



Oviposition Concealment Behavior of *Periplaneta americana* L. and its Application on Onthecal Trap in the Laboratory 【Research report】

美洲蜚蠊卵鞘掩埋行為及其應用為卵鞘誘集器之研究【研究報告】

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Abstract

When provided with styrofoam board, the female *Periplaneta americana* L. (Blattoidea : Blattidae) would deposit and conceal her oothecae during the oviposition period. The deposition behavior consisted of 3 main steps, namely, digging and ingesting the board (38.3 ± 10.5 min.), depositing the ootheca into the board (29.0 ± 8.9 sec.) and concealing the ootheca (44.5 ± 15.2 min.). Most of the *P. americana* oothecae were deposited into the styrofoam board traps and collected for the roach rearing in the laboratory. Several factors were found to affect the oviposition behavior of *P. americana* such as that the styrofoam board with larger size and looser structure (16.9 mm displacement/ 51.84 mm²/ 4.57144 kg) attracted more oothecae deposited. Furthermore, the unconcealed rate of the oothecae increased to 26.2% when the density increased from 1, 5 and 10 to 20 cockroaches in a rearing container. When the styrofoam board was thinner than 10 mm, the cockroach would still exhibit the concealment behavior but failed to conceal the oothecae. When the board was thinner than 3 mm, the roach would dig and chew but not deposit onto it. The oothecal parasitoid wasp, *Evania appendigaster*, would find and oviposit both in the concealed oothecae and unconcealed ones.

摘要

結構疏鬆之保麗龍板是引起懷卵美洲蜚蠊產下卵鞘及掩埋行為的誘因，因此可利用保麗龍板為其產卵誘集器。產卵鞘行為包括三步驟：一、挖取並吞食保麗龍板，須時 38.3 ± 10.5 分鐘來挖成和卵鞘大小相似之洞；二、產下卵鞘於挖好之洞內，此動作只費 29.0 ± 8.9 秒；三、吐出已吞食之保麗龍碎片掩埋卵鞘，歷時 44.5 ± 15.2 分鐘，完成掩埋行為然後離去。利用8種不同材質製成 $7\text{cm}^2 \times 2\text{cm}$ 之卵鞘誘集器，誘集美洲蜚蠊卵鞘，54.6%卵鞘會產在這些誘集器上，其中之77.6%產於保麗龍板上。若只以保麗龍、人造海綿及紗布三種有效誘集材質誘集，則有63.1%卵鞘產於其上，其中有74.6%產於保麗龍板上。保麗龍板大小、硬度及厚度會影響美洲蜚蠊產卵鞘及掩埋行為之意願。不管是否把卵鞘掩埋於保麗龍板內，卵鞘寄生蜂一瘦蜂，都可輕易找到美洲蜚蠊卵鞘寄生。

Key words: American cockroach, oviposition behavior, *Evania appendigaster*, parasitoid wasp.

關鍵詞: 美洲蜚蠊、產卵行為、寄生蜂。

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Oviposition Concealment Behavior of *Periplaneta americana* L. and its Application on Oothecal Trap in the Laboratory

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ABSTRACT

When provided with styrofoam board, the female *Periplaneta americana* L. (Blattoidea: Blattidae) would deposit and conceal her oothecae during the oviposition period. The deposition behavior consisted of 3 main steps, namely, digging and ingesting the board (38.3 ± 10.5 min.), depositing the ootheca into the board (29.0 ± 8.9 sec.) and concealing the ootheca (44.5 ± 15.2 min.). Most of the *P. americana* oothecae were deposited into the styrofoam board traps and collected for the roach rearing in the laboratory. Several factors were found to affect the oviposition behavior of *P. americana* such as that the styrofoam board with larger size and looser structure (16.9 mm displacement / 51.84 mm² / 4.57144 kg) attracted more oothecae deposited. Furthermore, the unconcealed rate of the oothecae increased to 26.2% when the density increased from 1, 5 and 10 to 20 cockroaches in a rearing container. When the styrofoam board was thinner than 10 mm, the cockroach would still exhibit the concealment behavior but failed to conceal the oothecae. When the board was thinner than 3 mm, the roach would dig and chew but not deposit onto it. The oothecal parasitoid wasp, *Evania appendigaster*, would find and oviposit both in the concealed oothecae and unconcealed ones.

Key words: American cockroach, oviposition behavior, *Evania appendigaster*, parasitoid wasp.

