ABSTRACTS (PH D THESIS)

A study of foraging behavior and physiological adaptation of western drywood termite: a framework for development of novel bandage system

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The western drywood termite, *Incisitermes minor* (Hagen), is one of invaded insect species, and was firstly reported in Japan in 1976. Since that date, 24 out of 47 prefecture have been infested by *I. minor*.

With current pest management industry standard for detection/inspection (visual searching) and remedial treatment (wood injection), it is hard to prevent drywood termite infestations for some reason including; 1) the lack of knowledge of foraging behavior and biological adaptations of drywood termites that involve survival in environmental stresses and 2) the high proportion of remedial intervention which only intends to kill drywood termites present at the time of application, whereas no preventive treatment which intends to stop or prevent reinfestation. Consequently, the drywood termite management should understand the foraging behavior and biological adaptations of drywood termites to provide a framework for improving efforts at detection and control when treatment is necessary

Quantitative observation of the foraging tunnels in Sitka spruce ad Japanese cypress caused by the drywood termite *I. minor* by 2D and 3D X-ray computer tomography (CT)

The cryptic lifestyle of drywood termites makes it difficult to study their foraging behaviour and to detect infestations in hidden regions. As CT scanning results show, the development of tunneling is affected by the physical constraints of knows with their high density, high extractive, and lignin contents. Based on these factors, foragers caused distinguished tunneling patterns based on the physical properties of wood during gallery construction. The Foragers primarily excavate along the earlywood in radial direction towards the outer surface of the wood to establish the primary and satellite chambers, followed by mainly superficial longitudinal expansion with occasional lateral deviations. These unique foraging patterns aid the development and optimization of the application of new remedial treatment using solid carbon dioxide as a chilling agent.

The role of physiological elements on cold tolerance of *I. minor*

Unlike endothermic animals, termites regulate the body temperature by the temperature of the environment evolving a diversity of competitive biological adaptation to ensure the survival under non-optimal temperature. This present section investigated on the correlation between genetic advance physiological elements and cold tolerance of three most widely distributed pest species in Japan: *Reticulitermes speratus* (Kolbe), *Coptotermes formosanus* Shiraki, and *I. minor*. First, to estimated and compared the SCP and the LLT of tested termite species using an ultra cooling freezer. Second, to measure the biological variations in an individual group of termite species to compared and identified correlation between the natural cryoprotectants and cold tolerance of three structural pests in Japan.

Table 1. Mean wet and dry mass, water relations, CP, and total lipid composition (mean ± SE) of three termite species

Elements	*I. minor*	*C. formosanus*	*R. speratus*
Wet body mass (mg)	9.96 ± 0.17^{a}	3.07 ± 0.02^{b}	2.08 ± 0.03^{c}
Dry body mass (mg)	2.78 ± 0.04^{a}	0.64 ± 0.01^{b}	0.41 ± 0.01^{c}
TBW content (%)*	72.0 ± 0.6^{c}	78.6 ± 0.5^{b}	80.1 ± 0.3^{a}
Low RH – CP** ($\mu gH_2O\ cm^{-2}\ h^{-1}\ mmHg^{-1}$)	(M) 2.11 ± 0.04^{b} (H) 3.36 ± 0.09^{b}	(M) 28.67 ± 0.67^{a} (H) 42.13 ± 0.86^{a}	(M) 31.26 ± 0.67^{a} (H) 42.04 ± 0.90^{a}
Body lipid (% of dry weight)	28.45 ± 0.53^{a}	17.32 ± 0.42^{c}	19.93 ± 0.49^{b}
Cuticular lipid (% of dry weight)	17.97 ± 0.41^{a}	9.10 ± 0.21^{b}	7.28 ± 0.25^{b}
Trehalose (% of dry weight)	0.28 ± 0.03^{c}	1.35 ± 0.3^{a}	1.04 ± 0.15^{b}
SCP (°C)	-12.6 ± 0.3^{a}	-9.3 ± 0.2^{b}	-5.7 ± 0.2^{c}
Heat of crystallisation (°C)	$\leq 0.8^{a}$	$\leq 0.3^{b}$	$\leq 0.2^{b}$
Heat of crystallisation (Sec.)	77 ± 4^{a}	30 ± 3^{b}	23 ± 2^{c}
LLT_{50}(°C)	-14.0 ± 0.2^{a}	-10.2 ± 0.2^{b}	-6.3 ± 0.1^{c}
LLT_{95}(°C)	-22.1 ± 0.2^{a}	-12.6 ± 0.1^{b}	-9.8 ± 0.2^{c}

