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ORIGINAL ARTICLE

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Feeding activities of *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe) as affected by moisture content of wood

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Abstract The relationship between the moisture content (MC) of wood blocks and the feeding activities of two Japanese subterranean termites, *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe), was investigated with two choice tests. When three wood blocks with low MC (6%–12%), middle MC (79%–103%), and high MC (140%–182%) were exposed to workers of *C. formosanus* and *R. speratus* in a choice test, the feeding preferences were found in the middle MC blocks for *C. formosanus*, and the middle and high MC blocks for *R. speratus*, although wood blocks of low MC were also attacked. In a second choice test, wood blocks consisting of five pieces with water-impregnated (MC: 133%–191%) top, middle, or bottom piece were exposed to workers of both species. Higher consumptions were generally obtained in water-impregnated wood pieces and bottom pieces.

Key words *Coptotermes formosanus* · *Reticulitermes speratus* · Moisture content · Feeding activity

Introduction

Termites, damp-wood termites, and subterranean termites in particular, are well known for their high water requirements.[1–3] Moisture can be obtained from many sources such as sugars in foods (by metabolic breakdown) and wet woods.[4] The moisture content (MC) of wood can affect the mode of feeding of different termite species.[4]

The relationship between feeding activities and ambient conditions such as temperature and relative humidity (RH) has been reported by many researchers.[5–13] The optimum temperature conditions for the feeding activities of Japanese subterranean pest termites *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe) workers were reported as 30°–35°C[5–8] and 25°–30°C,[8,9] respectively, when the termites were fed on filter papers and wood blocks. However, in the case of observations using acoustic emission (AE) monitoring at 12°–40°C, the highest activity was seen at 36°C[10] for *C. formosanus*. In contrast, the optimum RH for the wood-attacking activities was 90% for both species.[8] These pest termites, unlike dry-wood termites, require liquid water to survive.[2,14] Therefore, damage to houses caused by these subterranean termites is generally believed to occur at locations subject to high temperatures and high humidity.[2]

However, no study of these two species has been conducted regarding the effects of the MC of wood on feeding activities. The purpose of the present study was to clarify the relationship between the MC of wood and the feeding activities of two Japanese subterranean termites, *C. formosanus* and *R. speratus*, which are the most economically important species in Japan.

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Materials and methods

Test insects and wood specimens

Mature workers of two subterranean termites, *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe), were used as test insects. Those of *C. formosanus* were obtained from three laboratory colonies maintained in a termite culturing room at the Wood Research Institute of Kyoto University at 28° ± 2°C and more than 85% RH in the dark. *Reticulitermes speratus* workers were collected from three field colonies on the Uji Campus of Kyoto University (Uji City, Kyoto Prefecture), and they were kept in the culturing room. The latter were used for experiments within 1 month of collection.

Two different-sized sapwood blocks of Japanese red pine (*Pinus densiflora* Sieb. et Zucc), measuring 20 (R) × 20 (T) × 10 mm (L) for experiment I and 25 (R) × 25 (T) × 25 mm (L) for experiment II, were used as sample wood blocks. The latter was split into five pieces along with the annual ring (5 (R) × 25 (T) × 25 mm (L)).

Modification of moisture content in wood specimens

All wood specimens were oven-dried at 105°C for 24 h to calculate their MCs. After that, for experiment I, MCs of wood blocks were adjusted to 6%–12% (low MC), 79%–103% (middle MC), and 140%–182% (high MC) by air-drying, dipping in distilled water for 1 day, and vacuum impregnation of distilled water, respectively. For experiment II, top, middle, or bottom pieces of the five pieces were subjected to vacuum impregnation of distilled water to obtain high MC (133%–191%).

Bioassays

For experiment I, 300 workers and 30 soldiers of *C. formosanus* were put into an acrylic cylinder with a plaster bottom (90 mm in diameter and 50 mm in height), and a polystyrene dish with a rough surface (60 mm in diameter and 8 mm in height) was set bottom-up on the center of the bottom (Fig. 1A). For *R. speratus*, 500 workers were put into an acrylonitrile–styrene copolymer container (90 mm in diameter and 55 mm in height) with 10 g vermiculite (Neuchatel, grade 4, Australia) (MC: 175%) and the above-mentioned polystyrene dish (Fig. 1B). Three wood blocks, one each with low MC (6%–12%), middle MC (79%–103%), and high MC (140%–182%), were inserted into three openings (20 × 20 mm) of a plastic sheet (thickness: 1.0 mm) so that the wood blocks were not in contact with each other and were kept on top of the polystyrene dish during the test period. For both termites, two environmental conditions were employed, i.e., with (natural condition) and without (dry condition) a water supply. Three replicates for three colonies and two environmental conditions (natural and dry conditions) were employed (a total of 18 units for each species).