Introduction

Outdoors, female *Periplaneta americana* prefers to oviposit in moist and cryptic sites (Fleet and Frankie, 1974), often in the corner and crevice of her habitat (Roth, 1981). Sometimes, the oviposition sites would be away from the habitat, but usually remain closed to the corner and in the crevice of hidden places. In semiopened environments, such as a traditional market or a covered drain, the

ootheca is often partially covered by the mixture of saliva and dirt probably to prevent water loss and mechanical trauma (Provine, 1981). Therefore, it is very difficult to find ootheca of cockroach in the field. The present study adopted various kinds of substrate materials commonly used indoors to examine the preference and characteristic of *P. americana* oviposition behavior in an attempt to develop an oothecal trap to collect oothecae for rearing purpose.

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Materials and Methods

Insects

P. americana, collected from 16 traditional markets in Taiwan in April 1990 were reared in a $60 \times 30 \times 35$ cm³ container. It was glued by black paper outside, covered by a lid with screen and placed in a walk-in growth chamber at $27 \pm 1^\circ\text{C}$, $80 \pm 10\%$ r.h. and 12 h light: 12 h dark condition. The roaches were provided with short section of paper tubes as shelters, reared in the reversed condition from natural photoperiod, fed rat chow and given water with an automatic water supplier (modified from Alsop, 1990). Each container grew about 250 adult and nymph roaches. *Evania appendigaster* were collected at the same places as the American cockroach. After the parasitoid wasps emerged, they were put into a glass container (12 cm dia. \times 20 cm height) for mating and further ovipositing (if provided American cockroach ootheca).

Experiments

In the oothecal trap test, $60 \times 30 \times 35$ cm³ containers were used. To examine the depositing preference, 20 females and 10 males *P. americana* were placed on one side of the container with a toilet paper core tube as their hiding place and 8 different types of oothecal traps with the same size (7.5 cm² \times 2 cm) were randomly placed on the other side, namely a cardboard, a tile, an artificial sponge, a pile of plastic bags, a pile of gauze, a piece of plywood, a pile of newspaper and a styrofoam board. Besides, 15 females and 10 males were placed at another container in the same condition as described above, but only a styrofoam, an artificial sponge and a gauze were placed inside. The cockroaches were observed for 45 days, and the procedures were replicated 3 times. Furthermore, to examine the relationship between the numbers of oothecae being deposited and the types of styrofoam board, 4 different experimental

designs were adopted as follows: a) To test the effect of styrofoam hardness, 10 females and 10 males were reared in the container, with 3 kinds of $20 \times 20 \times 2$ cm³ styrofoam boards differing in their hardnesses (16.9, 10 and 4 mm displacement / 51.84 mm² / 4.57144 kg were verified) on the bottom for 30 days. b) To observe the concealment and cannibalism rate, 1, 5, 10 and 20 females were reared in 4 containers, respectively, with a same type of styrofoam board on the bottom of the containers. c) To test the effect of styrofoam thicknesses, 10 females and 10 males were reared in the container, with fixed and free styrofoam boards of 20, 10 and 3 mm thick (20×20 cm²), respectively, on the bottom. d) To examine the effect of the styrofoam board size, 4 styrofoam boards of different sizes as full, half, quarter and one eighth were put into the bottom of the container, respectively, with 10 females and 10 males inside (3 replications).

Finally, to observe the oviposition behaviors of both *E. appendigaster* and the cockroach, a female American cockroach was reared in a dia. 12 \times 20 cm glass jar with a circular styrofoam board (dia. 12 cm) on the bottom. After deposition, the cockroach was taken away before a 3-day-old female *E. appendigaster* was released into the glass jar.

Results

I. The ootheca concealment behaviors of *P. americana*

The interval of *P. americana* deposition in the reproductive stage lasted for 5.27 ± 1.85 days ($n=412$). At the carriage period, the ootheca was carried by the roach and remained visible outside of her vagina for 12–36 hours before deposited. Before the egg deposited, the cockroach started to look for an oothecal deposition site. She would then begin digging and ingesting styrofoam by mouthparts with

