Evaluation of the Utilization of *Ginkgo biloba* Leaf (GBL) Extract as an Eco-Friendly Wood Preservative

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Ginkgo biloba leaf (GBL) extract was evaluated as a wood preservative, considering its sustainable availability in forests and cities worldwide. Previous research has demonstrated the antibacterial and antifungal properties of GBL extracts. Based on this information, it was hypothesized that GBL extract could effectively combat wood decay. The wood preservation properties of GBL extracts were evaluated using the "Laboratory test method of natural decay resistance of wood" KS F 2213 (2018). Its performance was compared to that of ACQ-2, a commercial wood preservative. The GBL extract was tested against two common wood decay fungi, namely *Fomitopsis palustris* and *Trametes versicolor*. The results showed mass loss rates of 13.6% and 9.9% after culturing these fungi, respectively. Although the GBL extract did not surpass the performance of ACQ-2, it achieved a "resistant" grade according to KS F 2213 (2018). This indicates that GBL extract exhibits a significant wood preservation effect. Furthermore, the GBL extract retains the natural color of wood, which is an advantageous characteristic.

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INTRODUCTION

Wood is a natural resource with different textures, colors, and patterns, which can create a warm and inviting atmosphere for humans (Kotradyova *et al.* 2019; Jang 2022; Jang and Kang 2022a). Also, wood is a naturally porous material and has low thermal conductivity, which leads to improved energy efficiencies of buildings (Jang and Kang 2022b). Wood is relatively light and has sufficient strength, making it an ideal eco-friendly material for use as a building material (Wimmers 2017). However, the eco-friendliness of wood also provides a fatal disadvantage as a building material. Wood can be easily affected by moisture, mold, insects, and fungi. Therefore, when using wood as a building exterior material, preservative treatment is essential to protect the wood from these decay factors and improve durability (Jang and Kang 2023a,b).

There are several types of wood preservatives in common use. The first is chromated copper arsenate (CCA). It has three main components, namely copper, chromium, and arsenic. CCA provides an effective defense against fungi, insects, and vermin and experiences deep penetration into wood (Randall and Chen 1995). However, in many countries CCA has been restricted or regulated due to concerns about environmental contamination (Moghaddam and Mulligan 2008; Kim *et al.* 2009). The second chemical is alkaline copper quat (ACQ), which is a preservative liquid widely used as an alternative to CCA (Tascioglu and Tsunoda 2010). ACQ is composed of copper and an alkaline compound and is an environmentally friendly wood preservative because it does not contain arsenic. The third chemical is copper azole (CA), an antiseptic liquid composed of copper and azolate compounds. CA is also considered an environmentally friendly antiseptic solution and does not contain arsenic (Wang *et al.* 2014). Finally, borate-based chemicals are used to preserve wood. A borate preservative solution is non-toxic and has the advantage of being environmentally friendly (González-Laredo *et al.* 2015). However, wood that has been preserved using a borate-based method is sensitive to moisture and is suitable only for indoor use with little external exposure (Khademibami and Bobadilha 2022).

In addition to these, various eco-friendly and low-toxicity wood preservatives have been studied recently. Lee and Lee (2014) studied the antifungal effect of wood in the combination of dinotefuran, IPBC, and clove oil. Ajuziogu *et al.* (2019) found that compounds extracted from *Erythrophleum suaveolens* and *Pterocarpus erinaceus* plants had termite-preventive effects on wood. Rahman *et al.* (2019) investigated a 5% ethanol extract of *Azadirachta indica* leaf as a preservative that inhibits the growth of fungi on wood and is also effective against wood-destroying microbes. Šimůnková *et al.* (2022) investigated the protection of Norway spruce (*Picea abies*) trees from the termite *Reticulitermes flavipes* and the brown rot fungus *Rhodonia placenta* using lavender oil (LO), suggesting that it can be used as an excellent green wood preservative.

This study focused on the *Ginkgo biloba* leaf (GBL) extract. Along with *Quercus acutissima* and *Prunus serrulata*, *Ginkgo biloba* is widely distributed as a landscaping tree in forests and cities in Korea, Japan, China, Europe, and the United States (Pe *et al.* 2020).

