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Research Article

Palatability of Subterranean Termites *Coptotermes curvignathus* Holmgren Treated Pine Wood (*Pinus merkusii*)

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Abstract

Background and Objective: Baiting method can be used to evaluate subterranean termite presence, in which one of the most favorable wood species to termite that has been studied is pine wood. The high resin content in the pine wood reduce termite palatability. Thus, several treatments were employed to observe termite palatability to the treated pine wood. **Materials and Methods:** Samples of pine wood were treated with presto (0.4 bar, 100°C), boiled (100°C) and steamed (100°C). Each treatment was carried out for 5 h. Before being fed to the subterranean termites *C. curvignathus*, the wood sample was sanded to remove the resin that adheres to the surface of the sample test. The wood sample was fed to subterranean termites *C. curvignathus* based on SNI 7207: 2014. In this study the hardness of wood samples were also based on BS 373 1957. **Results:** The results showed that the 3 treatments could increase the palatability of subterranean termites *C. curvignathus* on pine wood. The percentage of weight loss in the treated wood sample was greater (12.48-30.39%) than the control (10.07%). Meanwhile the hardness of the wood sample with treatment were smaller (332.56-391.91 kg cm^{-2}) than the control (417.82 kg cm^{-2}). **Conclusion:** The best treatment was presto treatment. The presto treated pine wood has the lowest hardness value, thus the wood become softer and increasing the palatability of *C. curvignathus.*

Key words: Hot vapor treatment, hot water treatment, resinous wood, weight loss

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pine wood consist a high level of resin content thus it became interference for subterranean termite in consuming the pine wood. It is paramount to reduce the resin content in pine wood by heat treatment without degrading wood components (cellulose, hemicellulose and lignin). Wood components will degrade when heated, namely hemicellulose will be degraded in the temperature of 200-260°C, cellulose 240-350°C and lignin at temperatures of 250-500°C[1]. Hemicellulose was degraded at temperatures of 170-200°C while cellulose and lignin was not degraded at that temperatures level[2]. Meanwhile, decomposition of wood cell walls occurs in steamed wood at temperatures of 160°C and 180°C[3]. The degraded wood component will be less preferred by wood destroying organisms. Temperature 180°C heat treated wood has a higher resistance to termite attack[4,5]. Temperature and period of boiling wood process might drive hemicellulose and lignin to become soft and elastic without degrading it[6]. For this reason, the heating process that employed 100°C boiling temperature will not degrade wood component but rinse out the resin component, thus the treated pine wood is expected to be more desirable by subterranean termites.

In order to find out the diversity of termite species in an area, it is necessary to utilize cellulose material which is preferred as bait. One of the easily obtained cellulosic materials is wood. Subterranean termites preferred pine wood over acacia (*Acacia mangium*), rubber (*Hevea brasiliensis*) and sengon (*Falcataria moluccana*)[7]. Pine wood contains chemicals that can attract insects to approach it[8]. Pine wood belongs to the Pinaceae family and grouped into class 4 of durability so that it is susceptible to biological organism's attack such as soft rot fungi, decaying fungi and termite[9].

Some research results that employed pine wood as bait at a settlements location show that the frequency of subterranean termite attack against pine wood is not more than 20%. The study on the subterranean termite coverage in residential area showed that the frequency of termite attacks on pine wood in Taman Darmaga Permai, Ciampea, Bogor, West Java was 10.4%, while in Perumahan Alam Sinar Sari Darmaga Nature Housing, Bogor, West Java the frequency of attacks was 14.6%[10]. Similarly also conducted a study in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu Bekasi, West Java obtained the result that the frequency of such attacks was 15%[11]. Meanwhile the study in DKI Jakarta Province showed that the frequency of attacks on pine wood planted in settlements was 15.1%[12]. Some of these studies are field studies using untreated pine wood. Prior to the field study, it is necessary to conduct laboratory-scale research until the satisfactory treatment is found which can increase the palatability of termites against pine wood.