For experiment II, a similar experimental setup was employed except for the size of the rough-surface polyethylene dish (50 mm in diameter and 20 mm in height) and samples for both termites (Fig. 2A,B). A combined wood block with five pieces was put on the polyethylene dish. Two or three replicates for three colonies and four MCs were employed for the experiment II (a total of 36 units for *C. formosanus*

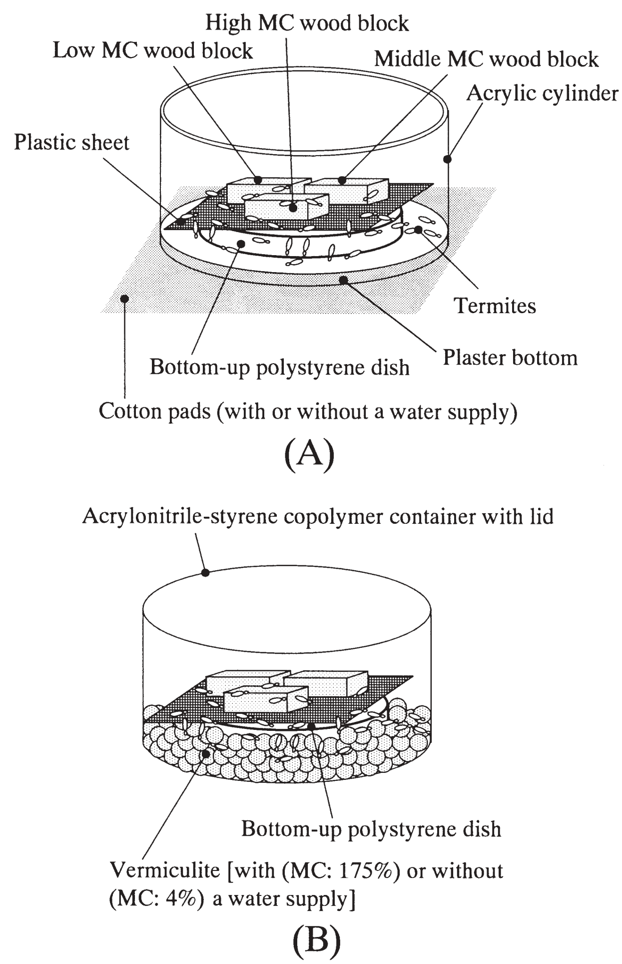

Fig. 1A,B. Experiment I setup. **A** Against *Coptotermes formosanus*, **B** against *Reticulitermes speratus. MC,* moisture content

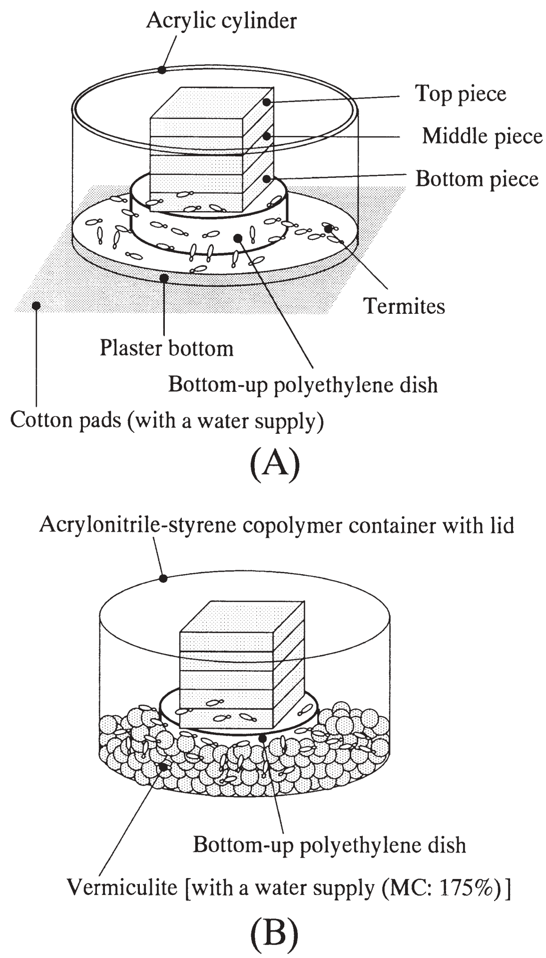

Fig. 2A,B. Experiment II setup. **A** Against *C. formosanus*, **B** against *R. speratus*

