The daytime indoor and outdoor temperatures of the subterranean termite Coptotermes curvignathus Holmgren (Isoptera: Rhinotermitidae) tunnel

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The daytime indoor and outdoor temperatures of the subterranean termite *Coptotermes curvignathus* Holmgren (Isoptera: Rhinotermitidae) tunnel

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Abstract. The termite's life cycle is affected by weather conditions, including temperature. To keep its activities safe from any direct light, termites design tunnels to hide. This research aims to analyze the temperature subterranean termite tunnel *Coptotermes curvignathus* inside and outside the room. Tunnel temperature measurement was carried out by thermocouple tool. The research was conducted at Forest Products Research and Development Center, Gunung Batu, Bogor. The results showed that the temperature in the tunnel's indoor ranged between 25.8 - 34.1 °C while temperatures in the tunnel's outdoor ranged between 25.0 - 32.7 °C. The tunnel's indoor temperature was 0.8 °C to 1.4 °C warmer than the tunnel's outdoor temperature, while the surrounding's indoor temperature was 0.2 °C warmer than the surrounding's outdoor temperature.

1. Introduction

Termites are one of the most widespread eusocial isopterous insects, bearing complex division of labor within each colony [1]. They are a dominant group of invertebrate decomposers of dead organic matter, in tropical and subtropical terrestrial regions [2]. Until this day, 2,600 species of termites have been found, and these species consist of 281 genera [3]. Termites spread from 45 °N to 50 °S, but they are not found in the Antarctic Continent. However, some termite genus is found living in very cold areas at an altitude of 3000 meters above sea level, for example, in Himalayas [4]. The diversity of termite species and their nests increase towards the equator, and their distribution is related to temperature and rainfall [4]. Meanwhile, according to [5], the diversity of termite species in South Jakarta is not related to the ambient air temperature as the air temperature in South Jakarta is relatively stable.

Coptotermes is one genus closely related with pest. It consists of major pest species causing damage to forest trees and also buildings [6]. One of the species of termite with a high attack intensity is *Coptotermes curvignathus* [7]. According to [8], *C. curvignathus* termite species has one of Indonesia's largest infested areas. *C. curvignathus* is the only termite species that can make secondary nests that allow them to attack high-level buildings. [9] stated that *C. curvignathus* colony could forage up to the top floor of an apartment building in South Jakarta. *C. curvignathus* species can also attack living trees in the outer bark and inmost component of the trees. When termite attack occurs, this can cause death to the tree [10].

Termites spend their entire life in soil or within their food source and die once removed from their protected environment and favorable humidity [11]. Termites are cryptobiotic organisms, which means they do not like to be exposed to light except in the reproductive caste when they come out of the nest as alates. Termites migrate and look for new food sources by building tunnels so that they are not exposed directly to light, and they can maintain the microclimate needed for their sustenance. Environmental factors affecting the development of termite populations are temperature, rainfall, humidity, nutrient availability, and natural predators [8]. [12] explain that termites tend to prefer places with high humidity. Furthermore, termites will maintain their nest temperature and humidity [13]. Meanwhile, according to [14], termites can maintain their nest's physical attributes to remain constant so that the nest's temperature and the surrounding environment's temperature will be different.

Global climate change causes irregular weather changes, and the same case also happened in Bogor. On the other hand, termites must maintain a stable temperature of the nest to survive. Therefore, it is necessary to investigate the optimum temperature of *C. curvignathus* nest in Bogor by measuring the temperature inside the subterranean termite tunnel located in the indoor and outdoor study site. This study aims to analyze the temperature of a subterranean termite *C. curvignathus* tunnel situated indoors and outdoors during the day.

2. Materials and methods

2.1. Indoor study

The indoor study was carried out in the Wood Drying Laboratory, Forest Products Research and Development Center (P3HH), Gunung Batu, Bogor, West Java, Indonesia. The materials used were a cross-section of *Pinus merkusii* wood with a dimension of 2.5 cm × 10 cm × 100 cm. Temperature measurement of the subterranean termite *C. curvignathus* tunnels in Wood Drying Laboratory was done utilizing a thermocouple instrument (figure 1) attached to the wood bait infested by termites. Ten stakes of *Pinus merkusii* were placed horizontally above the woodpiles attacked by subterranean termite *C. curvignathus*. Subterranean termite *C. curvignathus* species can be seen in figure 2. The temperature observation was conducted three times a day, at 08.00, 13.30, and 16.00 GMT+7 for 30 days. The wood bait installation in the Wood Drying Laboratory and the form of wood bait damage caused by *C. curvignathus* can be seen in figure 3.

