Anti-termite activities of Indonesia's essential oils against invasive drywood termite for wood product protection

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Abstract. The Indo-Malayan drywood termite, Cryptotermes cynocephalus (Light) (Kalotermitidae), is considered one of the most invasive drywood termites in the Southeast Asian region. Once infesting a timber, the colony of a drywood termite is very difficult to be controlled. Thus, the best way to mitigate a new infestation of a drywood termite is by applying chemical protection on wood. In recent years, particular attention has been given by researchers to develop and use organic termiticides, such as essential oils extracted from plants as active ingredients. The objective of the present study is to evaluate the repellency performance of several economically important essential oils from Indonesia, such as Clove (Eugenia caryophyllata), Cubeb Pepper (Piper cubeba L), and Lemon Grass (Cymbopogon winterianus Jowitt) against a drywood termite, C. cynocephalus. The test was performed by subjecting various concentrations of essential oil toward C. cynocephalus in the force-feeding test method. Sample weight-loss was evaluated after two weeks test. The results suggested that Clove oil has the highest repellence performance against C. cynocephalus, followed by Lemon Grass and Cubeb Pepper oils. The Termite mortality rate was also recorded to understand the toxicity performance of those essential oils.

1. Introduction
Termite became a major pest in the world, and the damage cost by a termite is estimated to be billion dollars [1, 2]. Drywood termite is a type of termite that dwells and forages in dry timber, sound wood, and wooden furniture. Their cryptobiotic life makes drywood termite infestation very difficult to detect, and advanced non-destructive tools are needed to locate the colony presence inside the attacked wood [3, 4, 5, 6]. Its habitat ranges from tropical areas to temperate regions. Cryptotermes cynocephalus is a drywood termite that despite commonly found in Indo-Malayan region, become invasive species that inhabit area beyond their range habitat [7].

Infestation of C. cynocephalus on timber is hard to contain once it enters the timber. Therefore, the effective way to prevent infestation is by treating the timber with wood preservatives. The use of wood preservatives makes the timber unappetizing for drywood termite [8]. Frequently used preservatives are oil-borne (creosote and pentachlorophenol) and water-borne type (chromium copper arsenate and copper azole), which reported effective protecting the wood against drywood termite. However, the chemicals have a harmful effect on the environment and human health [9].
Hence, scientific attention has been rising on using alternative wood preservatives from natural products such as essential oil from plants. Essential oil’s repellent effect and toxicity against termite and other insects have been reported in many research studies [10, 11]. The benefit of using essential oil as an alternative wood preservative is causing no damage to the environment and is naturally sustainable. Indonesia has enormous plant diversity, which is the source of essential oils. Yet, there are countless essential oils from Indonesia that have never been evaluated for their termiticidal properties. Thus, this study aimed to evaluate the anti-termite activity of several economically important essential oils from Indonesia, such as clove (Eugenia caryophyllata), cubeb pepper (Piper cubeba L), and lemongrass (Cymbopogon winterianus Jowitt) against a drywood termite.

2. Materials and method
Cubeb pepper (Piper cubeba L) and lemongrass (Cymbopogon winterianus Jowitt), essential oils were tested against dry-wood termite Cryptotermes cynocephalus (Light). Each essential oil were prepared in five different concentrations, i.e. 1%, 4%, 6%, 8%, and 10%. Each concentration of the essential oils was applied on a rubberwood block using the spraying technique. Untreated rubber woodblocks were also prepared for cooperative purposes.

The treated and untreated wood blocks were dried in the oven at 60°C for three days before being tested on the drywood termite according to a non-choice feeding test. Afterward, the woodblocks were placed in the bottom of the test container. The test containers were made from plastic with ventilated lid and a plastic-based pedestal with a large porous at the bottom of the container (figure 1). One hundred workers of Cryptotermes cynocephalus were then introduced into the container. The test container was then kept in the darkroom and condition at 28°C and 70% humidity. A Forced-feeding test was conducted for 14 days, and the observation was done on two days intervals. Termite mortality rate and wood sample weight loss were documented.