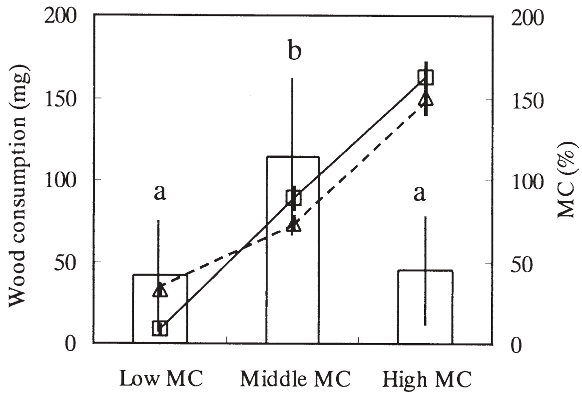

Fig. 3. Wood consumption of *C. formosanus* workers with a water supply for 3 days. *Error bars* show standard deviations. *Open squares* and *triangles* represent MCs before and after exposure to termites, respectively. The same letters indicate no significant difference at $P < 0.01$ (Tukey's test) $n = 9$

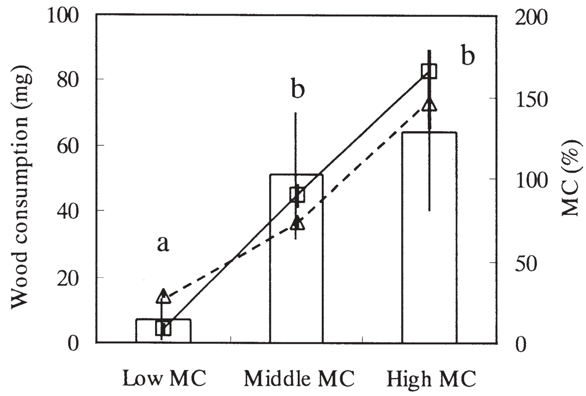

Fig. 5. Wood consumption of *R. speratus* workers with a water supply for 3 days. *Error bars* show standard deviations. *Open squares* and *triangles* represent MCs before and after exposure to termites, respectively. The same letters indicate no significant difference at $P < 0.01$ (Tukey's test) $n = 9$

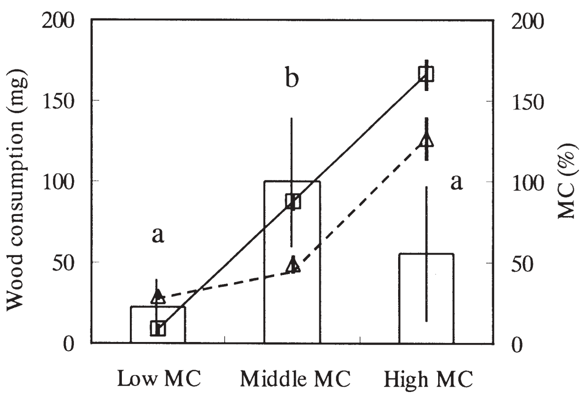

Fig. 4. Wood consumption of *C. formosanus* workers without a water supply for 3 days. *Error bars* show standard deviations. *Open squares* and *triangles* represent MCs before and after exposure to termites, respectively. The same letters indicate no significant difference at $P < 0.05$ (Tukey's test) $n = 9$

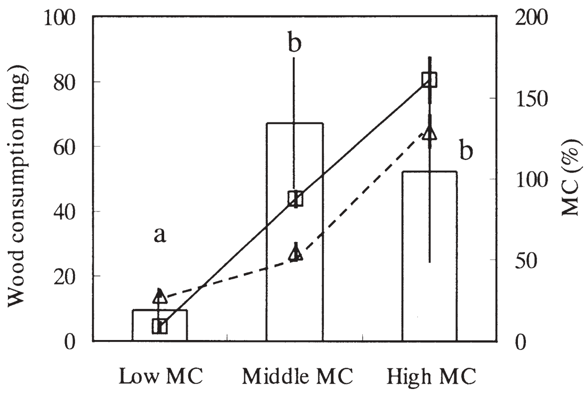

Fig. 6. Wood consumption of *R. speratus* workers without a water supply for 3 days. *Error bars* show standard deviations. *Open squares* and *triangles* represent MCs before and after exposure to termites, respectively. The same letters indicate no significant difference at $P < 0.01$ (Tukey's test) $n = 9$

and 24 units for *R. speratus*). Wood blocks with no vacuum impregnation of distilled water were employed as controls.