Figure 1. Thermocouple instrument used to measure the temperature in this study.

Figure 2. Subterranean termites *Coptotermes curvignathus*.

Figure 3. Wood bait installation inside Wood Drying Laboratory Forest Products Research and Development Center P3HH-Gunung Batu, Bogor, West Java, Indonesia in a horizontal manner (a) and subterranean termites *Coptotermes curvignathus* wood bait condition (b).

2.2. Outdoors study

The outdoor study was conducted in the P3HH Arboretum, Gunung Batu, Bogor, West Java, Indonesia. The location comprises a small forest cover with tall and big crowned trees. The baiting method was employed in order to collect the temperature data on a *C. curvignathus* nest. The material used in this study was pine wood (*Pinus merkusii*) for termite bait. [15] which showed that termites preference towards pine wood is higher than other species and pine wood has been used commercially termite bait [16]. Ten stakes of *P. merkusii* with a dimension of 2.5 cm x 2.5 cm x 30 cm were installed vertically on the ground with 25 cm inside the ground and 5 cm above. Previously, the thermocouple was attached to the ten stakes of wood bait. The installation of wood bait was observed for one month to note the temperature. The position of the wood bait and thermocouple in the arboretum can be seen in figure 4. The temperature observation was carried out three times a day at 08.00, 13.30, and 16.00 GMT+7.

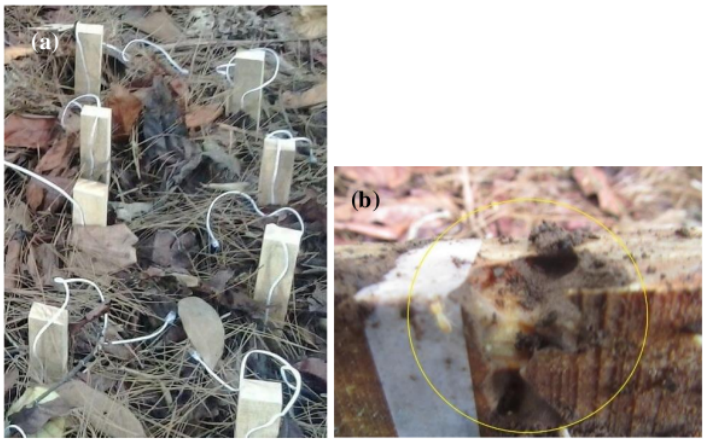

Figure 4. Wood bait installation in the outdoor study site in Arboretum P3HH-Gunung Batu, Bogor, West Java, Indonesia by vertical means (a) and termite infestation sign on the wood bait (b).

3. Results

3.1. The temperature of indoors situated subterranean termite tunnel

Wood baits were placed horizontally in woodpiles that have been attacked by termites *C. curvignathus* in the Wood Drying Laboratory. Of the ten stakes of bait wood placed, two wood baits were attacked by termites; termites did not attack the rest. The temperature data taken were the temperature of wood bait attacked by termites (two wood baits have been attacked by subterranean termites *C. curvignathus*). The temperature data from uninfested wood bait as many as four stakes were used to retrieve the control temperature data displayed on average.

The complete research results can be seen in figure 5, which shows the temperature of the *C. curvignathus's* tunnel in the Wood Drying Laboratory of the infested wood 1 ranging from 25.8 °C to 34.1 °C and the temperature of the infested wood 2 between 26 °C to 34 °C. The temperatures of the uninfested wood ranged from 25.6 °C to 33.8 °C. In comparison, the environmental temperature was 25.1 °C to 34.5 °C.

