**Kalappia celebica**, an endemic wood from Sulawesi Island: Chemical composition and its resistance against white rot fungi *Ganoderma tsugae* and *G. lucidium*

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**Abstract.** *Kalapi* wood (*Kalappia celebica* kosterm) is endemic to Sulawesi Island and is a monotype species in the Fabaceae family with limited distribution. This study investigates the chemical composition and natural durability of *Kalapi* (*K. celebica* Kosterm) wood against white rot fungi *Ganoderma tsugae* and *G. lucidium*. This study was conducted based on the TAPPI standard for moisture analysis content, ASTM-D for extractive content, holocellulose, and lignin, and method Cross and Bevan for cellulose. Durability observation was conducted in 12 weeks by assessing the percentage damage of wood samples caused by the fungi according to SNI standards 01-7207-2014. Results show that *K. celebica* has holocellulose, cellulose, and extractives at a high level, lignin was moderate, and had low hemicellulose. The results of testing the durability of wood shown that *K. celebica* has resistance to *G. tsugae* attack (class II) but is not resistant to *G. lucidium* (class IV), with an average weight loss of 3.14 % and 18.82 %, respectively.

**1. Introduction**

The island of Sulawesi in Indonesia is the largest land area in the Wallacea region, with a high level of endemism and designated as a biodiversity hotspot [1,2]. One of the riches of Sulawesi's flora is *Kalapi* wood (*Kalappia celebica* kosterm) is an endemic wood originating from the forests of Sulawesi Island and is a monotype species in the Fabaceae family, with a limited distribution in Malili (North Luwu) Tangketada, Abuki, Konawe, and East Kolaka [3]. This wood is included in high-quality trade timber, so it is widely sought after as a building material. Sulawesi's local inhabitants use *Kalapi* wood as building materials and houses, such as house poles, doors, windows, shipbuilding, and other parts requiring high strength [4]. Unlike other luxury wood such as Jati or Mahoni, *Kalapi* is currently a hard-to-find species. Its population in natural forests tends to decline and is included in the category of vulnerable species [5]. This condition may be due to excessive exploitation of natural forests without replanting, coupled with a lack of knowledge about this tree's cultivation and regeneration [6].

Although this wood is widely used by the community and traded, information about timber is still very limited. With the status of wood *Kalapi*, is an important reason to know the properties of the wood. The properties data of the wood are very important as a basis for wood use and as one of the conservation strategies in the use of this species.
Indonesia with a humid tropical climate allows the wood to be easily attacked by wood-destroying microorganisms such as wood rot fungi. One of the wood-rot fungi that often attacks wood both from the nursery, living trees, and dead stems is from the type of Ganoderma. Ganoderma species are caused by the white-rot of hardwood by decomposing lignin, cellulose, and related polysaccharides. The root and stem rots are caused by Ganoderma species, results in the loss in forestry yields, e.g., *Elaeis guineensis* (oil palm), [7] and other important trees, e.g., *Hevea brasiliensis* (rubber) [8]. In Indonesia, red root disease caused by the fungus *Ganoderma philli* is the most serious disease in the industrial plantations of *Acacia mangium* and Eucalyptus, and Sengon (*Falcataria sp*). *A. mangium* in Sumatra and Kalimantan, the incidence of attacks on Ganoderma in 3-5-year-old stands is 3-28% [9].

Kalapi is medium to heavy wood (strong class II) with densities ranging from 590-710 kg/m³ with a moisture content of about 15%, the color of heartwood was dark brown, very different from light brown sapwood with 3-5 cm thick [4]. However, other information like the chemical composition of wood and wood resistance has not been recorded. This study reports the durability of Kalapi wood against white rot *Ganoderma lucidium* and *G. tsugae* and its relation to its chemical composition of wood.

2. Material and methods

2.1. Materials

Kalapi wood (*K. celebica* Kosterm) (the diameter at breast height is 32 cm) was obtained from Anggoro village, Abuki District, Konawe Regency, Southeast Sulawesi, Indonesia. *G. lucidium* and *G. tsugae* fungi (Figure 1) were obtained from fresh mushroom fruit bodies around Tahura Nipa, Kendari Regency, Southeast Sulawesi. Mushroom specimens are stored in the Biology laboratory, Faculty of Mathematics and Natural Sciences, Halu Oleo University for observation and identification. The pure culture of *G. tsugae* and *G. lucidium* was obtained by sterilizing the surface of the mushroom fruit body. Mushroom fruit body cut into 1 x 1 cm size using 70% alcohol solution for 1 minute, followed by 1% chlorox solution for 30 seconds, then continued to soak it again into 70% alcohol for 1 minute. Pieces of fruit were inoculated into PDA media. Then the mushroom culture was incubated for 3-7 days at room temperature 27-30oC. Macroscopic identification of *G. tsugae* and *G. lucidium* fungi following [10,11] whereas microscopic identification is based on [12].

