaches were placed in the center arena and allowed access to food choices in eight peripheral chambers (modified from Reiersen 1995).<sup>(8)</sup>**

**RESULTS**

**Food preference of the German cockroach**

The homogeneity tests showed the variances to differ significantly at  $p < 0.05$ . Using *Mann-Whitney U*-test, the result showed that the male cockroaches preferred banana following by potato, pork, cheese, peanut, sugar, bread, and cat food, respectively. They preferred banana and potato significantly at  $p < 0.05$  (Figure 2A). The female cockroaches preferred banana following by potato, peanut, pork, sugar,

cheese, bread, and cat food, respectively. They preferred only banana significantly at  $p < 0.05$  (Figure 2B). Additionally, the males significantly preferred potato more than the females. In contrast, the female cockroaches significantly preferred peanut, sugar, and cat food more than the males at  $p < 0.05$  (Figure 3); and also evidently preferred peanut and sugar more than the males at  $p < 0.01$ .

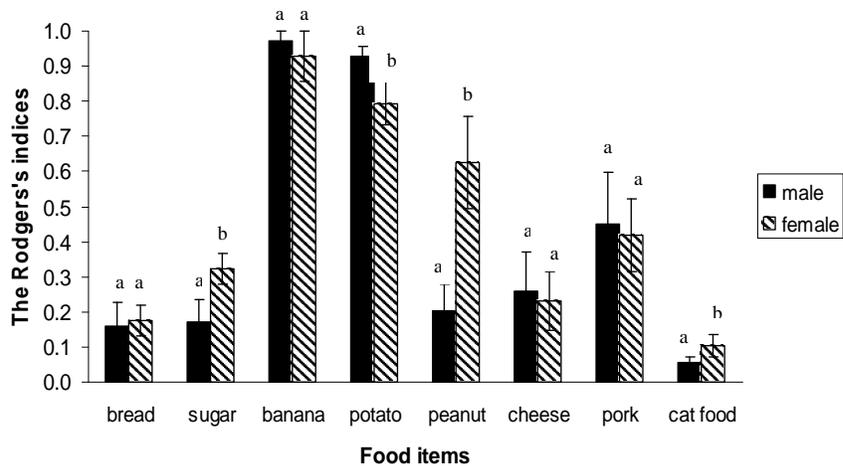


**Figure 2. Graphs show curves of means of proportion eaten by the male (A) and the female (B) German cockroaches of the eight food items. Each point on a curve represents a mean of proportion of food eaten in each time of observation.**

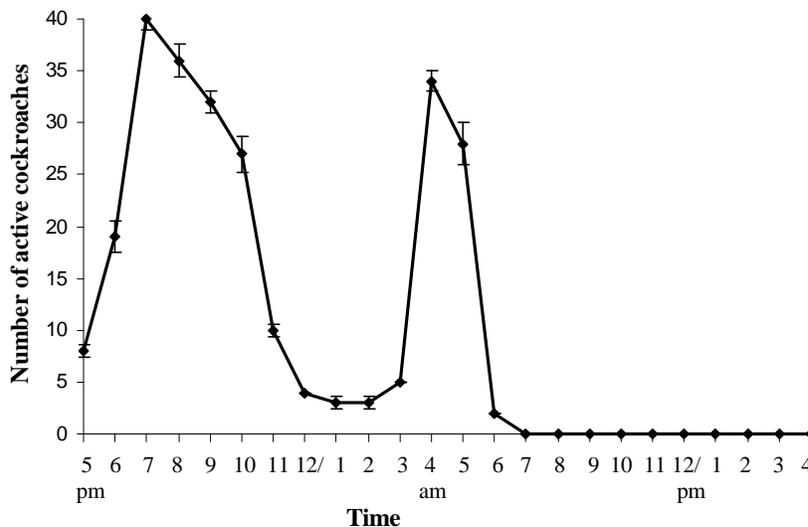
**Feeding behavior of the German cockroach**

The results showed that the German cockroaches usually hid in their harborage during daytime. The beginning of their feeding behaviors occurred around 05.00 pm and rapidly increased around 07.00 pm. They also showed the first peak during the hours between 07.00-10.00 pm. Their activities slowly decreased starting at 11.00 pm. Then, their feeding behavior was found again at 03.00 am and sharply

increased at 04.00 am. The second peak showed at 04.00-05.00 am. After that, their activities rapidly decreased around 06.00 am. They then hid in their harborage from around 07.00 am to 04.00 pm (Figure 4). Their feeding behavior started with leaving their shelter and swinging their antenna to detect food odor. The cockroaches walked to the food and touched it, then, they started to feed and drink.