Several scientific studies have reported the antibacterial activity of GBL extract against various bacterial strains. Lee *et al.* (2003) reported that domestic GBL extract has fungal inhibitory and insecticidal activities and suggested using it as a natural pesticide. GBL extract has demonstrated efficacy against well-known bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* (Boonkaew and Camper 2005; Konii *et al.* 2015; Ražná *et al.* 2020). Additionally, GBL extract has exhibited antifungal properties against fungal strains (Lee *et al.* 2010).

The antibacterial and antifungal activity of ginkgo leaf extract has been attributed to the presence of various compounds, including flavonoids, alkaloids, saponins, tannins, and polyprenols (Ubaoji *et al*. 2020). Therefore, these properties of GBL extracts might also be effective against wood decay.

Korean white pine (*Pinus koraiensis*) is a representative endemic species in Korea and is distributed in 21.3% of national forests and 78.7% of private forests. Recently, it has been recognized as an important building material that can replace the Japanese larch (Kim *et al.* 2015). In this study, Korean white pine was impregnated with GBL extract. Its preservative effect was investigated by applying wood decay fungi *Fomitopsis palustris* and *Trametes versicolor*.

EXPERIMENTAL

Specimens

Figure 1 shows the sample preparation in this study. Approximately 25-year-old air-dried Korean white pine sapwood boards 100 (L) × 2(R) × 2(T) were supplied from Jeonil Timber Co., Ltd (Kimje, Korea). They were kiln-dried by the supplier. The moisture content was approximately 12%, and the air-dried density was 0.44 g/cm^3. The timber was cut using a band saw into 2(L) × 2(R) × 2(T) cubes with 5 to 7 annual growth rings.

Fig. 1. Sample preparation of Korean white pine

GBL Extract

The GBL extract used in this study was supplied by Dain (Chungju, Korea). GBLs were finely ground and extracted by boiling in hot water at 100 °C for 30 min. The extract ingredients were GBL, butylene glycol, glycerine, 1.2 hexanediols, and water.

Pressure Impregnation

The impregnation process was carried out as described in previous studies (Jang and Kang 2023a, b). Korean white pine specimens were placed in the sample chamber and decompressed for 30 min with a vacuum pump (Fig. 2). Afterwards, the pressure impregnation chamber was filled with the samples and the water-soluble GBL extract (solid content: 5%). Then, nitrogen pressure was applied at 2.07 MPa (300 psi) for 24 hours. In addition, the commercial ACQ-2 preservative used in previous studies was used as a control (Jang and Kang 2023a, b).

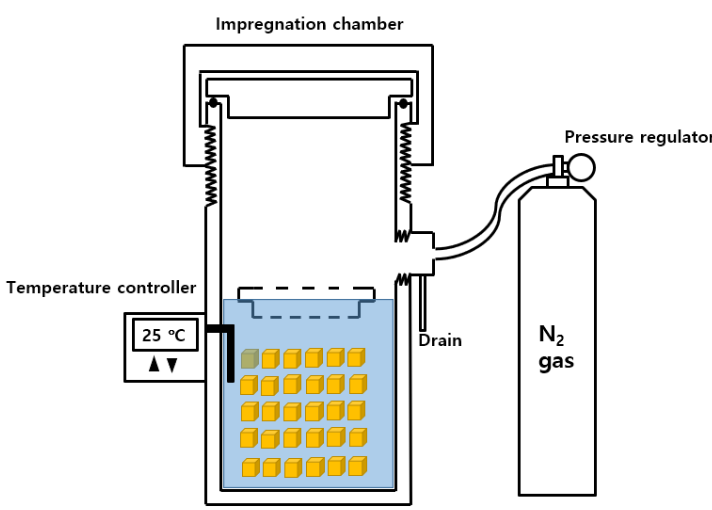


Fig. 2. Pressure impregnation chamber (Jang and Kang 2023a, b)

Decay Resistance Test

The wood decay test was performed according to the KS F 2213 (2018) standard. A 12-week decay resistance test was conducted after placing six cubic specimens each into a culture bottle containing *Fomitopsis palustris* and *Trametes versicolor*. After 12 weeks, the mycelium was removed from the specimen. Samples before and after culture were dried in a laboratory oven at 60 °C for 48 h, and the mass loss rate (%) was calculated as follows,

$$\text{Mass loss rate (\%)} = \frac{m_1 - m_2}{m_1} \times 100 \tag{1}$$

where m_1 is the mass of the specimen before decay and m_2 is the mass of the specimen after decay.