Therefore, it is necessary to conduct research to improve the preference of termites especially on pine wood by using heat without degrading wood components. This study was aimed to analyze the palatability of subterranean termites *Coptotermes curvignathus* on pine wood treated with presto, steaming and boiling based on the percentage of weight loss and to determine the hardness of pine wood after the treatment in a laboratory scale. Up to this time, the pine wood used for termite bait was untreated wood, thus with this treatment it is expected to intensify the number of termite infestation.

MATERIALS AND METHODS

This research was conducted from January-April, 2019 in the Termites Rearing Laboratory, Division of Wood Quality Improvement Technology. The sample was established at the Sawmill and Woodworking Laboratory (Workshop) IPB University (IPB). Mechanical properties testing were carried out at the Wood Engineering and Design Laboratory, Department of Forest Products, Faculty of Forestry, Bogor Agricultural University.

Materials used in this study is pine sapwood *(Pinus merkusii)* with the diameter of ±40 cm (Fig. 1) obtained from Ciampea, Bogor, West Java, Indonesia, healthy and active subterranean termites worker caste C. *curvignathus* (Fig. 1), alcohol 70% to sterilize test bottles, mineral water, distilled water, sandpaper and sand. The tools used in this study consisted of circular saws, moisture meters, ovens, presto pot, boiling and steaming pots, fans, electric scales, digital caliper, stationery, test bottles, desiccators, digital microscope endoscope camera magnifier 800X 8 LED, measuring cup, aluminum foil, stationery and camera. Mechanical testing tool universal testing machine brand Instron type 3369.

Research procedure

Subterranean termite identification: Subterranean termite specimens (soldier caste) were identified at the Termite Laboratory, Department of Forest Products, Faculty of Forestry, Bogor Agricultural University using the termite identification key[13]. Termite pictures were taken and the morphology of termite body was observed using a digital microscope endoscope camera magnifier 800X 8 LED with 10 times magnification. Termite identification was done descriptively by observing termite characteristics including body size,

Fig. 1(a-b): (a) *Pinus merkusii* log (b) Subterranean termites and *Coptotermes curvignathus* used in the research

mandible, head size, antenna segment and postmentum. The termite identification procedure was carried out using a full termite picture then an observation was made on the morphology of the termite's body. Morphological identification of *Coptotermes* termite species was based on Termites (Isoptera) of Thailand[14]. The head pictures of the termite were taken repeatedly and the head of the termites were measured from the mandible to the tip of the head.

Wood sample identification: Wood anatomy characteristics were inspected by evaluating the wood color, luster, texture and roughness. Then proceed by measuring the length of the fibers by the maceration process along with the cross section of pine wood by degrading the wood component to measure the diameter of the lumen and cells and the fiber wall thickness.

Maceration was done in accordance to the Schultze technique[15]. Test sample that has been cut into a matchstick-shape, was put into a test tube, then submerged into ±10 mL of HNO_3 50% and several KClO crystals[3]. The tube was then heated in a water bath at 80-90°C for approximately 4-5 min until it was white and the fibers appear to begin to separate. The reaction was stopped by adding enough distilled water. The maceration material was then separated from the reagent using filter paper and then rinsed using distilled water until it was free of acid. The maceration test sample is then stored in a sample tube and 2-3 drops of safranin coloring agent are added.

Wood was softened by boiling the test sample in distilled water at a temperature of 60-90°C for 24 h. The sample then was sliced using a microtome slide. The target thickness of the cut is 30 µm. Safranin is used as a coloring result from incisions and maceration fibers. Microscopic images of cross sections, radials and tangential and maceration fibers obtained through a microscope (Carton CB-10) using a USB 5 MP mounted camera. The image is stored in digital format for observation and measurement. Measurements were made using ImageJ Software which was calibrated using a stage micrometer.