Mean in the same column followed by different letters are significantly different (P <0.05, ANCOVA, Tukey's HSD)
*wet weight **cuticular permeability
(M) denotes surface area estimation using Meeh's formula, (H) denotes surface area estimation using Haagsma's formula

Unlike subterranean termites, western drywood termites cannot retreat from unfavourable conditions when it is necessary to escape. It is therefore not unreasonable to assume that the desiccation and cold hardiness tolerance of *I. minor* could be higher than subterranean termite species. Of the low temperature stresses that *I. minor* can overcome by a genetic advance in physiological elements such as water relation and cuticular structure. The SCP varied between -10.5 and -14.5°C while LLT ranged from -13.9 and -14.8 °C for LLT_{50} and below -22.0°C for LLT_{95}. Cold tolerance may influence by some physiological elements including low body water content and harder cuticle structure. As known termite cryoprotectant, trehalose, there was no clear indication that it function as a natural cryoprotectant in *I. minor*. Low concentration of trehalose may affect by their heritage physiological ecology.

Investigation of thermal conductive properties of structural timbers at low temperature region using solid carbon dioxide as a chilling agent

Knowledge of the thermal conductive properties of wood at low temperatures aids the development and optimization of the application of a lethal cold temperature treatment for drywood termites. This section explains the relationship between the thermal conductive properties of wood at low temperatures and important factors, the microstructural and anisotropy of wood.

The results indicate that the thermal conductive properties of wood at low temperatures are mainly affected by the composition and morphological properties of wood (i.e., density/ratio of earlywood and latewood, a proportion of heartwood and sapwood, pattern of growth ring). In particular, thermal conductive properties are mainly dependent on the pattern of the growth ring itself at low temperatures.

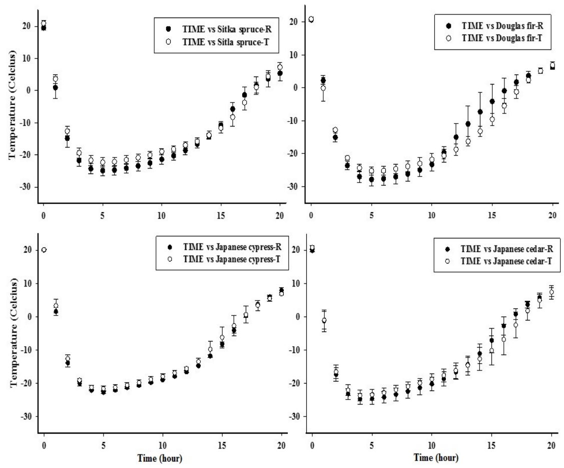

Figure 1. Comparison of the thermal conductive properties values obtained in both tangential and radial direction using solid carbon dioxide slabs

Novel application of a two-in-one bandage system for improving remedial and preventive treatment of drywood termite control

This section has presented a two-in-one bandage system, which combines of two or more treatment approaches with different mechanisms can cooperatively prohibit drywood termite eradication and prevent re-infestation. microstructural and anisotropy of wood using solid carbon dioxide as a chilling agent.

The effectiveness of the remedial treatment in a two-in-one bandage system was highly influenced by the microstructure of the wood and the dosage of the chilling agent. However, using polyurethane bandage system requires a much less chilling agent (1,200g CO_2 snow) to generate the core temperature of timber achieved a lower than required critical thermal minimum (CT_{min}) of drywood termite in the first 3 h in the much larger volume of structural timber (0.0115 m^{-3} of softwood). It explains the importance of designing and material selection for the insulation system to maximize the heat transfer properties of solid carbon dioxide. Regards the insecticidal activity evaluations, the difference in the mortality data indicates that there was a significant interaction between the dosage and the exposure time. With continuous exposure at the lowest concentration, worker health did not suffer significantly due to a delayed avoidance response of the termites. Meanwhile, with continuous exposure at higher concentrations, termites were overwhelmed by the excessive amounts of imidacloprid, which required more resources and time to cope with the stress, enhancing the recognition of advanced symptoms.

Although this study shows promise for improved methods of control and prevention for drywood termites, there is potentially adjusting this new control technique/device to meet the needs of the pest management industry. Area of potential future works is to develop the supercritical mixture of the chilling agent and insecticide. Using the supercritical CO_2 mixture, it would reduce the application time and cost for the pest management industry. In the current design, the increase the property of insulation of two-in-one bandage system by the implement of other insulative materials