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Evaluation of termite resistance of medium density fiberboard (MDF) manufacture from agricultural fiber bonded with citric acid

Yuliati Indrayani[a]*, Dina Setyawati[a], Sasa Sofyan Munawar[b], Kenji Umemura[c], Tsuyoshi Yoshimura[c]

[a]*Faculty of Forestry, Tanjungpura University, Jl. Imam Bonjol, Pontianak 78124, Indonesia*
[b] *Center for Innovation Indonesian Institute of Science (LIPI), Jl. Raya Bogor KM.47, Cibinong, Bogor 16912, Indonesia*
[c]*Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho, Uji, Kyoto 611-0011*

Abstract

Nowadays, the use of agricultural fibers for panel composite materials attracts great intention. Further, it is desirable to develop of natural adhesive derived from non fossil resources to be safe adhesive without using harmful chemical substances. In this study, citric acid application as natural adhesive was investigated for medium density fiberboard (MDF) manufacture from pineapple leaf fiber. The ratio of citric acid and sucrose and adhesive content was 25–75 and 20 wt%, respectively. Two different types of board consisting of three layers with target density of 0.8 gr/cm^3 were prepared. The board was hot pressed at 200ºC and 4.5 MPa for 10 min. Additional boards with same structure were prepared using citric acid only. The biological properties of the boards such as their resistance against subterranean termite attack have been examined. The results indicate that generally, there was a significant effect of impregnation with mixture of citric acid and sucrose and citric acid only on the susceptibility of the MDF board specimens. With regards to the percentage of specimen mass losses, fiber orientation had no significant effect on the termite resistance against *Coptotermes formosanus* Shiraki. Utilization of natural adhesive, citric acid was promising to be used for MDF manufacturing. Our findings show that the total adhesive content of 20% of the type a board could be used for agricultural fiber product applications to protect structures from degradation by termites.

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Keywords: Pineaplle leaf fibre; MDF; natural adhesive; citric acid; termite resistance

* Corresponding author. Tel.: +62-561-767673; fax: +62-561-767673.
E-mail address: mandaupermai@yahoo.com.

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1. Introduction

The demand for wood-based materials is increasing rapidly year to year. This phenomenon is able to attribute to decreasing of forest area which is influence the sustainability of forest. Nowadays, attention is paid to non-woody fiber which has gained high importance as a sustainable plant fiber resource for composite products as stated by Indrayani *et al.* [1]. So far, composite products are manufactured using synthetic adhesive which is obtained from fossil resources [2], besides synthetic adhesive is hazardous to environment and human being. Considering the sustainability and global environment effect and insufficiency of fossil resources, it is indispensable to reduce the consumption of synthetic adhesive. In the field of wood adhesive, it is needed to develop new environment friendly adhesive for composite manufacture to develop the sustainability. Bio-composite produce from agricultural fiber bonded with adhesive is one of the alternatives to substitute the using of solid wood.

Studies on natural adhesive using renewable resources such as protein, tannin and lignin have been investigated [1]. Many researchers have been reported ways of reducing the utilization of the synthetic adhesive such as development of natural adhesives [3] and binder less board [4,5]. Binder less board is composite product containing the chemical components in the raw material bonded without the use of adhesives [6].

Our previous research has been succeeded make MDF produce from pineapple leaf fiber using synthetic PF adhesive [1,7]. In order to minimize the utilization of synthetic adhesive, this study carries on investigating possibility of citric acid applied as natural adhesive for MDF manufacture from pineapple leaf fiber. Utilization of citric acid for wood composite particleboard manufacturing has been developed by Umemura *et al.* [2]. Citric acid (2-hydroxy-1,2,3-propane tri carboxylic acid) is an organic poly carboxylic acid containing three carboxyl groups [8]. In addition, citric acid has been researched as across-linking agent for wood [9], plant fiber [10], paper [11], starch [12] and bio-based elastomers [13].

Wood-based board depends on adhesive bonds for its integrity and susceptibility to biological degradation is first detected as adhesive bond failure [14, 15]. In other words, the adhesive has an important influence on termite resistance of wood-based composites. Subterranean termites are able to be the reason of extensive damage to wood, wood and non-wood composites therefore this product possesses little inherent resistance to termites attack.

In this study, MDF specimens produced from pineapple leaf fiber are subjected to termites' tests using subterranean termites *Coptotermes formosanus* Shiraki. The possibility of citric acid as natural adhesive for MDF manufacture from pineapple leaf fiber is also investigated. The aim of the study is to determine whether boards containing agricultural fiber and natural adhesive, citric acid, affected resistance to termites' attack in laboratory conditions.