Preparation of samples test: Sample used in this study were pine logs (*Pinus merkusii*) from Ciampea, Bogor, West Java, with a diameter of 40 cm. The utilized test sample was the sapwood with the sample size of the subterranean termite palatability test was 2.5×2.5×0.5 cm based on *Uji Ketahanan Kayu dan Produk Kayu Terhadap Organisme Perusak Kayu* (Wood And Wood-Based Products Durability Evaluation Towards Wood Degrading Organism)[16]. The size of the hardness sample was 2×2×6 cm in accordance to Methods of Testing Small Clear Specimens of Timber[17]. Each test is also prepared a sample control test. Each treatment will be made into 3 replications.

The steaming process was carried out by inserting the test sample into a steaming pan for 5 h at 100°C. The boiling process is carried out by inserting the test sample into a boiled pan for 5 h at 100°C. Presto treatment (0.4 bar, temperature 100°C) was carried out on the test sample for 5 h. After treatment, all test samples are removed from the test container and air dried. After air drying, all test samples (except control) are sanded to remove resin that sticks to the surface of the test sample.

Subterranean termite *C. curvignathus* palatability test: Wood samples were cut with a dimension of 2.5×2.5×0.5 cm based on *Uji Ketahanan Kayu dan Produk Kayu Terhadap Organisme Perusak Kayu* (Wood And Wood-Based Products Durability Evaluation Towards Wood Degrading Organism)[16]. The test sample was oven-dry at 60±2°C for 48 h to obtain the initial wood weight (W_1), the sand and the test bottle was rinse using alcohol 70% followed by sterilization using oven. Then the test sample is inserted into the test bottle so that one of the widest fields touches the wall of the test bottle. Then 200 g of sterile sand were inserted into the bottle followed by 30 mL of mineral water. A total of 200 healthy workers caste of

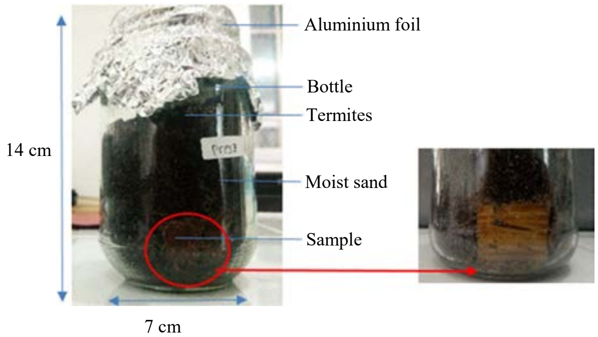

Fig. 2: Testing of the termite palatability of *C. curvignathus* based on SNI 7207: 2014

subterranean termites *C. curvignathus* termite were put into a test bottle then the test bottle was covered with aluminum foil and kept in a dark room for 4 weeks. The subterranean termite palatability test of *C. curvignathus* against pine wood test sample is presented in Fig. 2.

The termite's activities in the test bottles were monitored every day without distressing termites' activity. Water was added before the moisture content of the sand reached 2%. After 4 weeks the test sample is dismantled and cleaned. The test sample was put into the oven at 60±2°C for 48 h to get the weight of the wood after testing (W_2). The weight loss value of the test sample due to a termite attack is calculated by the following equation:

$$WL\ (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Where:

WL = Weight loss (%)
W_1 = Dry weight of wood oven before baited (g)
W_2 = Dry weight of wood oven after baited (g)

Wood hardness test: Wood hardness was tested using a mechanical instrument universal testing machine type 3369 Instron. The test sample used was 2×2×6 cm according[17] to BS-373-1957. The hardness value is calculated by the equation:

$$H = PA$$

Where:

H = Hardness (kg cm^{-2})
P = Maximum load (kg)
A = Surface area of the compressive area (cm^2)

Statistical analysis: Qualitative data was presented in the form of pictures or graphics and described qualitatively, meanwhile quantitative data were calculated using Microsoft Excel 2013 and analyzed using SPSS 17.0. If the results of the variance analysis at the 95% confidence interval were significant, the analyzing process will be continued using Duncan test.