her six legs fixed. The concave that she dug had a wider opening and a narrower bottom. The width around the concave top was *ca.* 8.8 mm and the length *ca.* 10.2 mm. While near the bottom, the width narrowed to be *ca.* 5.2 mm and the length *ca.* 8.9 mm. The depth of the concave was *ca.* 5.5 mm. The digging and ingesting process took about 38.3 ± 10.5 minutes ($n=8$). After digging, she drove her body forward and deposited the ootheca for only 29.0 ± 8.9 seconds. If the ootheca was not dropped right into the concave, she would moisten the ootheca with her saliva, and press them deeper into the hole by her mouthparts. It is evident now that the saliva could facilitate the positioning of the ootheca into styrofoam but whether there is a certain enzyme or chemical to dissolve the styrofoam still remains uncertain. By this time, the cockroach went back to its original position and started to chew styrofoam within the circle by her fixed forelegs and hind legs as the axis. The swallowed styrofoam which was mixed with saliva would be regurgitated to the surface of the ootheca. After 20 min., the ootheca would be coated largely. Then, the cockroach chewed down the styrofoam and moved the fragments directly to cover the oothecae without regurgitation. When the *circa* styrofoam surface used up, the roach reached the styrofoam fragments around and moved depending on its middle legs as the axis without leaving the site. After the concealment process was completed, the cockroach would then leave the site. It took 44.5 ± 15.2 min. to bury the ootheca (Fig. 1). In a confined space, the cockroach sometimes would return with some styrofoam debris to cover the site again. While in an open space, she would not go back. However, in the crowded condition, if the ootheca in the styrofoam was not buried deep enough, other cockroaches would cannibally consume the ootheca and deposit right at the side. When the concave

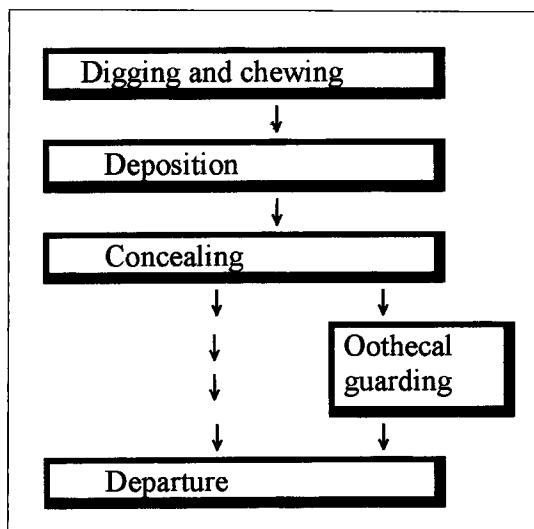


Fig. 1. Model of the depositing and concealing behaviors of the American cockroach.

was deep enough, the roach would deposit overlappingly on the same site. The maximum layers of the oothecae were found to be 3 in the same hole. When a used styrofoam board with many cavities on it was adopted, the roach would deposit her oothecae unconcealedly along the inner surface of the cavities.

II. Oothecal traps test

In the container without any oviposition trap inside, the oothecae were deposited in rat chow pile (cockroach diet), the hidden place formed by toilet paper cores, or even on the ground. With traps inside the container, it was found that 54.6% ($n=379$) of oothecae were deposited in 3 different kinds of traps, namely styrofoam, artificial sponge and gauze. The ootheca deposition rate in the styrofoam appeared the highest (77.6%) (Table 1), and most of the oothecae deposited in styrofoam were covered. However, the deposited oothecae in the artificial sponge and the gauze were not concealed because these two materials appeared too hard to be chewed and torn.

No ootheca was deposited in the

other kinds of traps, such as tile, wood board, piles of newspaper and cardboard. Therefore, later on, only these 3 effective traps were put inside the container for further testing. It was found that 63.1% (n=206) of the oothecae were deposited in the styrofoam, the sponge and the pile of gauze, and 74.6% of out of these 63.1% in the styrofoam.

Since American cockroach preferred to deposit the ootheca in the styrofoam which was relatively loosely structured, the styrofoam boards with different hardness were tested on this cockroach. A steel bar with 51.84 mm² surface area was pressed onto the styrofoams with the same force (4.57144kg) and the depth of the concave created by the force was measured as an indicator of the hardness of the styrofoam. No ootheca was deposited in the hardest one (4 mm depth

displacement), which is often used to protect fragile merchandise (Table 2). On the other hand, 63.1% and 36.9% of oothecae were deposited in the other two softer styrofoam boards (16.5 and 15.0 mm depth displacements).

When different numbers of American cockroaches were put into the containers, the total ootheca numbers of 10, 51, 72 and 131 were deposited by 1, 5, 10 and 20 cockroaches, respectively. 26.2% of the oothecae were unconcealed in the highest density of 20 cockroaches, and 18.4% and 16.1% when 5 and 10 cockroaches were presented. The cannibalism rate increased from 1.9% to 9.1% when the density of the cockroaches increased from 5 to 10 (Table 3).