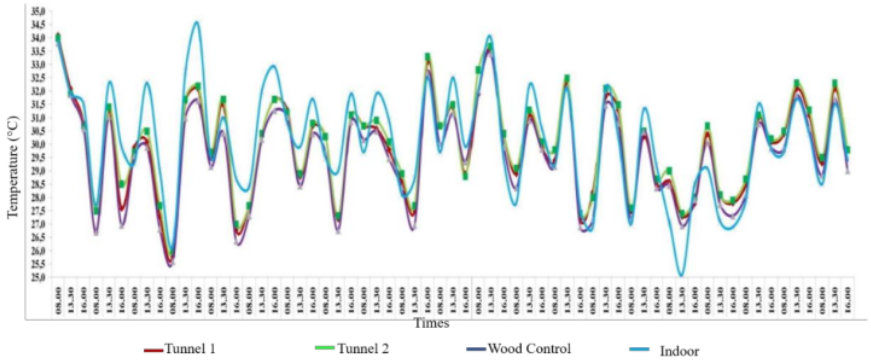

Figure 5. Temperature inside subterranean termite *Coptotermes curvignathus'* tunnels, wood control, and indoor environment temperature.

Meanwhile, the average temperature data based on the observation period is portrayed in figure 6. The average temperature at 08.00, 13.30, and 16.00 GMT+7 of the infested wood 1 was 29.4 °C, 30.6 °C, and 29.7 °C. Meanwhile, the infested wood 2 was 29.6 °C, 30.7 °C, and 29.9 °C. In the wood control, 29.1 °C, 30.3 °C, and 29.4 °C. The environmental temperature is 28.9 °C, 31.1 °C, and 30.3 °C. The difference in average morning temperature in infested wood is 0.5 °C - 0.7 °C higher than the environment temperature and 0.4 °C - 0.5 °C higher than wood control temperature. During the day, the average infested wood temperature was 0.4 °C - 0.5 °C lower than environmental temperature and 0.3 °C - 0.4 °C higher at the temperature of the wood control. In the afternoon (16.00 GMT+7), the average temperature of infested wood is 0.5 °C lower than environmental temperature and 0.3 °C - 0.5 °C higher than the temperature of wood control.

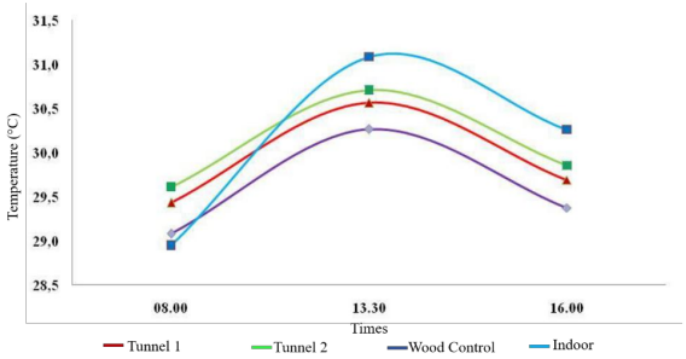

Figure 6. Average temperature of subterranean termite *Coptotermes curvignathus'* tunnel, wood control, and indoor environment at 08.00, 13.30, dan 16.00 GMT+7

3.2. The temperature of outdoors situated subterranean termite tunnel

The Forest Products Research and Development Center (P3HH) Arboretum, Gunung Batu, Bogor, West Java, Indonesia, has high trees covering the study site. Moist leaves and tree branches covered the ground surface. Changes that occur in the surrounding environment will have a direct influence on the wood bait.

There were ten stakes of wood baits that were buried vertically. From 10 stakes of wood baits, there was only one infested stake found. The temperature data used in observation were from wood bait temperature infested by termites (one temperature data), four data uninfested wood bait temperature, and the control temperature. Those data were displayed by means.

The result can be seen in figure 7, which shows that the temperature value of *C. curvignathus* infested wood was 25 °C - 32.7 °C, the wood control temperature was 24.8 °C – 32 °C, and the environment temperature was 25.1 °C - 34.3 °C. Meanwhile, the average temperature according to the observation period can be seen in figure 8. The average temperature at 08.00, 13.30, and 16.00 GMT+7 for infested wood 1 was 28.6 °C, 30.8 °C, and 28.7 °C, respectively. The wood control temperature was 28.3 °C, 30.5 °C, and 28.7 °C. The environment temperature was 29 °C, 31.4 °C, and 29.7 °C.