2.2. Methods

2.2.1. Determination of wood chemical components. Determination of wood chemical components Kalapi includes determination of moisture content, cellulose, lignin, hemicellulose, and extractive content. Determination of moisture content according to the TAPPI method T 264 om-88 [13]. Levels of holo cellulose according to the ASTM method D 1104-56. Cellulose content according to Cross and Bevan methods Determination of lignin levels is carried out according to ASTM D 1106-56, and extractive determination refers to ASTM D 1107-96 [14,15]. The results of the analysis of wood chemical components refer to the Department of Agriculture, 1976 classification [16] in Table 2.

2.2.2. Wood resistance test for fungal attack. The method used is the Kolle-flash method, which is adapted to the method of testing wood against fungi by SNI Standards 01-7207-2014 [17]. The media is homogeneously dissolved into the bottle as much as 80 ml per bottle. The test samples were dried (103 ± 2) °C until a constant weight was obtained. Then the cooled sample (size 5 cm x 2.5 cm x 1 cm) was inserted into a bottle that had been cultured aseptically and was incubated for 12 weeks. After incubation, the test sample is cleaned from the mycelium installed and dried at a temperature of (103 ± 2) °C until a constant weight is obtained. The percentage of weight loss due to fungal attack samples was analyzed using a factorial complete randomized trial design (wood section and wood location in dolog) (Figure 2) and Tuckey's follow-up testing (P <0.05). The average percentage of wood weight loss is grouped based on the durability scale following SNI 01-7207-2014 (Table 2).
3. Results and discussion

3.1. Chemical composition of Kalapi wood

The results of the wood component analysis Kalapi are shown in Table 1. The results showed that the levels of Holocellulose were included in the high category and were dominated by cellulose by 62% and hemicellulose including low, while the lignin and extractive were high.

![Figure 1](image1.png)

**Figure 1.** a. Disc of Kalapi (*K. celebica*) wood: hearthwood (H), sapwood (S), b. The fruiting body of *G. tsugae*, c. The fruiting body of *G. lucidium*

![Figure 2](image2.png)

**Figure 2.** Wood sampling for assaying chemical composition (1 and 2): a. near the bark, b. Middle, c. Near pith, d. Wood branch, and wood resistance against fungi (3): bark (B), Pith (P), sapwood (S), hearth wood (H)
Table 1. Chemical composition of *Kalappia celebica* from Southeast Sulawesi

| Chemical composition | Position of wood | Composition class |
|----------------------|-----------------|------------------|
|                      | Near bark       | Middle           | Near pith | Average |                   |
| Water content        | 24.1            | 12.3             | 17.5      | 17.97   | Low               |
| Holocellulose        | 75.5            | 76.1             | 75.2      | 75.60   | High              |
| Cellulose            | 63.6            | 62.3             | 60.2      | 62.03   | High              |
| Hemicellulose        | 12.3            | 14.1             | 13.1      | 13.17   | Low               |
| Lignin               | 48.1            | 27.3             | 23.2      | 32.87   | Moderate          |
| Extractives (Ethanol-Benzene) | 13.2         | 19.3             | 15.4      | 15.97   | High               |

When viewed from its chemical composition class, the Kalapi wood is estimated to have high strength and durability. However, because the holocellulose level is also high, this wood is also susceptible to destructive microorganisms such as termites and fungi because cellulose is the main food of the two organisms. Whereas when viewed from extractive levels, wood that has a high extractive content generally has high wood durability.

![Figure 3. Comparison of chemical composition wood stems and branches of *K. celebica*](image)

The lignin and holocellulose content of wood in stems and branches show almost the same value, while extractives of the wood stem are higher than that of branches. The chemical composition between the stems and branches of the kalapi wood did not show a significant difference (Figure 3), this could be due to the age of the wood thought to have passed adolescence, so that the apical growth effect on the branches was not visible despite the cellulose content in the stem (62.3%) higher than the branch (57.3%). A study on teak (*Tectona grandis*) showed that trees with slow growth rates had lower extractive content than trees with moderate or fast growth rates, but there were no significant differences from the main components [18].