The thickness of the styrofoam board was also one of the factors that affected the ootheca concealment behavior of

Table 1. Preference of the oothecae deposition by American cockroach on the various materials

Materials	Test 1	Test 2
	% (SD) deposited ¹⁾	% (SD) deposited ¹⁾
Styrofoam	77.6 (8.9) ^c	74.6 (6.8) ^b
Artificial sponge	18.7 (6.4) ^b	13.1 (3.4) ^a
Gauze pile	3.7(2.8) ^a	12.4 (5.6) ^a
Plywood pile	0	—
Tiles pile	0	—
Plastic bag pile	0	—
Newspaper pile	0	—
Carton paper pile	0	—
Total oothecae	207 of 379 (54.6%)	130 of 206 (63.1%)

1) Means followed by the different letters within the same column are significantly different by Duncan's new multiple range test at 5% level

Table 2. Preference of ootheca deposition by American cockroach on the styrofoam boards of different hardnesses

Styrofoam hardness (mm displacement / 51.84mm ² / 4.57144kg)	% of ootheca deposited Means (SD) ¹⁾²⁾
16.9 (loose)	63.1 (6.6) ^a
15.0 (medium)	36.9 (6.6) ^b
4.0 (hard)	0 ^c

1) During the test, 98 oothecae were deposited totally

2) Means followed by the different letters within the same column are significantly different by Duncan's new multiple range test at 5% level

American cockroaches. Most of the oothecae were laid on the styrofoam of 20 mm thick and over 82% of those were concealed completely. However, when the styrofoam was thinner than 10 mm, American cockroaches still conducted the concealment behavior, but over 60% of the oothecae were deposited barely. When the board was thinner than 3 mm, roaches would dig and chew but no ootheca deposition occurred (Table 4).

When the bottom of the container was padded completely with a styrofoam board, all the oothecae were deposited on the board, and 94.7% of those were concealed. When the styrofoam boards failed to cover the entire bottom of the container, the deposition rate on the boards also declined, but the oothecae concealment rate on the boards remained

over 90% (Table 5).

III. The oviposition behavior of *Evania appendigaster* on the styrofoam-concealed oothecae of American cockroach

It has been known that *E. appendigaster* shows fixed action pattern of oviposition behavior on the uncovered ootheca (Yeh and Mu, 1994). It was found that *E. appendigaster* could easily locate the concealed oothecae by olfaction. When the *E. appendigaster* approached the American cockroach ootheca concealed in the styrofoam, *E. appendigaster* first would probe it by its antenna drumming. When there was debris of styrofoam hindering drumming, *E. appendigaster* would dig the debris out by 2 forelegs synchronously. After the ootheca was

Table 3. The percentage of unconcealed oothecae and cannibalism with 4 different densities of females American cockroach in the container

Cockroach density	Total Oothecae ¹⁾ deposited	Unconcealed % ²⁾ (SD)	Cannibalism % ²⁾ (SD)
1	10	0 ^c	0 ^d
5	51	18.4 (7.0) ^b	1.9 (1.5) ^c
10	72	16.1 (4.5) ^b	5.0 (4.6) ^b
20	131	26.2 (8.4) ^a	9.1 (2.0) ^a

1) Total number of 3 replications

2) Means followed by the different letters within the same column are significantly different by Duncan's new multiple range test at 5% level

Table 4. The relationship between the thickness of the styrofoam boards, both fixed and non-fixed, and the concealing percentage of the American cockroach

Thickness of styrofoam (mm)	Total Oothecae ¹⁾ deposited	% of oothecae concealed (SD)
20		
Fixed	88	93.7 (3.1)
Free	77	82.3 (7.3)
10		
Fixed	78	33.6 (6.4)
Free	63	22.9 (3.8)
3		
Fixed	0	0
Free	0	0

1) Total number of 3 replications

Table 5. The oviposition of the *P. americana* and the size of styrofoam board in the container.

Styrofoam area (Container size)	% Oothecae deposited on styrofoam (SD)	% Oothecae concealment (SD)
Full	100 (0)	94.7 (0.9)
Half	89.6 (2.8)	92.3 (6.4)
Quarter	81.1 (2.6)	92.2 (2.9)
One eighth	63.8 (8.6)	90.7 (2.9)

partially exposed, the wasp would drum it by antennae again to exploit the right parasitoidic object. After oviposition, the wasp would push some styrofoam debris back and then left. If a cockroach was presented before the oviposition stage, she would threaten the *E. appendigaster* by her antennae or even run close to push the wasp away. So the wasp would be interrupted for her oviposition behavior and run away, and, therefore, no oviposition would be completed. If there came another subsequent parasitoid wasp, superparasitism would be produced by its ovipositing on the same ootheca. In the process of oviposition, except the cleaning up the styrofoam debris which concealed the ootheca, the oviposition behavior of *E. appendigaster* on the concealed ootheca was almost identical to that on the bare one.