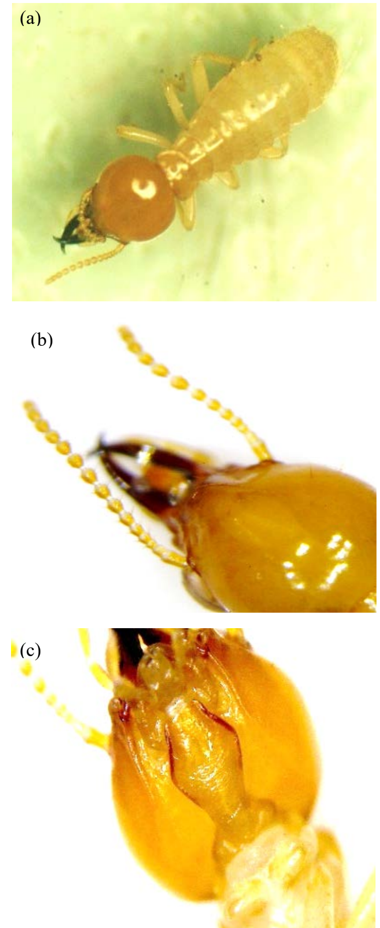

Fig. 3(a-c): (a) Soldier caste 10 times magnification, (b) Termite head morphology *C. curvignathus* including 30×magnification antennae and mandible, 30 times magnification and (c) subterranean termite postmentum 30 times magnification

RESULTS

Subterranean termites *Coptotermes curvignathus*: Observations of subterranean termites soldier caste using a digital microscope, termites were identified based on their external morphology without dissecting them. The results showed that the type of termites that was used in this study was *Coptotermes curvignathus* (Fig. 3a). This was supported

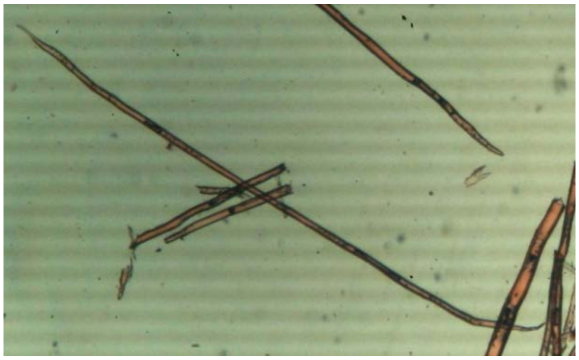

Fig. 4: Pine wood fiber morphology using 10x magnification

by the characteristics found in termites during the observation. The head was round and yellow. The antenna was moniliform, the number of segments in the antenna was 15 (Fig. 3b), the antenna was brownish yellow and the 2nd antenna segment was slightly longer than the 3rd and 4th segments. The mandible was shaped like a sickle and is much curved at the end and had a reddish brown color. The neck consists of a *postmentum* where there were waist-like curves (Fig. 3c). Fontanel was very clearly visible and usually secreted white liquid (*exudate*) which was used for defense against enemies. Labrum and pronotum were yellow. The abdomen was covered with hair that resembles yellowish white thorns.

Pine wood anatomy (*Pinus merkusii* jungh): Pine wood used as a test sample has whitish cream sapwood and dark brown heartwood, with fine wood texture, smooth and lustrous wood surface. Anatomical characteristics results from fibers as seen in Fig. 4, hundred of pine fibers were measured then displayed the average distribution of fiber length, fiber diameter, lumen diameter and wall thickness of 3691.62 µm of fiber length, 47.67 µm of fiber diameter, 29.5 µm of lumen diameter and wall thickness of 9.08 µm. Microscopic images of longitudinal, radial and tangential section (Fig. 5).