All test units were kept in the culturing room for 3 days, and the blocks were recovered, measured for their wet masses, washed with tap water, and oven-dried at 105°C for 24 h to calculate MCs and wood consumptions.

Results

Experiment I

The mean wood consumptions per 300 workers (*Coptotermes formosanus*) and 500 workers (*Reticulitermes speratus*) for 3 days, and the MCs of wood blocks are illustrated in Figs. 3,4 and 5,6, respectively.

Three hundred *C. formosanus* workers consumed a total of 200 mg and 177 mg under natural (Fig. 3) and dry conditions (Fig. 4), respectively, and no significant difference was obtained between conditions (*T*-test, $P < 0.05$). Significantly higher wood consumptions (ca. 100 mg) were obtained for middle MC blocks (79%–103%) compared with those with low MC (6%–12%) and high MC (140%–182%) (Tukey's test, $P < 0.05$) under both natural and dry conditions. The lower MCs were obtained from blocks exposed to dry conditions after the experiment.

In the case of *R. speratus*, the insects consumed a total of 122 mg and 129 mg under natural (Fig. 5) and dry conditions (Fig. 6), respectively. As observed for the *C. formosanus* workers, no significant difference in the total consumption was observed between conditions (*T*-test, $P < 0.05$). Significantly higher consumptions (50–70 mg) were observed at middle MC (79%–103%) and high MC (140%–182%) blocks compared with those at lower MC (6%–12%), regardless of conditions (Tukey's test, $P < 0.01$). A similar tendency was observed between MCs maintained at natural and dry conditions after 3 days, as in the case of *C. formosanus*.