3. Results
After 14 days of the testing period, it was observed that each essential oil has a mortality effect on drywood termite Cryptotermes cynocephalus (Light). Clove oil showed an increased mortality rate along with the increasing concentration (figure 2). The highest mortality rate (100%) was achieved by clove oil 10% concentration at 12 days of observation and 8% concentration at 14 days of observation. On the other hand, the treatment group with 2% clove oil had the lowest mortality rate with 60% mortality in 14 days.
Cubeb pepper essential oil showed the same mortality pattern as clove oil; increasing cubeb pepper concentration follows with an increasing mortality rate (figure 3). Cubeb pepper oil with the highest mortality rate was shown by 10% and 8% concentration with 100% and 93% mortality rate respectively at 14 days of observation.

Lemongrass oil had the lowest mortality effect against Cryptotermes cynocephalus, with no treatment group achieving a 100% mortality rate in 14 days of observation. The best effect was shown by 10% concentration lemongrass oil by 99% mortality rate at day 14th.
Figure 4. The mortality rate of Cryptotermes cynocephalus after 14 days exposed to lemongrass essential oil.

Comparison of mortality effect of three essential oil showed that clove oil had the highest termite mortality followed by cubeb pepper and lemongrass oil, suggesting that clove oil has the highest toxicity effect against drywood termite (figure 4). A similar result was reported by Zhu et al. [12], clove oil has a 100% mortality effect on Coptotermes formosanus in 2 days at 50 µg/cm². Evaluation of clove oil and lemongrass oil against Odontotermes obesus displaying high mortality effect [13]. Lemongrass has the lowest mortality effect in this study. Nevertheless, it was reported to have a fumigant effect that can be used alone or along with another termiticide for wood product preservation [14].

Figure 5. Comparison of the mortality rate of Cryptotermes cynocephalus after 14 days exposed to clove, cubeb pepper, lemongrass essential oil. Different letters indicate significant differences (P < 0.05).
Figure 6. Weight loss of wood sample treated by clove (a), cubeb pepper (b), and lemongrass (c) after 14 days exposed to *Cryptotermes cynocephalus*.

Clove oil, cubeb pepper oil, and lemongrass oil treatment groups showed that the higher oil concentration induced lower weight loss of wood samples (figure 6). It means that the higher concentration of essential oil on wood samples generates a more repellent effect on drywood termite. Moreover, figure 7 showed that clove oil showed the lowest weight loss, followed by cubeb pepper and lemongrass oil, suggesting that clove oil exhibits the highest repellence against drywood termite.

Figure 7. Weight loss of wood sample treated by clove, cubeb pepper, and lemongrass after 14 days exposed to *Cryptotermes cynocephalus*. 
The strong scent and plant metabolites are responsible for the repellent activity of essential oil [10]. Monoterpenes and sesquiterpenes are plant metabolites associated with the repellent properties of many essential oils [15]. Citral is the most important monoterpenic component of lemongrass, which is responsible for repellent activity [16]. In clove oil, eugenol is the primary component that also has a repellent effect against insects [17]. In comparison, cubeb pepper has β-caryophyllene as a primary component that has repellent activity [18, 19]. However, due to its high volatility, essential oil application is limited as an insecticide [20]. Therefore, advanced technology or method is needed to retain and stabilize the release effect.

4. Conclusion
Clove oil showed the highest anti-termite activity against C. cynocephalus, followed by cubeb pepper and lemongrass oils. Clove oil with 10% concentration resulted in 100% of termite mortality at 12 days observation.

5. References
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Acknowledgment
The study was supported by the Japan-ASEAN Science Technology Innovation Platform (JASTIP) Program, a collaborative project of Kyoto University and LIPI under Work Package (WP) 3: Bioresources and Biodiversity. JASTIP is fully supported by the Strategic International Collaborative Research Program (SICORP) of the Japan Science and Technology Agency (JST), within the framework of the Collaboration Hubs for International Research Program (CHIRP).