Palatability of subterranean termite *C. curvignathus* against wood pine: The results showed that the highest weight loss was found in the presto treated pine wood, which was 30.39%, followed by boiled and steamed treated wood, respectively 13.13, 12.48%. Control wood has the lowest fed percentage, the value of weight loss was 10.07%. Based on Fig. 6 it can be seen that there is an increase in weight loss of pine wood after being treated with presto, boiled and steamed compares to controls. The results of analysis of variance at 95% confidence intervals showed that heat treatment on wood had a significant effect on the weight loss

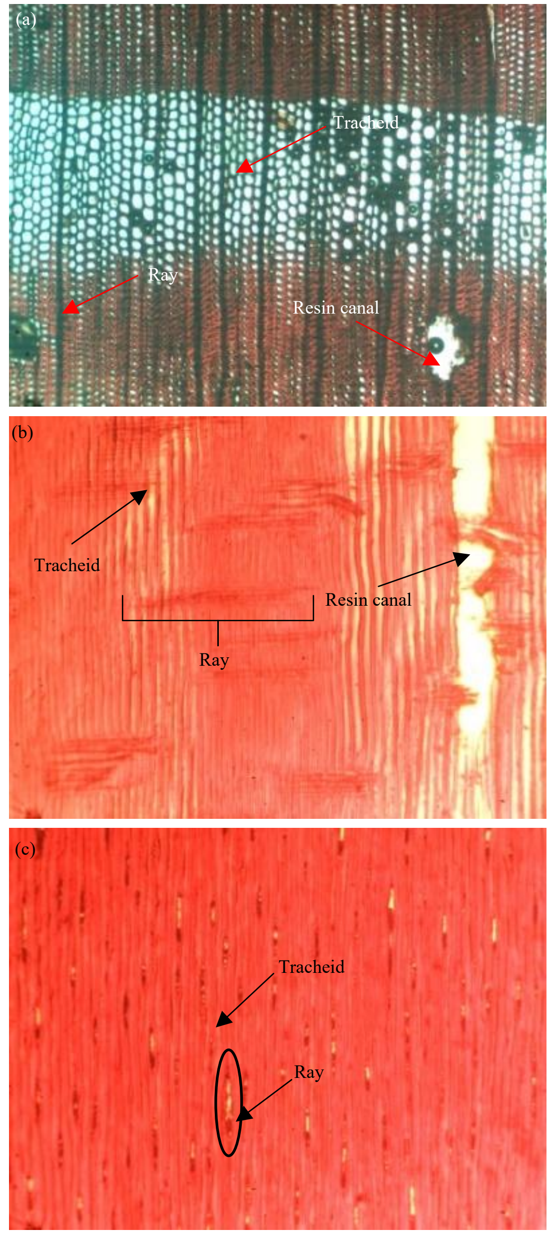

Fig. 5(a-c): Pine wood (a) Cross section, (b) Radial section and (c) Tangential section macroscopic picture with 40 times magnification

of the test sample. Duncan test results showed that the weight loss value of the control test samples due to the termite attack was significantly lower ($p<0.05$) from the presto treated samples but the control test samples were not significantly different ($p<0.05$) from another heat treatments. This shows that applying heat to the deciduous wood has an effect on weight loss of the test sample.

Hardness: The results showed that the highest mean value of wood hardness was found in the control sample of

