

Methods to Determine the Minimum Number of Termites Required to Cause Visible Damage to Susceptible Plastic Films

by

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Abstract

While the use of a laboratory nest of *Coptotermes formosanus* has previously been shown to be effective for determining the comparative termite-resistance of plastics with the aid of wood attachments to facilitate termite hits, this method can not be used with insecticide-treated plastics. Therefore, a few modified JWPA Standard No.17 or JWPA Standard-TW-S.1 (=JIS K 1571- 2004) laboratory test methods were compared with regard to their suitability for evaluating the termite-resistance of plastics, since the existing Japanese standardized methods do not accurately reproduce termite damage to susceptible plastics under actual service conditions. One of the modified methods was suitable for determining the minimum number of termites required to attack high density polyethylene (HDPE) film so that it was possible to standardize the method to compare the termite-resistance of non-woody materials with or without chemical treatment. When termites were introduced to a HDPE film with an approximately 1 g wood block in a 4 cm i. d. container, 300 workers of *Coptotermes formosanus* were required for termites to attack from a straight scratched surface, which was equivalent to a termite density (pressure) of 24 workers/cm² foraging area. The required termite pressure may be varied by altering the number of termites, quantity of wood (food) and size of the foraging area.

Key words: termite-resistance of plastics, high density polyethylene (HDPE), *Coptotermes formosanus*, termite density (pressure)

Introduction

Some early, extensive laboratory and field studies addressed the comparative termite-resistance of plastic materials. Laboratory evaluations were performed with Australian termite species, and they reported wide variations in the susceptibility of plastics to termite attack and the effects of different termite species (Gay and Wetherly, 1962, 1969). Watson et al. (1984) supported the notion that a laboratory test could be used to examine the termite-resistance of plastics. Although these Australian researchers used relatively large quantities of termites (10 g of termites) without specifying how many termites were required to cause damage to plastics, they could reproduce the termite-susceptibility of plastics as determined in field tests by others who exposed cable coverings to subterranean termites (Beal et al., 1973; Yamano, 1976; Beal and Bultman, 1978).

Unfortunately, there is no recent information available regarding the resistance of plastics to subterranean termites. This is partly due to the lack of standardized laboratory and field methodologies for assessing the resistance of plastic materials to subterranean termites. The inability of the existing Japanese standardized methods (Rosenblat et al., 2005) and a slightly

modified method (Rosenblat and Tsunoda, 2006) to reproduce the effects of termite attack on plastic films, bars and tubes strongly supports the need for new methodologies to examine the termite-resistance of plastics. Termite tunneling behavior, the size of the test container, the number of termites (termite pressure) and the termite species are all thought to be influential factors. The use of a laboratory nest provided information on the relative resistance of plastic materials in a recent study (Tsunoda et al., 2010). However, this does not seem to be suitable for insecticide-treated materials, since the sacrifice of many termites or even a whole colony is unavoidable. Although that report also described a method for determining the minimum number of termites required to cause visible damage to susceptible plastics, detailed information on the test method was not presented. The aim of the present study was to explore test methods for determining the minimum number of termites required to damage the straight surfaces of plastic materials. The obtained results could help to reduce the number of termites needed to as few as possible to compare the termite-resistance of various plastics.

Materials and methods

Test plastic materials: Since termites tended to attack films more readily than bars and tubes (Tsunoda et al. 2010), high density polyethylene (HDPE) film (0.16 mm thick) with Shore D hardness 68 was used. Preliminary trials were conducted to select methods worthy of further consideration. A single test material was preliminarily tested according to the experimental design, whereas 6 replicates were examined for a selected test method, which was expected to produce reliable comparative data on the termite-resistance of susceptible plastic film such as HDPE.

Test termites: Sound mature larvae (workers) and soldiers of *Coptotermes formosanus* Shiraki were obtained from a laboratory colony that was originally collected from Wakayama Prefecture, Japan and has been maintained in a concrete trough at the Research Institute for Sustainable Humanosphere of Kyoto University. Laboratory tests showed that sugi (*Cryptomeria japonica* D. Don) sapwood (2 x 2 x 1 cm) always sustained >20% mass loss, when it was exposed to 150 workers and 15 soldiers of *C. formosanus* for three weeks in the dark (e. g. Tascioglu and Tsunoda, 2010).

Forced-feeding method (1) Preliminary tests: Table 1 shows the 8 methods used in the preliminary trials. The assembled units were maintained at $28 \pm 2^\circ\text{C}$ and >80% RH in the dark for 4-6 weeks. The test methods were designed based on the existing Japanese standards to simplify the handling of termites.