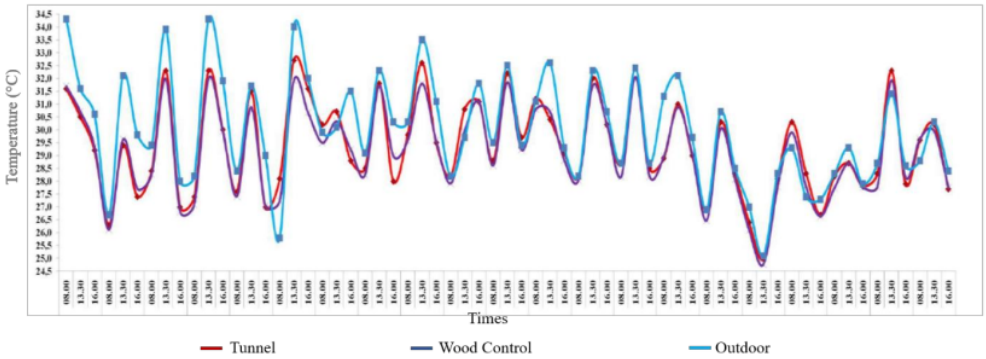

Figure 7. Temperature inside subterranean termite *Coptotermes curvignathus'* tunnels, wood control, and outdoors environment temperature.

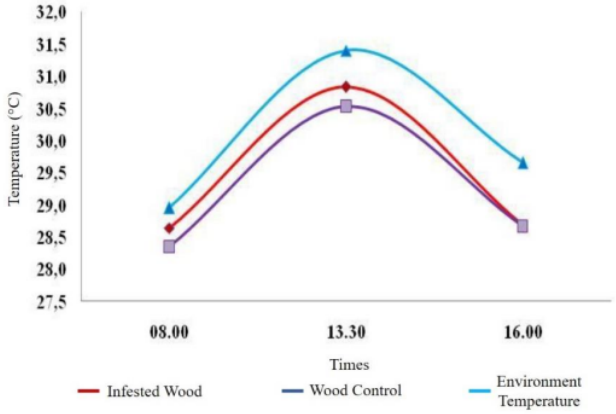

Figure 8. Average temperature of subterranean termite *Coptotermes curvignathus'* tunnel, wood control, and outdoor environment at 08.00, 13.30, dan 16.00 GMT+7.

3.3. The comparison of indoors and outdoors situated subterranean termite tunnel temperature

The temperature data of subterranean termite tunnel of the wood control and environment temperature for indoor and outdoor studies are summarized in table 1. According to the data, the indoor environment temperature was almost similar to the outdoor environment temperature. Meanwhile, the temperature of indoors situated subterranean termite tunnel was warmer than the outdoors's.

Table 1. Termite tunnel temperature of termite tunnel, wood control, and the indoor and outdoor environment

No	Temperature Measurement Sites	Temperature (°C)	
		Indoors	Outdoors
1	Termite tunnel 1 (infested wood)	25.8-34.1	25.0-32.7
2	Termite tunnel 2 (infested wood)	26.0-34.0	-
3	Wood Contol	25.6-33.8	24.8-32.0
4	Environment	25.1-34.5	25.1-34.3

4. Discussion

Based on the data from figure 5, the temperature patterns of infested wood (the temperature inside the subterranean termite tunnel) situated indoors and the wood control temperature tend to follow the environment temperature. However, there were several different temperatures recorded in each measurement. The different temperature values of the infested and wood control temperature indicate that termites have attacked the wood. According to [17], elevated temperatures indicate that there were termites in the area. According to [18], based on Ruelle's research in 1964, the difference in termite diurnal temperature varies and can exceed 3 °C. Temperature values between the infested wood, wood control, and the environmental temperature were different. The temperature of the infested wood was warmer than the control temperature. This condition was due to termite activities like chewing wood and termite mechanisms that control their nest temperature.

In contrast, there were no termite activities in the wood control that can produce heat, so the subterranean termite tunnel's temperature becomes warmer. Temperature differences also occur in the wood control and environment temperature. Environment temperature has direct contact between the surrounding air and the thermocouple; thus, suppose there were changes in wind characteristics will directly affect the measurement value. In contrast, there was no direct contact mechanism between the thermocouple and the external air, and when changes happen, it requires a certain amount of time for the air to enter the wood control.

