Latency of Sugar Selection Behavior in German Cockroaches, 
*Blattella germanica* (Dictyoptera: Blattellidae)

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Abstract. Sugar is a phagostimulant component of cockroaches bait. Knowledge of the chemosensory response of German cockroaches to sugar is necessary to design bait formulations. This study was aimed to determine the behavior of sugar selection by German cockroaches, based on latency parameters toward the bait. Observation methods were done using behavior sampling with CCTV cameras. Observations were made on fifteen mixed-sex from VCRU, BKL, PDG, JKT-b, and PKU-b strains with the treatment of plain agar and agar containing four types of sugar i.e., glucose, fructose, sucrose, and maltose with a concentration of 1 M each. The observation was carried out for 12 hours. Data were analyzed using Two-way ANOVA followed by the Duncan test for p<0.05. Correlation between sugar and latency was analyzed with redundancy analysis. The result showed that the treatment but not the strain influenced the behavior of latency. The VCRU, BKL, PDG, and JKT-b strain were showed the fastest latency toward maltose and sucrose, while the PKU-b strain was toward plain agar. There was a strong correlation between sugar and latency for 0.77 (axis 1) and 0.61 (axis 2), with a total variance of 89.7% resulted from the redundancy analysis. Those indicate that the German cockroaches perform the sugar selection with a preference of maltose, and sucrose is more stimulating than glucose and fructose.

1. Introduction

German cockroach, *Blattella germanica* Linnaeus (Dictyoptera: Blattellidae) is a synanthropic insect and a settlement pest insects harmful either economically, healthy, or aesthetically. Because it is detrimental, it should be controlled. One method of controlling their population is to apply insecticides mixing bait, and food containing phagostimulants. The success of the feeding method in controlling German cockroaches is primarily determined by the interest, preference, and palatability of cockroaches towards the bait. An attempt to improve the effectiveness and the insect preference of bait is a phagostimulant addition. Sugar is the most widely used compound as phagostimulant because it acts as an energy source for insects [1, 2, 3].

Sugar that commonly used as a phagostimulant for commercial bait in controlling German cockroaches is glucose. The recent problem with it is that several German cockroach strains have been detected to avoid commercial bait containing glucose, causing many failures of bait-based in controlling German cockroaches [4,5,6]. Our unpublished research based on 21 of German
cockroaches strain originated from 12 provinces in Indonesia, showed that four strains were detected to develop glucose aversion behavior, one of which was Jakarta-b (JKT-b) strain and Pekanbaru-b (PKU-b). This glucose aversion behavior is a phenomenon of behavioral resistance.

Therefore it is necessary to examine an alternative for glucose substitution as phagostimulant based on sugar selection behavioral approach. This study aimed to determine the latency in the process of selecting sugar by field strains of German cockroaches having different resistance status conditions toward fipronil insecticides, and to detect potentially developing glucose aversion behavior.

2. Methods

German cockroaches used consisted of Vector Control Research Unit (VCRU) strain, the susceptible standard strains, and four field cockroach strains that originated from four provinces. VCRU was obtained from Universiti Sains Malaysia, and have been reared since 2007 in the Laboratory of Entomology, School of Life Sciences and Technology, Institut Teknologi Bandung, Bandung, Indonesia. The field cockroach strains were originated from Bengkulu (BKL), Padang (PDG), Jakarta-b (JKT-b), and Pekanbaru-b (PKU-b). Those four field strains resulted from the evolution selection of glucose aversion behavior. They have been reared in the same laboratory as VCRU between 2007 and 2011. Based on the previous unpublished study, two strains, i.e. BKL and PDG, were susceptible to fipronil insecticide and were a non-glucose aversion, and the other two field strains, i.e., JKT-b strain and PKU-b strain, were resistant to fipronil insecticide and were potentially evolved glucose aversion. Each strain consisted of 15 mixed-sex cockroaches: five males, five females, and five nymphs. The treatments were agar containing glucose, fructose, sucrose, maltose of 1 M each, and plain agar as the control.

Observation of latency was assessed using a behavioral sampling method with continuous recording for 12 hours (6:00 p.m.-6:00 a.m.) by means of CCTV camera CCTV [7]. The observation was carried out in the l x w x h = 40x25x30 cm3 testing arena with shelter and drinking water in the middle. Ten minutes before the observation, five similar sex/stadium cockroaches were fasted for 24 hours, marked with acrylic paint on the wing, then acclimatized in the testing arena. Following the acclimatization, four agar treatments were each laid out in four corners of the testing arena, and one plain agar was in the middle of the arena. Observation of the latency was done for each agar treatment for each strain. Latency was measured at the time of toward and arrived in the agar treatment.