Forced-feeding method (2) Selected test: Test method (G) was selected because it gave the best results among the 8 methods shown in Table 1 when 300 workers and 30 soldiers were introduced into the upper chamber. Since the HDPE film with a smooth surface did not allow termites to attack from the straight surface, surface-scratched films were used. Scratches were made on the central area (three film specimens) or the whole area (three specimens). The assembled test units were visually inspected every day to examine termite penetration.

Table 1 Test methods in the preliminary trials

Test method (brief description)	Test container	Number of termites (W + S)*
(A) Modified JWPA Standard-TW-S.1 (1992): Increased number of termites	Acrylic cylindrical chamber (8 cm in inner diameter (i. d.) and 5 cm in depth) with a 5 mm-thick plaster bottom	500 + 50
(B) Modified JWPA Standard-TW-S.1 (1992): Increased number of termites; wood attachments to facilitate termite access		
(C) Modified JWPA Standard No. 17 (1992): Film specimen buried vertically at a depth of 4 cm in the soil of the lower container	Double-story acrylic cylindrical chamber (each 8 cm in i. d. and 5 cm in depth; termites introduced to 175 g crushed nest materials + 70 g water in the lower chamber with a 5 mm-thick plaster bottom	
(D) Modified JWPA Standard No. 17 (1992): The same as (C); wood attachments		
(E) Modified JWPA Standard No. 17 (1992): Increased number of termites; Smaller containers; a wood block on the film specimen	Double-story acrylic cylindrical chamber (upper; 4 cm in i. d. and 6 cm in depth; lower: 4 cm i. d. and 5 cm in depth; termites introduced to 13 g of effective phosphate- rich soil + 7 g water in the lower chamber with a 5 mm- thick plaster bottom . A piece of water-moistened sugi (<i>Cryptomeria japonica</i>) wood 3 x 3 x 0.5 cm was on the film specimen	
(F) Modified JWPA Standard No. 17 (1992): The same as (E) with further modifications	The same as (E) with additional modification: Both chambers are filled with soil (5 cm deep); a pair of pine wood blocks is used to sandwich the test film; termites are introduced into the lower chamber	
(G) Modified JWPA Standard No. 17 (1992): The same as (E) with additional modifications	The same as (E) with additional modifications: Only the lower chamber is filled with soil + a piece of sugi wood 3 x 3 x 0.5 cm on top the soil; another sugi wood block 1 x 1 x 2 cm or plaster on the film specimen as food and or water source with termites in the upper chamber (Fig. 1)	150 + 15
		300 + 30
		500 + 50
(H) Modified JWPA Standard No. 17 (1992): Increased number of termites, film specimen sandwiched between two wood blocks	The same as (C) with additional modifications: termites introduced to 50 g of effective-phosphate-rich soil + 50 g water in the lower chamber with a 5 mm- thick plaster bottom. A piece of sugi wood 3 x 3 x 0.5 cm is placed under the film specimen and another two sugi wood pieces 1 x 1 x 2 cm are placed on the film with termites	900 + 90
		1200 + 120

*W: workers and S: soldiers **Film specimen size:** 4 x 2 cm for test methods (A) ~ (D); 5 cm in diameter for (E) ~ (G); 9 cm in diameter for (H). **Test duration:** 6 weeks for (A) ~ (D); 4 weeks for (E) ~ (H).



Fig. 1 Test method (G) using 300 workers and 30 soldiers of *Coptotermes formosanus* with a sugi wood block (1 x 1 x 2 cm) and a pine wood block (3 x 3 x 0.5 cm) in the upper and lower-chambers, respectively [(1) and (2)] or a small amount of plaster [(3) and (4)] in the upper chamber instead of sugi wood block

Results and discussion

Table 2 summarizes the results of the preliminary trials. Signs of termite attack were observed with film specimens in test methods (A), (B) (Fig. 2), (G) and (H). Methods (G) and (H) reproduced termite penetration through a straight surface with scratching. Although the smoothness of the surface did not seem to affect the attack of plastic materials when they were exposed to a laboratory-maintained termite colony (Tsunoda et al., 2010), no termite attack (not even surface nibbling/scratching) was seen with any film specimen without scratching regardless of the test method used in the current experiments.

