

ON FEEDING ACTIVITIES IN THREE SPECIES OF COCKROACHES IN JAPAN

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Introduction

Cockroaches are the most common insect pests in commercial and residential areas in the urban and hiding in cracks and crevices that are difficult to treat with insecticides. At present, therefore, they are one of the most difficult urban insect pests to control even for the professional pest control operators. Particularly, the German cockroach, *Blattella germanica*, is difficult to control since they have a high reproduction rate and are capable of hiding in the areas that are out of reach of hands due to their smaller size. Pyrethroid insecticides have been widely used for control of cockroaches, however, their flashing effect can not be seen in most cases of these days, probably due to the decreased sensitivity of cockroaches against pyrethroids or the biology of hiding in deeper harborage. In Kochi prefecture, house-wives are successfully using a bait (an attractant feed) so-called "the boric acid ball" which is a mixture of boric acid with wheat flour, onion, milk or other ingredients based on their own recipe to control cockroaches in their houses. However, some reduction of the sensitivity of cockroaches against this attractant feed has already been seen as evidenced by the voice of house-wives saying that some cockroaches still can be observed in fall season in houses treated with this attractant feed. This may indicate that this attractant feed has the property allowing rapid development of resistance because it takes relatively long time from ingestion to death. Thereafter, various bait products have been developed and formed the main current of the household insecticide now to control cockroaches resistant to pyrethroid insecticides. Even though the bait formulation is considered to be most effective at present, only a few information is available regarding the feeding response of cockroaches to the attractant feed and the knowledge on the basic feeding habit of cockroaches is also very limited. How much food is cockroach eating? And what feeding rhythm does cockroach have? Starting from these simple questions, it was decided to conduct the experiments to obtain some basic information which will facilitate the evaluation of cockroach baits. Since cockroaches have a circadian rhythm, that is, their life activities during 24 hours appear regularly, it is expected that their daily feeding may occur regularly. However, quite interesting results on feeding habit of cockroaches, particularly in females, could be obtained from this observation. That is, a feeding behavior which is considered to be similar effect as the bloodsucking activity of mosquitoes in order to supply nutrition before oviposition was also observed in cockroaches. This report describes this new information on the feeding behavior of cockroaches. In addition to the German cockroach, *B. germanica*, the

Black cockroach, *Periplaneta fuliginose*, which can be commonly observed in western Japan and the American cockroach, *P. americana*, which is becoming popular recently in the urban district, were included in the study for comparison.

Method

Insects used : Three species of cockroaches, the German cockroach (*Blattella germanica*), the Black cockroach (*Periplaneta fuliginose*) and the American cockroach (*P. americana*) were used. All these cockroaches were obtained from the stock colonies being reared in our laboratory. Adult males and females were used.

Test pots : Plastic containers, 10 cm in bottom diameter x 12 cm in upper diameter x 10 cm in depth, were used. Each container was covered with a piece of cloth and fixed with a rubber band. In each container, a plywood shelter, a water bottle and the test diet were provided (Fig. 1).

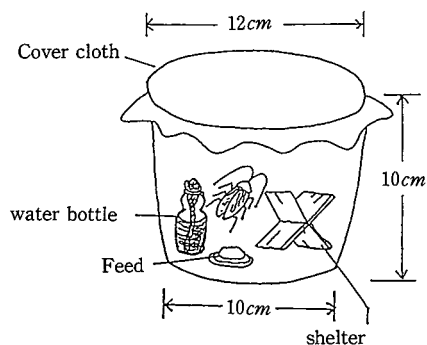


Fig. 1. Diagram of Cockroach Container

Test diet : The test diet was prepared by mixing pelleted insect chow and lard at the rate of 3:2 w/w and provided to each pot at the rate of 3 g/day. Evaporation of water from the test diet was problem to obtain the accurate consumption, but the problem was solved by coating the pelleted insect chow with lard. This procedure also allowed to measure many samples in one day.

Therefore, the test diet in the container was replaced with the freshly prepared test diet every and weighed to obtain the accurate daily food consumption. 3 g of daily diet is sufficient for more than 10 cockroaches up to 24 hours, but it was provided to only 3 cockroaches in one container. The water bottle in the container was replaced with the fresh water bottle every day.