The goal of the study is to enhance the sustainability of forest and environment by developing composite product from pineapple leaf fiber natural adhesive.

2. Methodology

2.1. Board Preparation

Pineapple (Ananas comosus (L.) Merr.) leaves were used as raw material. MDF was manufactured according to Indrayani *et al.* [1,7] and Munawar*et al.* [16]. The fibers were taken out from pineapple leaves by decortications. They were cut to 35 cm in length and manually combed to obtain straight fibers. Next, they were oven-dried to moisture content of about 5%. MDF boards at a target density of 0,8 gr/cm^3 were manufactured measuring 35 cm x 35 cm x 0.4 cm. Adhesive solutions were prepared containing mix of citric acid and sucrose and citric acid only. Citric acid (anhydrous) and sucrose were purchased from Nacalai Tesque, Inc. (Kyoto, Japan), and applied without further purification. The ratio of citric acid and sucrose, and the adhesive content were 25–75 and 20 wt%, respectively. The fibers were dipped into the adhesive solutions. Excess impregnation adhesive was squeezed out by passing the fiber thorough a pair of rollers. The impregnated fibers were dried at room temperature for 24 hours to let adhesive content of 20% (dry weight) of the fibers.

Two sets of boards were produced. First, unidirectional board as Type I was created with all layers oriented in the longitudinal direction. Second, cross-oriented as Type II was consisted of a plywood-type board with an orientation of 0º-90º-0º. The MDF was prepared in three layers of about 1:1:1 weight ratio. The mats were consolidated in laboratory hot press with specific pressure of 4.5 MPa and at pressing temperature of 200ºC for 10 minutes to completely cure the adhesive [2]. Afterward, all boards were conditioned at 20ºC and 65% relative humidity (RH) for seven days prior testing.

2.2. Termite Bioassay

MDF specimens measuring 20 x 20 x 10 mm were obtained from MDF boards and exposed to the subterranean termites *Coptotermes formosanus* Shiraki in accordance with Japan Wood Preserving Association (JWPA) standard [17]. An acrylic cylinder measuring 80 mm in diameter and 60 mm in height sealed by a 5 mm thick of hard dental plaster (New Plastone, GC Corp.) was applied as a container. A test specimen was placed at the centre of the bottom of the test container. A total of 150 worker termites and 15 soldiers termites collected from a laboratory termite colony at RISH, Kyoto University, were introduced into each test container. The assembled containers were set on wet cotton pads to maintain the humidity and kept in an unlighted room controlled at 28°C and >85% RH for 3 weeks.

Three specimens for each MDF were exposure against termites. Small wood blocks of Sugi (*Cryptomeria japonica*) were also employed for control purposes. At the end of the experiment, the specimens were removed from the containers, carefully cleaned the debris from termite attack, oven-dried and reweighed to determine the percentage of weight losses and to record survival rates of termite. The weight loss of the specimens was calculated based on the differences in the initial and final oven- dry weights of the specimens after cleaning off the debris from termite attack.

3. Results

Average weight loss and termites survival percentage of MDF specimens during 3-week termite bioassays are shown in Figs 1 and 2. In this study, it was observed that MDF specimens containing mix citric acid and sucrose were the least resistant compared to other MDF specimens. MDF specimens containing citric acid were resistant to termite attack during termite bioassays. Weight loss value in MDF specimens made from citric acid was lower than in MDF specimens containing mix citric acid and sucrose (Fig.1). Average weight loss value of MDF specimens containing mix citric acid and sucrose was obtained more than 10 %, while average weight loss of MDF specimens containing citric acid was obtained less than 10%. However, no statistically significant difference was observed on average weight loss of the specimens between mix citric acid and sucrose and citric acid (Tukey'stest:$P < 0.05$) except in unidirectional board.

Citric acid (2-hydroxy-1,2,3-propane tri carboxylic acid) containing poly carboxylic acid [8] may explain greater durability of the MDF containing high citric acid. High citric acid content of MDF devastates the termites, consequently lower in weight losses. The results suggest that chemicals derived from the citric acid may show inhibitory properties against termite. Moreover, this finding supports previous observation by Raina *et al.* [20] that orange oil has been shown to exhibit varying degrees of effectiveness against *Coptotermes formosanus.*

Average weight loss in MDF specimens containing 100% citric acid was 8.34 %, while the MDF specimens produced from mixed citric acid and sucrose caused more weight loss (12.01%). Despite lower and higher percentage weight losses of MDF specimens were determined in MDF specimens of unidirectional board. However, there was no statistically significant effect of fiber orientation on the susceptibility of MDF specimens to termite attack during termite bioassay (Tukey's test: $P< 0.05$).