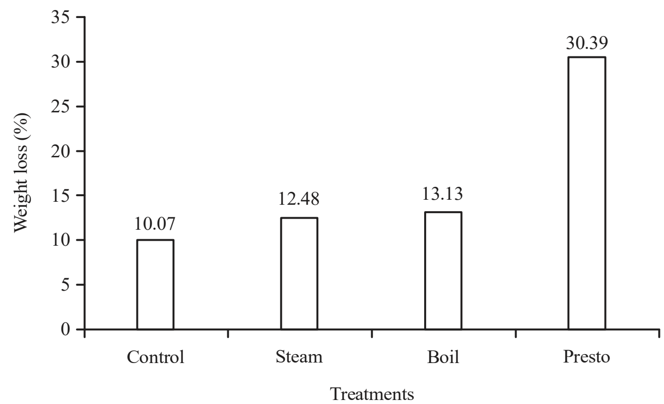

Fig. 6: Weight loss (%) of pine wood with various treatments

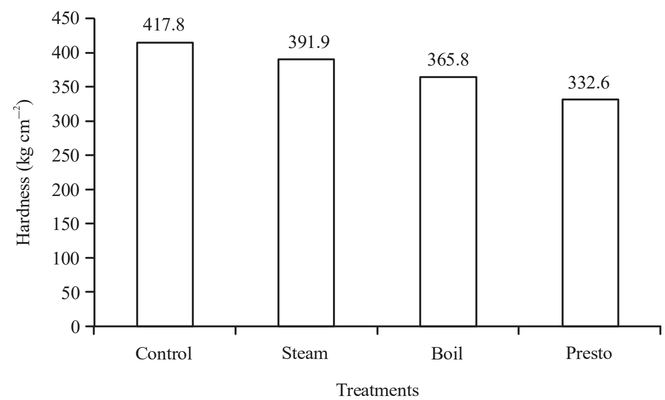

Fig. 7: Mean tangential hardness of pine wood with various treatments

417.82 kg cm^{-2}, followed by steamed samples 391.91 kg cm^{-2}, boiled sample 365.77 kg cm^{-2} and presto sample 332.56 kg cm^{-2} as presented in Fig. 7. The results of the analysis of the 95% confidence interval showed that heat treatment in the test sample did not have a significant effect on wood hardness. The heat treatment that was done in this research causing the decreasing of the hardness value compared to the control wood. The longer period of heat treatment on wood will soften the wood and reducing the resin contain in wood significantly, thus resulting a decreasing value of hardness.

DISCUSSION

C. curvignathus was known as the largest termite of the genus *Coptotermes*. These termites have a body length of 5.56-7.13 mm, head length with mandible 2.46-2.66 mm, head length without mandible 1.56-1.68 mm, maximum head width of 1.40-1.44 mm[13]. The termite *C. curvignathus* belongs to the subfamily Coptotermitinae and the Rhinotermitidae family. This family characteristic has a fontanel, the pronotum is rather flat and smaller than the head[18].

Based on these anatomical features, the pine species used in this study is *Pinus merkusii*[9]. The anatomy of wood can be influenced by differences in genetic, environmental and cell maturity factors. Even explicitly wood also has variations between both types, between genera in a family, between similar trees and in one tree trunk. The anatomy of wood is also influenced by the age of the tree[19].

Wood resistance to subterranean termite attack can be evaluated by determining the weight loss. Severe loss indicated a termite response to the wood sample that was being fed for 4 weeks. Wood sample weight loss can be influenced by several factors including the level of termite consumption. The percentage of wood consumed by termite was influenced by the environment, number colony and body size. The increasing value of weight loss in heat-treated test samples is caused by the influence of water and hot steam which makes the resin contained in pine wood come out and appeared on the surface, marked by the rough surface and visible shiny yellow color on the surface of the wood. The effect of pressure on the presto treatment reduced the resin content in the pine out more significantly than the boiled and