Environmental conditions : The insectary was kept at $25 \pm 1^\circ\text{C}$, 65% of relative humidity and 16-hour light cycle.

Number of insects : 1, 2 and 3 cockroaches was used in one container for each sex. Each set of experiment consisting three different numbers of cockroaches was run at least 10 times and the observation period was 30 days for each set of experiment.

Calculation of food consumption : The test diet before and after use was weighed at noon every day using an analytical balance.

The daily food consumption was calculated using the following formula and corrected for weight change of control diet.

Daily food consumption = (Weight of test diet given 24 hours before-Weight of remained test diet after 24 hours) x (Weight of control diet after 24 hours exposure)/ (Weight of control diet before exposure)

This study was performed from April, 1993 to March, 1994.

I thank Ms. Keiko Maeda, Osugi Junior High School, for her assistance with determination of food consumption of cockroaches.

Results

- (1) Daily fluctuation of daily food consumption in three species of cockroaches : Each set of experiment was repeated at least 10 times and data obtained were too large to show all of them, therefore data showing a typical trend are shown in Figs. 2 and 3. As obvious from these data, vigorous daily fluctuation of food consumption could be seen in females of all species, but food consumption was low and daily fluctuation was small in males. A large amount of food consumption was observed at certain interval in females but such fluctuation of food consumption was not observed in males. As a result of further review of data, it was found that such large amount food consumption occurred at the day of oviposition in females except for a few cases. The day of oviposition was defined as the day the egg case was deposited. In the experiments using 2 and 3 females, this trend was more clearly observed. In order to review this trend further in detail, the whole observation period was divided into the day of oviposition and other period during which oviposition was not observed (oviposition interphase) and food consumption during each period was statistically analyzed.

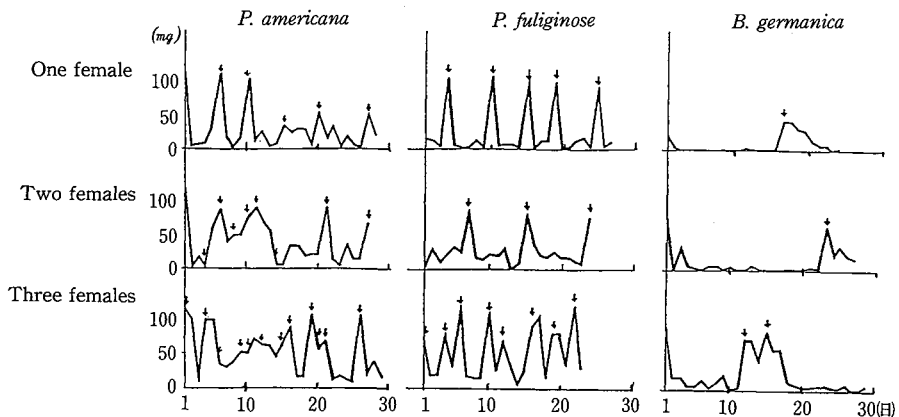


Fig. 2. Daily Changes of Food Consumption of the Females of Three Species of Cockroaches Reared Individually and in Group. (Arrow indicates the day of oviposition)

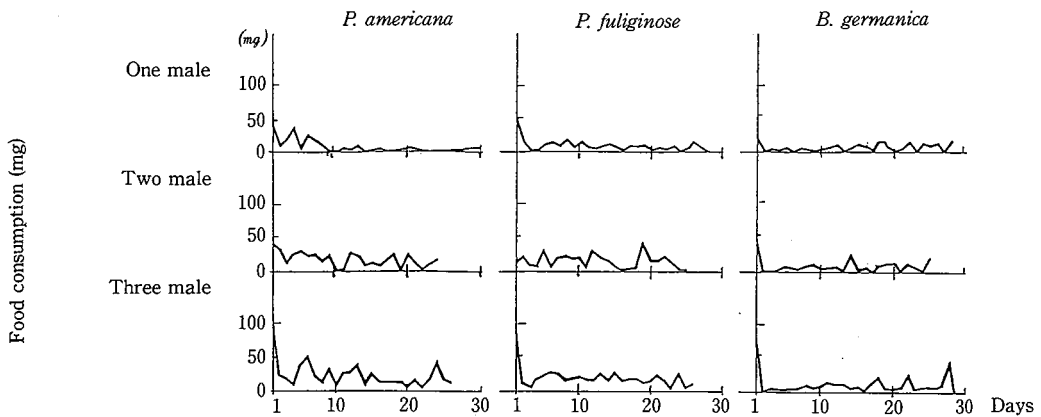


Fig. 3. Daily Changes of Food Consumption of the Males of Three Species of Cockroaches Reared Individually and in Group.