Discussion

Outdoors, the cockroach usually covers the oothecae by the natural substrates in the surroundings or leaves it bare in a shelter. However, lately, we found that the oothecae of *P. americana* were deposited barely or concealed incompletely with some dirt or its feces in the corner and crevice of her habitat both indoors and outdoors. Probably the American roaches are evolving from outdoor habitat insect to semi-sheltered and indoor one where the condition is more advantageous for survival. Therefore, they may be losing their concealment

behavior when depositing ootheca. But when we presented some soft material in their habitats, the concealment behavior was induced. The present study which was conducted indoors used styrofoam boards as the oothecal trap and found that the concealment behavior was induced by the presence of them (Tables 2, 3 and 4).

The ootheca which covered 14–18 American cockroach eggs for the prevention of water lose (Provine, 1981) still showed a preference of being concealed. When the substrate was the styrofoam, then the oothecae would be entirely laid in it. Although in the condition of r.h. 15%, the eggs in the oothecae still hatched (Roth and Willis, 1955). Therefore, these coverings, beside being able to prevent from water loss, probably could help the oothecae avoid attacking from herself (Willis and Lewis, 1957), other cockroaches and natural enemies. The concealment behavior would be induced by the presence of the styrofoam board. When the oviposition was interrupted, the roach would stop digging for a while and then continued to dig, or looked for a new place to dig again. It seems that this behavior is on the way of evolution from concealing the ootheca to leave it exposed. The behavior of ovipositing the ootheca on the styrofoam board can be used for collecting the ootheca in a rearing container in the laboratory by removing the oothecae from the board every 4 weeks (the eggs of the American cockroach hatch around 30 days at 29°C

or 32 days at 27°C (Willis *et al.*, 1958; Provine, 1981). There is a good practice in the field when the styrofoam board is placed in a butcher stand at a tradition market, and would collect a lot of oothecae. However, the limitation of the styrofoam board as the oothecal trap for field control is that it is effective only for American cockroach because American cockroach is the only household one that would oviposit in the styrofoam board. When styrofoam boards are used as the American cockroach oothecal trap, they should be as big as cockroach's habitat, thicker more than 10 mm, soft and fixed. If the styrofoam is not fixed well, the roach will not be able to reach above it, and will then try to dig along the lateral sides. Eventually, the roach will quit depositing on it. The present study also found that when the deposited oothecae abounded, the cockroach would consumed the old ootheca in order to have an available deposition site. This behavior seems to associate with the regulation of the population density. Because it is not difficult for the *E. appendigaster* to find the concealed American cockroach oothecae, the concealment styrofoam seems not able to prevent the ootheca from the attack of parasitoids enemy (Fleet and Frankie, 1975). However, it probably has a role in the protection against the predator such as human being.

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美洲蜚蠊卵鞘掩埋行爲及其應用爲卵鞘誘集器之研究

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摘 要

結構疏鬆之保麗龍板是引起懷卵美洲蜚蠊產下卵鞘及掩埋行爲的誘因，因此可利用保麗龍板爲其產卵誘集器。產卵鞘行爲包括三步驟：一、挖取並吞食保麗龍板，須時 38.3 ± 10.5 分鐘來挖成和卵鞘大小相似之洞；二、產下卵鞘於挖好之洞內，此動作只費 29.0 ± 8.9 秒；三、吐出已吞食之保麗龍碎片掩埋卵鞘，歷時 44.5 ± 15.2 分鐘，完成掩埋行爲然後離去。利用8種不同材質製成 $7\text{cm}^2 \times 2\text{cm}$ 之卵鞘誘集器，誘集美洲蜚蠊卵鞘，54.6%卵鞘會產在這些誘集器上，其中之77.6%產於保麗龍板上。若只以保麗龍、人造海綿及紗布三種有效誘集材質誘集，則有63.1%卵鞘產於其上，其中有74.6%產於保麗龍板上。保麗龍板大小、硬度及厚度會影響美洲蜚蠊產卵鞘及掩埋行爲之意願。不管是否把卵鞘掩埋於保麗龍板內，卵鞘寄生蜂—瘦蜂，都可輕易找到美洲蜚蠊卵鞘寄生。

關鍵詞：美洲蜚蠊、產卵行爲、寄生蜂