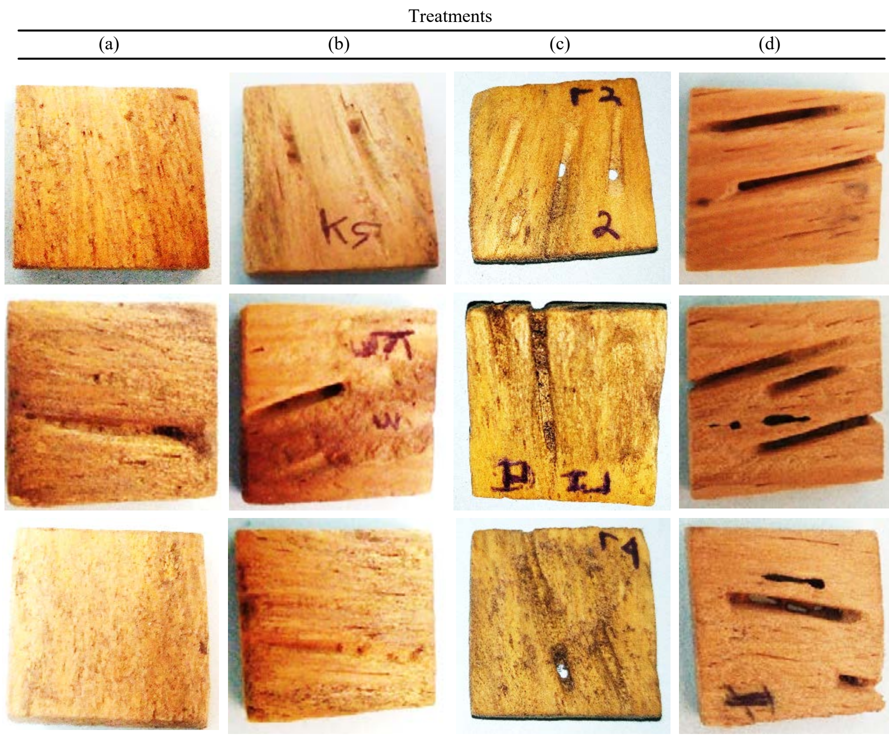

Fig. 8: Condition of (a) Control test examples, (b) Steamed, (c) Boil and (d) Presto after 4 weeks of feeding of termites *C. curvignathus*

steamed treatment. This makes the wood softer which was more desirable to termites.

Based on the 4 weeks baiting test results, there were holes on the baited samples due to termites attack (Fig. 8). The higher consumption rate indicates the termites most preferred wood. Visually, the control test sample has a mild level of damage, it appears to be small hole due termite consumption activities. While the test boiled and steam treated sample had a higher damage rate than the control wood, while in the presto treatment wood displayed the highest level of damage. This implied that by giving heat treatment to the wood can increase termite consumption rate on wood bait.

The properties of the wood hardness are measure of wood ability to resist the stress or the pressure on the wood surface. This ability is also often referred to as the ability of wood to withstand abrasion on the surface[20]. Hardness of wood is influenced by many factors including the density and structure of wood cells, humidity and temperature.

The control sample has the highest hardness value because the test sample was not given any heat treatment so there was no reduction in the hardness value of the wood did not decrease and it is in accordance with the previous study that stated the hardness value of pine wood is 350-560 kg cm^{-2}. Whereas the steamed and boiled treated wood hardness value was decreasing, due to the presence of heat in a relatively long time and the release of resin from the pine wood[21], the time or period of heat treatment exerts a greater influence than the temperature factor on changing wood properties. Boiled treatment may turn hemicellulose and lignin softer and more elastic that can decline the hardness value of wood[6]. The presto treatment has the lowest hardness value because there was pressure applied on the presto treatment which was releasing more resin content in the pine wood. Pressure on wood may decrease the mechanical properties of wood. The presence of pressure can reduce mechanical properties of wood[22]. This shows that the value of wood hardness is influenced by the value of applied pressure.

The heat treatment on wood could give negative impact such as a 15% reduction of density based on the wood species that was employed to the heat treatment process, which was correlated with the declining mechanical properties such as strength, hardness and elasticity. This change in properties is due to physical and chemical changes from wood which is subjected to heat treatment[1]. In the example of the test steamed, boiled and presto treated wood hardness decreased, that increasing the palatability of the termites preferred and made them easier to consume wood.

CONCLUSION

Presto (0.4 bar, 100°C), boiled (100°C) and steamed (100°C) treatments can increase the palatability of the termites of *Coptotermes curvignathus* on pine wood. The treatment can decrease the hardness of pine wood. The presto treated pine wood has the lowest hardness value, thus the wood become softer and increasing the palatability of *C. curvignathus*. Consequently, it is recommended to treat the pine wood using presto treatment before the baiting process.

SIGNIFICANCE STATEMENT

This study discovered the beneficial effect of heat-steamed and presto treatment which increased termite palatability to pine wood. Thus, a recommendation could be given to the professionals and community to optimize the effectivity of baiting method in order to evaluate termite presence using presto treated pine wood. The information potentially becomes a fundamental baseline for researcher to increase the validity of termite species diversity evaluation.

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