(2) Comparison of food consumption during the day of oviposition and the pre-oviposition period : Results for experiments using 1, 2 and 3 cockroaches per container are summarized

Table 1-1 Mean Daily Food Consumption (mg/Roache) in 99 % Confidence Limit for the Females of Three Species of Cockroaches

No. of roaches	<i>P. americana</i>		<i>P. fuliginose</i>		<i>B. germanica</i>	
	Whole period		Whole period		Whole period	
	Day of oviposition	oviposition interphase	Day of oviposition	oviposition interphase	Day of oviposition	oviposition interphase
1	14.8± 6.2	0.7±0.6	15.6± 6.2	0.6±0.5	2.1±0.3	0.3±0.1
	69.8±23.3	0.7±0.6	65.9±14.4	0.6±0.5	6.6±2.1	0.3±0.1
2	37.4±10.7	3.7±3.6	29.0± 3.2	5.2±4.7	3.3±1.9	1.5±1.4
	67.6± 3.6	3.7±3.6	64.9±23.4	5.2±4.7	5.4±3.5	1.5±1.4
3	42.3±14.9	8.4±4.5	42.4±16.3	13.4±1.3	7.2±2.4	3.2±1.3
	77.2±17.0	8.4±4.5	91.2± 5.6	13.4±1.3	15.8±4.6	3.2±1.3

Table 1-2 Mean Daily Food Consumption (mg/Roach) in 99 % Confidence Limit for the Males of Three Species of Cockroaches

No. of roaches	<i>P. americana</i>	<i>P. fuliginose</i>	<i>B. germanica</i>
1	8.0±1.3	7.7±1.1	0.9±0.3
2	61.8±2.1	14.0±5.5	1.8±0.7
3	23.6±6.4	19.0±2.4	2.5±0.4

in Table 1 and shown in Fig. 4. As obvious from these data, it was found that food consumption of females significantly increased in the day of oviposition compared to respective oviposition interphase. There

were 3 to 4 days food consumption was not significantly increased even though oviposition was observed, but an empty egg case after the female ate the content was found in these days.

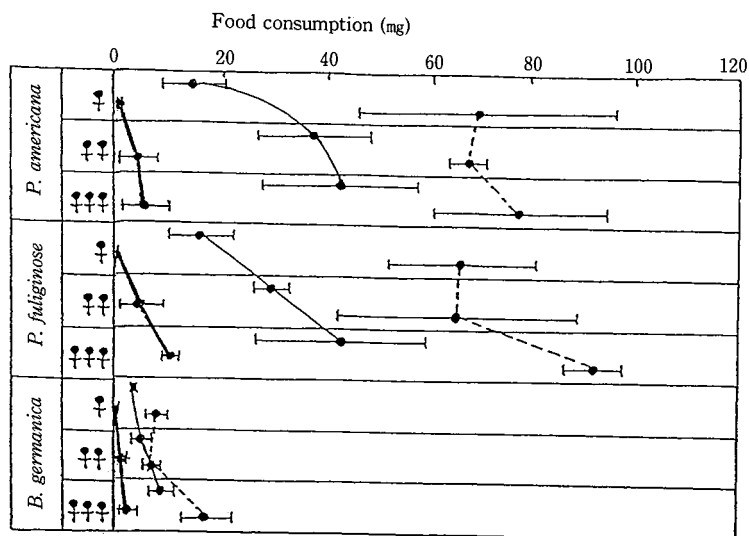


Fig. 4. Mean Daily Changes of Food Consumption with 99% Confidence Limit of the Females of Three Species of Cockroaches Reared Individually and in Group.