3.2. Natural durability of Kalapi wood against white-rot fungus *G. tsugae* and *G. lucidium*

The results of testing the durability of wood against attacks of *G. tsugae* and *G. lucidium* are shown in Figures 3 and 4. It is known that commonly heartwood has a higher extractive content than sapwood. Extractives can be used as a toxic substance for wood destruction microorganisms such as fungi. From Table 1, it can be seen that middle and near heartwood has higher extractives than sapwood/near the bark, this is related to the cause of weight loss of heartwood on the base lower than heartwood and sapwood on the middle and the top of the wood.
Figure 4. Weight loss of Kalapi wood after being attacked by *G. tsugae*. H (heartwood), S (sapwood).

Figure 5. Weight loss of Kalapi wood after being attacked by *G. lucidium*. H (heartwood), S (sapwood).

Naturally, the durability of wood is determined by the role of specific extractive substances of each wood. For example, in teak (*Tectona grandis* L.f) there is tectoquinone and Ebony wood (*Diospyros virginia*) containing 7-methyl juglone compounds as anti-termites. Likewise, tannin extracts containing high polyphenol compounds can prevent the wood from attack by termites and fungi (Pujirahayu et al., 2015).

Table 2. Classification of wood resistance based on the weight loss due to fungi attack.

| Class | Resistance       | Weight loss (%) |
|-------|------------------|-----------------|
| I     | Very resistant   | < 0.5           |
| II    | Resistant        | 0.5 - 4.9       |
| III   | Moderately resistant | 5.0 - 9.9   |
| IV    | Non-resistant    | 10.0 - 30.0     |
| V     | Perishable       | >30             |

Source: SNI 01–7207–2014
Table 3. Weight loss and wood resistance of *Kalappia celebica* against *G. tsugae* and *G. lucidium*

| Fungy          | Wood position | Class    |
|----------------|--------------|---------|
|                | Base | Middle | Top  | Average |         |
| *G. tsugae*    | 1.16 | 3.17   | 5.09 | 3.14    | II (resistant) |
| *G.lucidium*   | 13.01| 19.55  | 23.91| 18.82   | IV (non-resistant) |

After a fungal attack on wood for 12 weeks it was seen in a decrease in wood weight by an average of 3.14% in wood attacked by *G. tsugae* and on average 18.82% in wood attacked by *G. lucidium*. Based on (Table 2) and the average of weight loss (Table 3), it can be concluded that the Kalapi wood has resistance to *G.tsugae* attack (class II) but is not resistant to the attack of *G. lucidium* (IV). These results indicate that the ability of *G. lucidium* to decay Kalapi wood is higher than that of *G. Tsugae*. Similar results were reported by [20] that *G. lucidium* isolates generally cause a greater decrease in wood weight (*Quercus hypoleucoides, Prosopis velutina Woot, Abies concolor Lindl., And Pseudotsuga menziesii* (Mirb.)) than in *G. tsugae* isolates. Both fungi *G. lucidium* and *G. tsugae* causes simultaneous decay in all woods, and there is a trend towards simultaneous delignification and decay.

The durability of wood against fungi varies depending on the condition of the wood, and the number of extractive substances it contains. These results indicate that extractive substances in Kalapi wood may be toxic to *G. tsugae* not toxic enough to *G. lucidium*. Although extraction is a wood component that can determine the wood resistance to microorganisms, the durability of wood is not only determined by extractives. Some woods with high extractive content such as teak (*Tectona grandis*) have an anti-termite, 2-methylantraquinone substance but the compounds are not toxic to wood rot fungi. Likewise, Bawang wood (*Azadirachta excelsa*) has high extractive substances (7.87 %), but its resistance is classified as class III [21]. It can be concluded that the durability of wood other than determined by the type and number of compounds contained in extractive substances, is also determined by the type of wood-destroying microorganisms (termites, fungi, bacteria) and the method of testing performed.

The lack of data about the population of the kalapi tree (especially the seedling and sapling stage in nature) may be caused by the Ganoderma or another fungus attack on the seedling phase, or the pole phase, although there have been no reports of this. This can happen because the type of fungal host is very broad and can be found on dead wood or trees that are still alive, such as Sengon (*Paraserianthes falcatoria*), Lamtoro (*Leucaena leucocephala*), Saga (*Adenanthera microsperma*), Mahagony (*Swietenia mahagoni*), *Acacia mangium*, rambutan (*Nepehelium lappaceum*), Albizia procera, even Eboni trees (*Ebenaceae*) [9] and can attack at various stage of a tree live.

4. **Conclusions**
Kalapi wood has high levels of holocellulose, cellulose, lignin, and extractive, while hemicellulose is low. Kalapi wood has resistance to fungal attack *G. tsugae* (class II) but is not resistant to *G. lucidium* (class IV) attacks.

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**Declaration of competing interest**
The authors declare no conflict of interest.

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