Data were analyses using two way ANOVA continued with Duncan test for p< 0.05 [8]. Redundancy Analysis (RDA) software Canoco v4.55 [9] was used to investigate the correlation between latency and type of tested sugar for each strain of German cockroaches. The standard grouping of correlation numbers was as follows [10]:

0 : no correlation
>0-0.25 : extremely weak correlation
>0.25-0.5 : fair correlation
>0.5-0.75 : strong correlation
>0.75-0.99 : extremely strong correlation
>1 : perfect correlation

3. Results

The results showed that the type of sugars but not the strains significantly affected the latency (p<0.05, F(1.4)=3.32). The latency of VCRU strain was the fastest toward sucrose (4726.53 seconds), alike the latency toward maltose (4954.07 seconds), whereas the most protractedly latency was toward fructose (11810.6 seconds). BKL and PDG strains showed the fastest latency toward maltose, 2428.8, and 2135.6 seconds, respectively. The most protractedly latency for BKL strain toward glucose was 7890.4 seconds. PDG strain showed the longest latency toward fructose (14891 seconds). JKT-b strain showed the fastest latency toward sucrose (3173.87 seconds), while the longest latency toward control
was 7775.53 seconds. PKU-b strain represented the promptest latency toward control (2650.93 seconds) and the longest latency toward sucrose (10146.13 seconds) (figure 1).

Figure 1. German cockroaches latency for VCRU, BKL, PDG, JKT-b, and PKU-b strains toward sugars treatment (mean ± sd) (VCRU: Vector Control Research Unit, BKL: Bengkulu, PDG=Padang, JKT-b=Jakarta-b, PKU-b=Pekanbaru-b).

Redundancy analysis (RDA) revealed a strong correlation of German cockroaches latency with sugars (axis-1= 0.77, axis-2= 0.61, total variance: 89.7%). The biplot indicated distinct latency characteristics between field strain for non-glucose aversion and field strain that potentially evolved glucose aversion behavior. BKL and PDG strain with non-glucose aversion status possessed latency characteristics similar to VCRU strain that demonstrated the fastest latency toward maltose and sucrose, but the longest latency toward fructose. Strains that potentially evolved glucose aversion behavior ( JKT-b and PKU-b) showed distinct latency characteristics to VCRU, BKL, and PDG strains, mainly the latency toward fructose (Figure 2).

Figure 2. Biplot latency of German cockroaches in each treatment (L-VCRU = Latency of Vector Control Research Unit strain, L-BKL=Latency of Bengkulu strain, L-PDG=Latency of Padang strain, L-JKT-b=Latency of Jakarta-b strain, PKU-b=Latency of Pekanbaru-b strain)
4. Discussion

Latency is the time since the appearance of sugar objects as excitatory (time t = 0) up to the first appearance of a specific behavior [7]. In this study, latency is defined as the time when cockroaches first come to sugar.

The results showed the fastest latency was, generally, toward maltose and sucrose, except for PKU-b strain (plain agar). The cockroaches detect their feed initially using olfactory sensilla following by gustatory sensilla to determine food suitability [11, 12]. At the time of food searching, cockroaches swing their antennas to detect food odor, then proceed toward food and reach it [13]. Maltose and sucrose are the two most intense phagostimulants for German cockroaches. Sugar is an odorless compound. Therefore, the cockroaches recognized them through gustatory sensilla [14, 15]. It is defined that sugar detection ability is a substantial factor in determining the food source acceptability [16].

Insects, in general, including cockroaches, maintain their ability to select food optimally for their survival and development [17, 18, 19]. Initially, the cockroaches tend to consume the first food they found [20]. However, after a particular time of consumption, the metabolic responses proceed. When the food fulfilled their nutrition needs, the process of eating continued, but if not, the eating process ceases, then they search distinct food sources to fulfill their nutrition [21].

The biplot of Figure 2 implies latency of BKL strain and PDG strain that similar to that of VCRU but differs from JKT-b strain and PKU-strain (latency toward fructose). Fructose is likely less excited than maltose and sucrose. This observation corresponds with the findings reporting that standard strain cockroaches are more attracted to maltose and sucrose than to glucose and fructose. Therefore, field strain merely is attracted to maltose and sucrose (Dorie strain); even Cincy strain is not interested in maltose, sucrose, glucose, and fructose [22]. It implies that the correlation amongst resistance occurs shown by the response of German cockroaches to sugar selection for the first time. The response of insects toward the stimulation might vary not only according to biotic factor, abiotic factor, and the previous experience but also might be affected by the physiological condition [23].

5. Conclusion

German cockroaches were more attracted to maltose and sucrose than to other sugars, showing by their preference to come and consume them during the initial search for feed.

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