(♣ : Number of roaches)

---●--- : Day of oviposition, —●— : Whole period, —●— : Pre-oviposition period

Conversion of mean food consumption of 2 and 3 cockroaches per container during the whole period shown in Table 1-1 into food consumption per cockroach gave 18.7 and 14.1 mg for female of the American cockroach, 14.5 and 14.1 mg for the Black cockroach, and 1.7 and 2.4 mg for the German cockroach, respectively. Food consumption of one cockroach per container shown in Table 1-1 was 14.8, 15.6 and 2.1 mg, respectively. There were no statically significant differences among these values for each species. In males, converted food consumption per cockroach from data of 2 and 3 cockroaches per container gave 8.4 and 7.9 mg for the American cockroach, 7.0 and 6.3 mg for the Black cockroach and 0.9 and 0.8 mg for the German cockroach, respectively, and there were no significant differences from the respective food consumption values of one cockroach per container shown in Table 1-2 and Fig. 5. There were no significant differences in food consumption among female groups during the oviposition interphase. Food consumption of females in the day of oviposition, however, was at least 2 times higher in the plot of one cockroach per container compared to the plots of 2 and 3 cockroaches per container in either species except for the plot of 3 cockroaches per container of the German cockroach, indicating that food consumption in the day of oviposition is enhanced further in one cockroach per container.

The ratios of food consumption in the day of oviposition/that during the oviposition interphase period for each plot were 99.7, 18.3 and 9.2 for the American cockroach, 109.8, 12.5 and 6.8 for the Black cockroach and 22, 3.6 and 4.9 for the German, respectively. These data support the above conclusion.

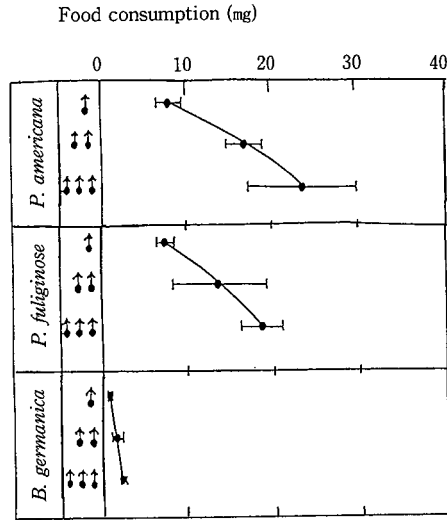


Fig. 5. Mean Daily Changes of Food Consumption with 99% Confidence Limit of the Males of Three Species of Cockroaches Reared Individually and in Group.
(↑ : Number of roaches)

Table 2 Daily Food Consumption (mg/Roach) for the Males and Females of Three Species of Cockroaches

			Min. ~Mean Max.
<i>P. americana</i>	Female	mg/g b. wt. mg/roach	0.50~10.0~ 62.8 0.70~14.8~ 93.1
	Male	mg/g b. wt. mg/roach	0.30~ 7.1~ 9.0 0.30~ 8.0~ 9.3
<i>P. fuliginose</i>	Female	mg/g b. wt. mg/roach	0.60~16.3~ 77.7 0.60~15.6~ 80.3
	Male	mg/g b. wt. mg/roach	0.20~14.8~ 17.0 0.10~ 7.7~ 8.8
<i>B. germanica</i>	Female	mg/g b. wt. mg/roach	1.10~30.0~123.9 0.08~ 2.1~ 8.7
	Male	mg/g b. wt. mg/roach	0.30~22.8~ 30.5 0.01~ 0.9~ 1.2

As shown in Table 2, food consumption expressed by mg/g body weight/day or by mg/cockroach/day of females was 2 to 3 times higher than that of males for either species. The German cockroach is smaller in the body size and its food consumption per cockroach is lower than other two cockroaches, but food consumption in mg/g body weight/day of the females of the German cockroach is

still about 2 times higher than that of the males.