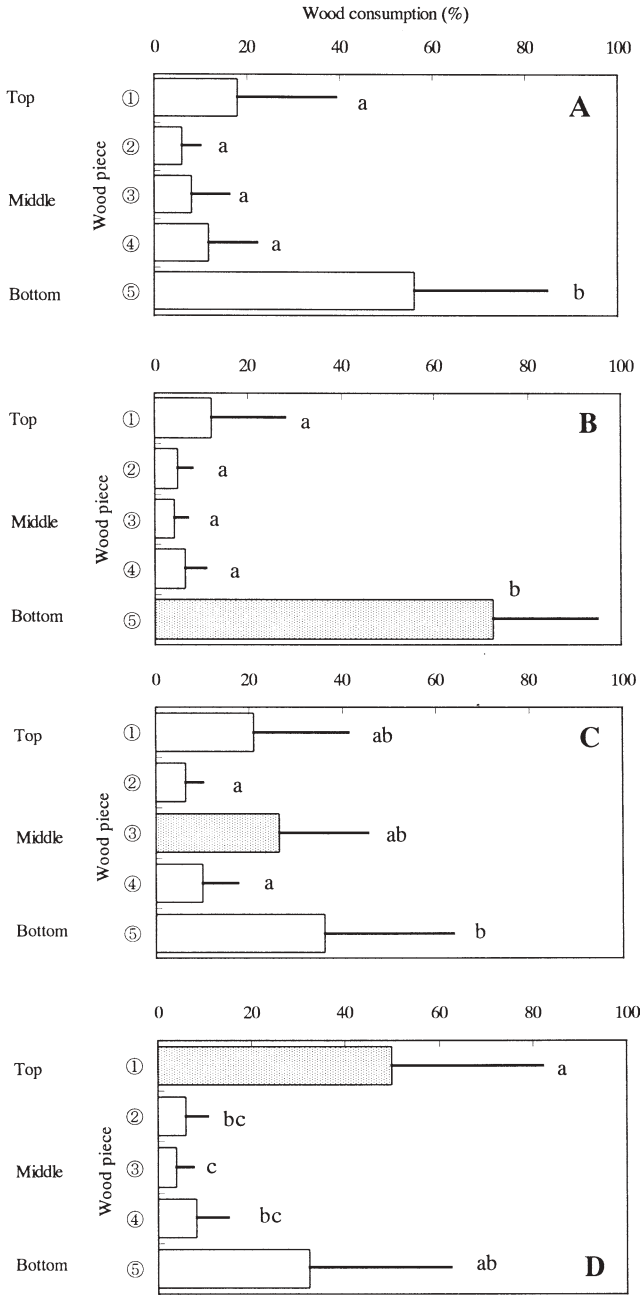

Fig. 7A–D. Relationship between the MC of wood pieces and consumptions for *C. formosanus* for 3 days. Wood consumptions are expressed as a percentage of the total mass consumption of each unit. *Error bars* show standard deviations. *Dotted bars*, high MC. **A** All pieces are air-dried, **B** bottom piece is impregnated with distilled water, **C** middle piece is impregnated, **D** top piece is impregnated. The same letters indicate no significant difference at $P < 0.05$ (Tukey's test)

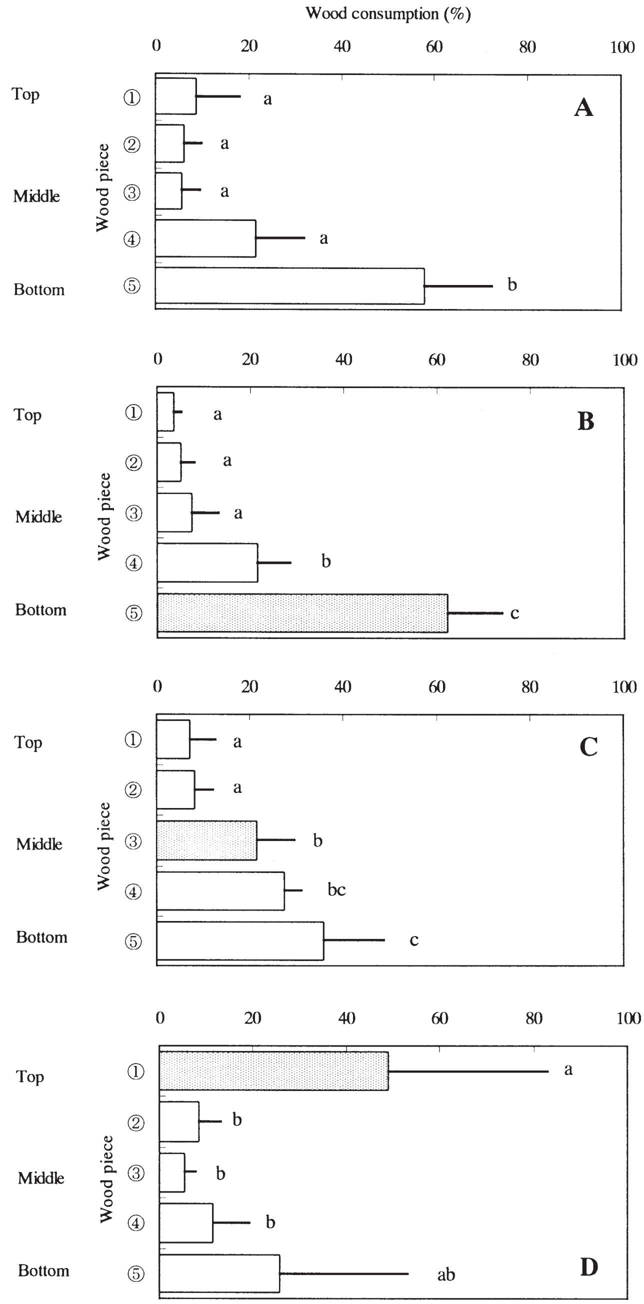

Fig. 8A–D. Relationship between the MC of wood pieces and consumptions for *R. speratus* for 3 days. Wood consumptions are expressed as a percentage of the total mass consumption of each unit. *Error bars* show standard deviations. *Dotted bars*, high MC. **A** All pieces are air-dried, **B** bottom piece is impregnated with distilled water, **C** middle piece is impregnated, **D** top piece is impregnated. The same letters indicate no significant difference at $P < 0.05$ (Tukey's test)

Experiment II

Figure 7 (*C. formosanus*) and Fig. 8 (*R. speratus*) show the mean wood consumptions of each piece expressed as a percentage of the total mass consumption of a unit over 3 days.