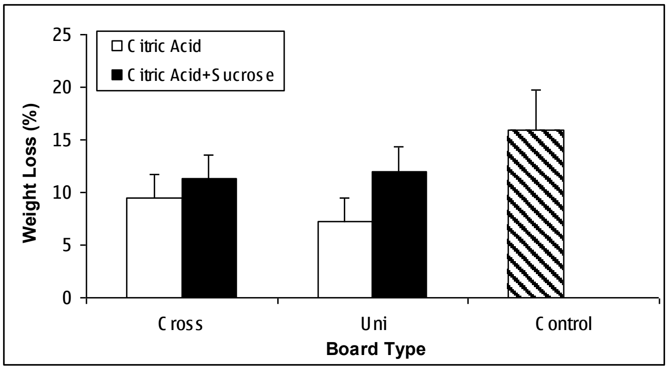

Fig1.Weight loss in MDF specimens after 3 weeks exposure to termite *Coptotermes formosanus* Shiraki. UB,uni-oriented; CB,cross-oriented.

Comparing to solid wood specimens (*Cryptomeria japonica*), the average weight loss value was higher in solid wood control (15.86%). Imamura [19] states that Sugi (*Cryptomeria japonica*) is classified as Moderately Resistant (MR). This comparison of MDF and solid wood specimens should be helpful in determining the effects of natural adhesive citric acid during the composite manufacturing.

The outcome as shown in Fig.2 illustrates that average termite mortality of control Sugi (*Cryptomeria japonica*) was obtained at 14.11%. In contrast, the average termite mortality of the MDF specimens containing citric acid adhesive was around 59.11 %, while the mix citric acid and sucrose adhesive reached to 49.50 % at the end of the tests (Fig.2). This observation highlighted that MDF specimen with citric acid adhesive impregnation resulted lower worker termite mortality than those impregnated with mix citric acid and sucrose adhesive (Fig.2). It is able to be stated that high citric acid content of the MDF devastates termites, consequently higher in termite mortality.

As shown in Fig.2, no significant difference was observed between termite mortalities in unidirectional board (Uni) and in cross-oriented board (Cross) boards (Tukey'stest:$P<0.05$). This is indicated that fiber orientation has no effect on termite mortality. Previous findings of Indrayani *et al.* [1] support these results describing that no effect on termite mortality on MDF manufactured from mix between high and low molecular weight PF resin and high molecular weight PF resin.

In general, termite mortality was confirmed to the weight loss in the specimens. In contrast to the MDF fiber, small wood blocks of Sugi (*Cryptomeria japonica*) shows lower termite mortalities (Fig.2) and higher weight loss (Fig.1).

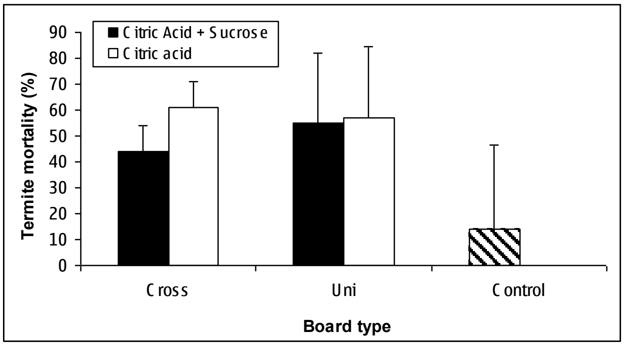

Fig2.Termite mortality during the-3 weeks exposure of MDF to termite *Coptotermes formosanus* Shiraki. UB,uni-oriented; CB,cross-oriented.

4. Conclusion

MDF manufacture from pineapple leaf fiber bonded with citric acid and sucrose show the feasibility of a natural adhesive. Laboratory test against subterranean termite *Coptotermes formosanus* Shiraki shows that utilization of pineapple leaf fiber and natural adhesive citric acid is effective in prohibiting degradation by termites. Termite resistance test reveals citric acid adhesive impregnating pineapple leaf fiber MDF appears to be suitable for building construction materials purposes and promising for development of durable construction material. It is not merely useful as a renewable and environmentally friendly construction material for region with a low available of wood product but also has are promising alternatives to the declining of wood supply.

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