- (3) Periodicity of food consumption increase : From the aforementioned results, it is clear that food consumption of cockroaches increases in the day the egg case was deposited. Then, data were analyzed to know their oviposition intervals. For the females of the American and the Black cockroaches, the highest incidence (47.6%) was 5 day-interval, then 4- and 6-day intervals (9.0% each) followed by 3-, 7- and 8-intervals (4.8% each). For the females of the German cockroach, the oviposition intervals were within 20 to 32 days with large

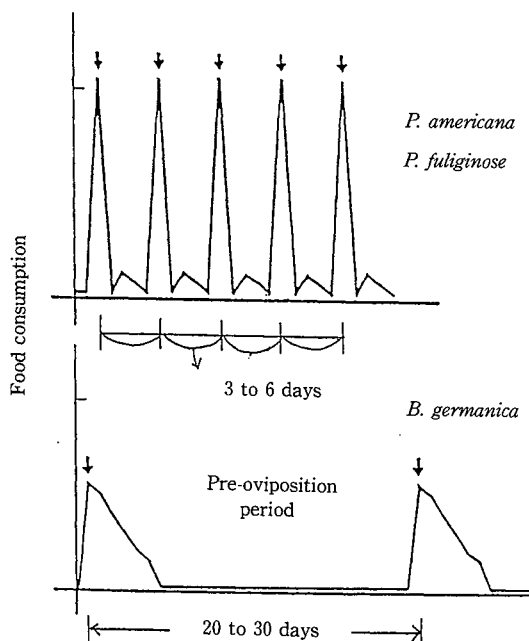


Fig. 6. Diagram Showing Feeding Characteristics of the Females of Three Species of Cockroaches. (Arrow indicates oviposition)

differences among individuals, but the highest incidence was 25-day interval (65%).

From these results, the relationship between the oviposition interval and food consumption can be summarized as shown in Fig. 6. For the females of the American and the Black cockroaches, the increase of food consumption appeared at 3- to 8-day intervals which exactly correspond to the interval of their oviposition. Occasionally, relatively higher food consumption could be seen in the following day the egg case was deposited. For the females of the German cockroach, the highest food consumption was observed at 20- to 30-day intervals which are equivalent to the oviposition intervals of this species, thereafter their food consumption decreased gradually during several days to reach their normal consumption level.

Discussion

Food consumption for 3 species of the cockroaches significantly increased in the day of oviposition (the day the egg case was deposited) and the increased food consumption appeared in coincidence with the oviposition interval. These observations clearly indicate that the increasing of food consumption in the females of these 3 species of cockroaches relates to their oviposition.

This trend indicates that the oviposition, namely deposition of the egg case, may somehow stimulates the formation of the next egg case. Similar to blood sucking of mosquitoes before the oviposition, such increase of food consumption is considered to occur from the physiological

requirement of cockroaches in order to obtain nutrition required for the formation of the next egg case. This trend has already been observed in our laboratory tests with a toxic bait : we found that it was not necessarily true that all cockroaches ate the toxic bait during night time, particularly in the German cockroaches it was thought there was a problem in the efficacy of an attractant bait since they spent a relatively long period without feeding. This time it was found that this fact particularly relates to the physiological characteristics of the females. It is surprising that such interesting result could be obtained as a new finding which has not known in the past.

There are several cases in which satisfactory control of the German cockroach with an attractant bait can not be obtained within a short period of about one month in field trials due to fluctuation of the performance. From the present finding, it is too hastily to attribute such poor performance of to a reduction of the sensitivity of the cockroach against an attractant bait. Regarding this point, the author is delighted to be able to explain such question by the present finding.

Generally, the nymphs of cockroaches live in group and a pheromone therefor is well known. When the nymph is reared individually, its food consumption is very low and its growth is very slow. Interestingly, however, in case of the adult female, particularly in the day of oviposition, food consumption was more than 2 times higher in one cockroaches per container compared to 2 or 3 cockroaches per container.

Conclusion

In 3 species of the cockroaches tested, it was found that food consumption of the females increased in the day of oviposition. In this case, the day of oviposition was defined as the day the egg case was deposited. In the Black and the American cockroaches, this interval was 3 to 6 days. In the German cockroach, the situation was different from other two species ; increased food consumption appeared 20 to 30 days interval with gradual decrease thereafter during 3 to 4 days and the oviposition could be seen in the first day food consumption increased.

It was considered that increased food consumption related to nutrition supply required for the next egg formation.

The ratio of food consumption in the day of oviposition and in the oviposition interphase for one cockroach per container was 109.8 for the Black cockroach, 99.7 for the American cockroach and 22.0

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