The average temperature in the termite tunnel in figure 6 was steady, ranging from 29.4 °C - 30.7 °C. This condition shows air temperature, gas content, and heat generated in the nest regulation. According to [19], carbon dioxide gas and other gases that termites do not require must be removed and replaced with the oxygen needed for the termite respiration process. Therefore, there are some conditions for termites to open or close their nests. As mentioned before, there will be air exchanges from the outside to the inside nest along with these conditions.

Wood infested by subterranean termites *C. curvignathus* tends to have a stable temperature. According to [14], termites can maintain the ideal temperature inside their nest. This statement was supported by the result exposed in figure 5, and the infested wood was more stable to the environment temperature changes. The infested wood temperature by *C. curvignathus* in the Wood Drying Laboratory range from 25.8 °C - 34.1 °C, which was different from the optimum temperature of *Macrotermes* termites, namely 29 °C - 32 °C, but this result is still under the optimum temperature interval of insect which is 15 °C - 38 °C [19].

There always various weather conditions during the period of observation. It was noted that there had been some rain in the afternoon and evening which caused the measure of ambient temperature lower than the infested and wood controls. However, the infested wood temperature tends to be stable and warmer than wood control and the environment temperatures. This condition verifies that termite can maintain stable nest temperature by insulation.

Meanwhile, the temperature patterns of infested wood (the temperature inside the subterranean termite tunnel) in the outdoor study site and the wood control temperature also follow the environment temperature pattern (figure 7). At the beginning of the study, the temperature of control and infested woods were in a line. The temperature in the soil was lower than the environment temperature above the ground. This condition means that the wood bait has not been infested by termites and measures the soil's temperature. There was a different temperature between infested wood and wood control, and the appearance of subterranean termite tunnels in wood bait indicates that termites have begun to consume the wood.

Diurnal temperatures in a termite nest may vary and exceed 3 °C [18]. Figure 8 shows the average temperature of infested wood, wood control, and the environment above the ground level. The average temperature of control and infested wood by subterranean termite *C. curvignathus* were lower than the environment temperature.

The research result showed that the temperature inside the *C. curvignathus* nest is relatively different from Macrotermes, which ranges between 29°C - 32°C (table 1). The range of temperature may differ depending on the species of termites. [20] stated that *Macrotermes* nest structure could create a stable

microclimate, 30°C. A nest's structure may effectively act as a regulator to keep the temperature inside stays stable [21]. Like dry wood termites *Cryptotermes brevis* in Hawaii, their nest could keep inside temperature between 24.33-37.04 °C despite the outside temperature ranging between 8.71-43.31 °C [22].

Table 1 showed that indoor temperature was not significantly different from outdoor temperature. This condition occurred because the indoor temperature was affected by the room's shape, which has an open structure (Wood Drying Laboratory). Meanwhile, in the indoor study site, the subterranean termite tunnel temperature was higher by 0.8 °C - 1.4 °C than the tunnel temperature. The difference was caused by the study site's physical characteristics, which lack proper shelter; hence, the weather elements could affect the termite's activity. As explained beforehand, the study was done outdoor (in an arboretum) on many occasions often showered by rain; thus, termites in the infested wood bait roamed to the deeper region of the ground. In addition, a study carried out by [23] stated that temperature inside the nest of subterranean termite *C. curvignathus* is warmer by 1.3 °C than the temperature outside the nest in the laboratory.

Subsequently, this research could be a theoretical baseline for the database development of termite presence in construction wood based on temperature differences (between infested wood and uninfested one) through sustainable termite management. The study on the optimum temperature of termite sustenance could also become a preventive action to avoid the suitable microclimate condition for termite infestation in the building.

5. Conclusion

The indoor study site subterranean termite tunnel (25.8 – 34.1 °C) was warmer than the tunnel outdoor study site (25.8 – 34.1 °C). The termite tunnel found on the indoor study site was warmer by 0.8 °C - 1.4 °C than the termite tunnel in the outdoor study site. Meanwhile, the indoor temperature (25.1-34.5 °C) was warmer by 0.2 °C than the outdoor temperature (25.1-34.3 °C). The temperature inside the subterranean termite tunnel was significantly lower than the surrounding environment temperature.

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