**Figure 3. Rodgers's indices comparing between M+F German cockroaches for each food item. These indices infer the food preference in male and female cockroaches (rang 0-1, 0 = avoid and 1= prefer). The bar graphs with different letters are significantly different at  $p < 0.05$  (Mann-Whitney U-test).**



**Figure 4. Mean numbers of active cockroaches observed during 5.00 pm to 4.00 pm. Total of 20 male and 20 female German cockroaches were observed in this experiment (5 replicates). Each point represents the mean number of active cockroaches at each time of observation.**

**DISCUSSION**

Several important inferences may be derived from our data such as interesting differences in food choices, sex specific differences of the German cockroaches food preferences, and their feeding behavior. The most notable difference was in nutritional preferences between the male and female cockroaches. They were contrarily significant to the sex differences in protein utilization.

For nutritional requirements, it is well known that the German cockroaches prefer diets which are higher in carbohydrate than in fat and protein content.<sup>(9)</sup> Moreover, under conditions of complete inanition, the cockroaches will eat nearly any food substance that they encounter, unless deprived for a set period of time.<sup>(8)</sup> From our observations, when we placed them in the center of the olfactometers, they

walked directly to the nearest food and fed on it. Their behavior corresponded with other insects which did not respond to monotonous odors as vigorously as when they were very hungry.<sup>(8)</sup> When the cockroaches were full, they hid around the border of the chambers. Then, they surveyed the foods in every chamber of the olfactometer before the foods were chosen.

Our results showed that the male German cockroaches significantly preferred banana and potato whereas the female cockroaches significantly preferred only banana. We believe that the cockroaches preferred banana and potato due to their richness in carbohydrate. The carbohydrate content could serve them as a primary energy source.<sup>(1)</sup> Most of the German cockroaches preferred banana more than any other food, only small numbers preferred cat food. Besides the nutritional factors, the odors and textures of foods are also important. Cockroaches often respond to food odors over short distances.<sup>(8)</sup> In our experiment, the odor of banana was stronger than the others, moreover, the banana texture was soft and mushy. Thus, the banana attracted the ravenous cockroaches. In contrast, the texture of cat food was very rigid, and the cockroaches might be aroused and attracted by soft and freshly foods which are easy to eat under stress condition such as starvation.

For the sex-specific differences of the German cockroaches, cockroaches and other animals are able to self-select a suitable diet given a variety of nutrient choices.<sup>(1)</sup> The female cockroaches heavily invest in production of large ootheca unlike males that produce small spermatophores.<sup>(10)</sup> Moreover, female fecundity commonly depends on the ingestion of protein necessary for egg development.<sup>(8)</sup> Accordingly, the female cockroaches require substantially more protein than the males.<sup>(11)</sup> When Rodgers's indices for food preference were calculated for the various types of food, significant differences between male and female preference for peanut and sugar were noted, implying that female cockroaches could be considered as protein-hungry and energy-hungry (Figure 3). The female German cockroaches require large amounts of nutrient reserves, especially proteins, for oothecal production. Additionally, more energy is needed during preoviposition, incubation, and oviposition periods.<sup>(9)</sup> The results also corresponded to previous studies. For example, female peacock butterflies and Adonis blue butterflies preferred amino acid-rich floral nectars whereas the males of both insects preferred sugar-rich floral nectars.<sup>(4,5)</sup> Furthermore, the male Madagascar hissing cockroaches were also reported to prefer carbohydrate-rich foods whereas the females preferred protein-rich foods.<sup>(1)</sup>

For the feeding behavior, the German cockroaches are nocturnal insects.<sup>(2)</sup> The foraging activity of the German cockroaches were related to the general circadian activity phases<sup>(12)</sup> and corresponded with the results of this experiment. The foraging time occurred during the dark with two

peaks of feeding activity. The first peak occurred during the hours between 07.00-10.00 pm and the second peak occurred during 04.00-05.00 am. For the first peak, the cockroaches left from their shelter and foraging activity occurred not far from their harborage. In the second peak, their activities occurred more distant from their shelter than the first peak. In addition, each cockroach showed the same feeding behavior pattern. Firstly, the cockroach left the shelter and swung its antenna to detect food odor by the chemoreceptors which are located on the antennae.<sup>(9)</sup> Secondly, it walked to the food and touched it. Finally, the cockroach fed on the food or drank some water using its mouthpart.

In conclusion, cockroach trapping should be during hours of darkness. Carbohydrate-rich foods with strong odor such as banana and protein-rich foods such as peanut are probably good baits for trapping the German cockroach in fields. Ultimately, cockroach trapping with non-chemical baits could be used for domestic pest control.

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