As a control unit (Figs. 7A and 8A), all wood pieces were air-dried and their mean MC was about 25% after the experiment. Relationships between the locations and wood consumptions are shown in Fig. 7A for *C. formosanus* and Fig. 8A for *R. speratus*. For both species, bottom pieces were consumed significantly more (Tukey's test, $P < 0.01$), and the mean consumptions were ca. 56% for *C. formosanus* and ca. 58% for *R. speratus*. In the case of bottom pieces with high MC (133%–191%) (Figs. 7B, 8B), higher consumptions were measured in bottom pieces for *C. formosanus* (ca. 72%) and *R. speratus* (ca. 62%), respectively (Tukey's test, $P < 0.01$). For middle pieces with high MC (Fig. 7C), although no significant difference was observed (Tukey's test, $P < 0.05$), higher consumptions were obtained in top, middle, and bottom pieces for *C. formosanus* workers compared with other MCs. In contrast, *R. speratus* workers consumed significantly more from the middle to bottom positions (Tukey's test, $P < 0.05$) (Fig. 8C). In the case of top pieces with high MC, both species preferentially fed on top pieces (Tukey's test, $P < 0.05$), and the mean consumptions for both pieces were ca. 50% (Fig. 7D for *C. formosanus* and Fig. 8D for *R. speratus*). In addition, although no significant difference was observed (Tukey's test, $P < 0.05$), higher consumptions were found in the air-dried bottom pieces for both species (Figs. 7D, 8D).

Discussion

Moisture can be obtained from many sources, primarily from water held in wood and the metabolic breakdown of sugars in food.[4] In a previous study, all the workers died after 2 days for *Reticulitermes speratus* and after 4 days for *Coptotermes formosanus* when cultured with an air-dried wood at 25°C and 70% RH without a water supply.[15] In the present experiment, almost all termites survived in the termite culturing room under dry conditions (without a water supply) for 3 days. These findings clearly indicate that *C. formosanus* and *R. speratus* workers are able to take moisture from wet wood to survive.

When three wood blocks with low MC (6%–12%), middle MC (79%–103%), and high MC (140%–182%), were exposed to workers of *C. formosanus* and *R. speratus* in a choice test, the feeding preferences were found in middle MC blocks for *C. formosanus*, and middle and high MC blocks for *R. speratus*, although wood blocks of low MC were also attacked (Figs. 3–6). No difference in feeding preferences was found between environmental conditions (natural and dry conditions) for either species (Figs. 3–6). These findings suggest that subterranean termites such as *C. formosanus* and *R. speratus* preferentially feed on wet wood, unlike dry-wood termites, which can survive in the air-dried woods.[2]

We have previously reported that *R. speratus* workers lost their masses at a constant rate over 36 h (−1.2%/h), whereas *C. formosanus* workers lost mass by according to two different rates depending on the test time: −1.75%/h for 0–8 h and −0.56%/h for 8–60 h,[15] and that both rhinotermitids had a similar tolerable maximum mass loss of approximately 40% of sound mass.[15] Therefore, *C. formosanus* workers must have a higher desiccation tolerance than those of *R. speratus*. This difference may be closely related to the following ecological and physiological characteristics of the termites.

Coptotermes formosanus constructs a well-compartmentalized nest with feeding sites separated by up to 100 m, and risk exposure to the outside air, while *R. speratus* nests are located in the feeding sites and have no special structure.[2] In addition, *C. formosanus* is distributed in the southern parts of Japan with higher mean temperatures, whereas *R. speratus* in found throughout most of the country.[16,17] The fact that *R. speratus* workers have a higher body water content (315%–360%) than *C. formosanus* workers (255%–300%)[15] may also support the difference in optimum MCs for the feeding activities of termites.

In the case of experiment II, the highest consumptions of both species were observed at bottom and/or high MC (Figs. 7, 8) pieces. This finding suggests that both the distance to food from the habitat and MC affect the feeding activities of the termites. In general, subterranean termites such as *C. formosanus* and *R. speratus* have underground nests, and construct runways for entering a building.[2,18] These living habits probably explain their feeding preferences for bottom pieces.

The present results suggest that the MC of wood blocks is one of the major factors affecting the feeding activities and the location of two Japanese subterranean termites. Between the two species, this tendency is more clear in *R. speratus*.

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