Table 2 Summarized results obtained by 8 test methods

Test method	Number of termites (W + S)	Result summary
(A)	500 +50	• Eroding from the edge of the film specimen • 100% mortality by the end of 4 weeks
(B)	500 +50	• Eroding from the edge of the film specimen • 17% mortality by the end of the 6-week test
(C)	500 +50	• All termites on the surface of the soil were milky-colored at the end of 5 weeks • 100% mortality by the end of the 6-week test
(D)	500 +50	
(E)	500 +50	• 100% mortality by the end of 2weeks, possibly due to overcrowding
(F)	500 +50	
(G)	150 + 15	• Trace of nibbling from the edge of the film specimen • No penetration possibly due to low termite density (pressure)
	300 + 30	• Penetration from the straight scratched-face within 2-4 days
	500 + 50	• No penetration from the straight scratched-surface with 40-50% mortality, possibly due to overcrowding (too high termite density)
(H)	900 + 90	• Penetration from the straight scratched-surface within 3 days
	1200 +120	• 100% mortality by the end of 2 weeks, possibly due to overcrowding

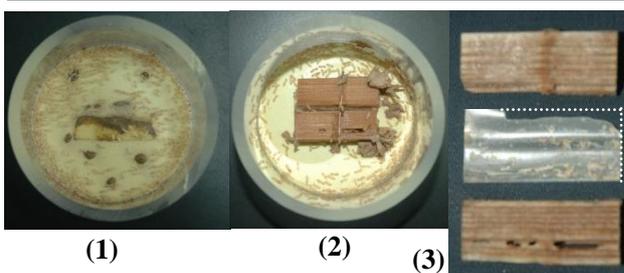


Fig. 2 Test methods (A) and (B) using 500 workers and 50 soldiers of *Coptotermes formosanus*

(1) Test method (A): without wood attachment, (2) Test method (B): with wood attachments, and (3) Disassembled film specimen/wood attachments

Since we should seek to reduce the number of sacrificed termites in any standardized method, only test method (G) using 300 workers and 30 soldiers was selected for further examination with 6 replicates. One replicate experienced microbial infection and all of the termites died within a week or so, and thus the data were discarded. As shown in Fig. 3, termites could penetrate the straight scratched-surface. This meant that when a sufficient amount of food was provided with a well-balanced ratio of the termite feeding area to the number of termites used, termites could freely move for feeding and penetrate through the straight surface of a susceptible plastic film such as HDPE. However, termites that were introduced to the soil in the lower chamber did not penetrate the straight surface of film materials [test methods (A)-(F)].

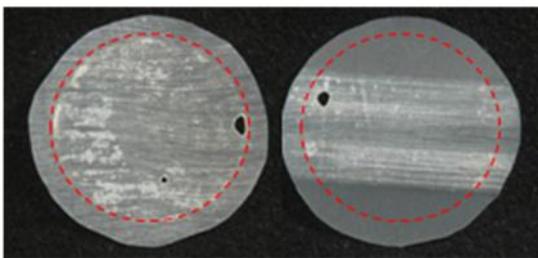


Fig. 3 Film specimens of HDPE (high density polyethylene) recovered after 4 weeks of exposure to 300 workers and 30 soldiers of *Coptotermes formosanus*. Dotted circle: Area exposed to termite attack, (1): Entire surface scratched, (2): Half of the surface scratched

• Once termites made a tunneling hole, they did not always need to widen the hole.

Test method (H) with 900 workers and 90 soldiers was also promising, but this was considered to be unrealistic in terms of the number of termites required for duplicate tests. Although this method used a lower density of termites (300 workers/ 4π cm² foraging area versus 900 workers/ 16π cm² foraging area) than the successful test method (G), three times more termites were required to penetrate the straight surface of HDPE film.

Conclusions

The present results suggest the importance of surface smoothness and the extent of termite pressure, which was reflected by the ratio of the area/space for termite feeding activity to the number of termites used when a sufficient amount of food is available. Workers of *C. formosanus* were encouraged to attack susceptible HDPE film from a straight scratched-surface at a termite density of 24 workers/cm², as demonstrated by test method (G). Food availability [approximately 1 g for 300 workers in the test method (G)] was also thought to be a critical factor that relieved termites from stressful competition to obtain access to the food source. In addition, test method (H) with 900 workers could reproduce penetration from a straight surface at a termite density of 18 workers/cm² with twice the amount of wood as food. Both methods enable us to supply water for termites by pipetting water onto a wood block(s) or plaster when necessary.

Test method (G), as discussed above, was shown to be suitable for evaluating the termite-resistance of non-woody materials with or without chemical-treatment, and should be considered in the development of a reliable standard test method.

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