RESULTS AND DISCUSSION

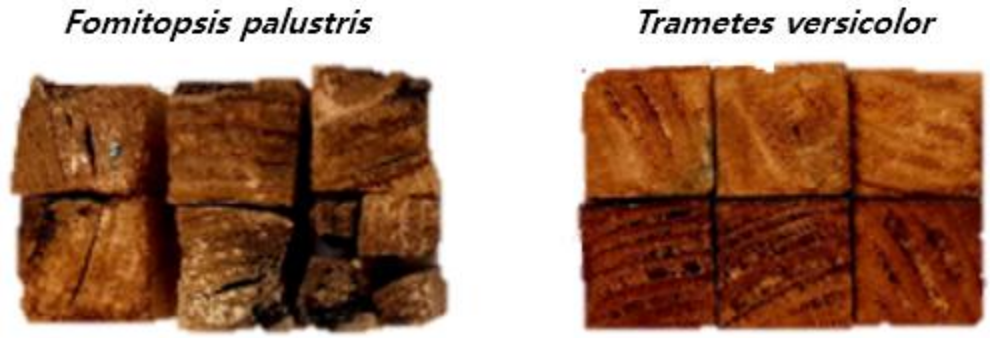
Visual Inspection

Figure 3 shows the natural decay resistance tested samples according to KS F2213 (2018) to confirm the anti-rot effect of GBL extract applied to Korean white pine. In the untreated sample, decay progressed significantly with both strains. Compared with *Trametes versicolor*, the degree of decay of *Fomitopsis palustris* was more severe. ACQ-2-treated samples exhibited significantly less macroscopic decay than their untreated counterparts. However, the samples treated with ACQ-2 took on a dark blue color characteristic of ACQ-2. The GBL extract-treated samples exhibited significantly less decay than the untreated samples. Also, compared to ACQ-2, there was no significant difference visually. In addition, samples treated with GBL extract retained the natural color of the wood.

Decay Properties

Figure 4 provides the Korean white pine's mass loss (%), depending on preservative treatment. The mass loss and standard deviation of untreated samples after *Fomitopsis palustris* culture were 34.08 ± 10.53%, and those after *Trametes versicolor* culture were 17.05 ± 7.49%. This showed degradation performance similar to that estimated by visual inspection. On the other hand, samples treated with ACQ-2 preservative had mass loss values of 9.52 ± 3.42% for *Fomitopsis palustris* and 0.33 ± 0.34% for *Trametes versicolor*. Finally, the mass loss of the GBL-preserved samples was 13.58 + 1.48% for *Fomitopsis palustris* and 9.93 ± 0.76% for *Trametes versicolor*.

Son *et al*. (2010) reported weight loss values ranging from 7% to 10% when assessing the wood decay caused by exposing hot water treated (70-90 °C) cedar to *Fomitopsis palustris* and *Trametes versicolor* for a duration of 12 weeks. Kim *et al*. (2010) reported weight loss of 16% and 13%, respectively, after exposing yellow poplar (*Liriodendron tulipifera L.*) heat-treated at 200 °C for 12 hours to *Trametes versicolor* and *Tyromyces palustris* for 6 weeks. In comparison with previous studies on non-toxic wood preservative treatments, the wood preservation performance of GBL extracts was found to be comparable to them.



(a) untreated

(b) ACQ-2 treated

(c) GBL extract treated

Fig. 3. The natural decay resistance tested samples according to KS F2213

According to KS F 2213 (2018), wood decay resistance is divided into 4 grades according to the average mass loss. An average mass loss of 0 to 10% is “highly resistant,” 11 to 24% is “resistant,” 24 to 44% is “moderately resistant,” and 45% or more is “slightly resistant or nonresistant.” Specimens treated with ACQ-2 were rated “highly resistant.” Although the decay performance of the GBL-treated specimens was lower than that of commercial preservatives, it preserved the original color of the wood. The “resistant” grade of the GBL-treated specimens signified the value of this less-toxic treatment for preservation of wood.

This study was a brief evaluation of the effect of GBL extract on wood decay. Further improvement of wood decay performance can be achieved by adding various agents or oils to these extracts. From previous studies, it is known that ginkgo biloba extract contains antibacterial substances such as flavonoids, alkaloids, saponins, tannins, and polyprenol (Ubaoji *et al*. 2020). The study found that these chemicals could also be effective in wood decay.

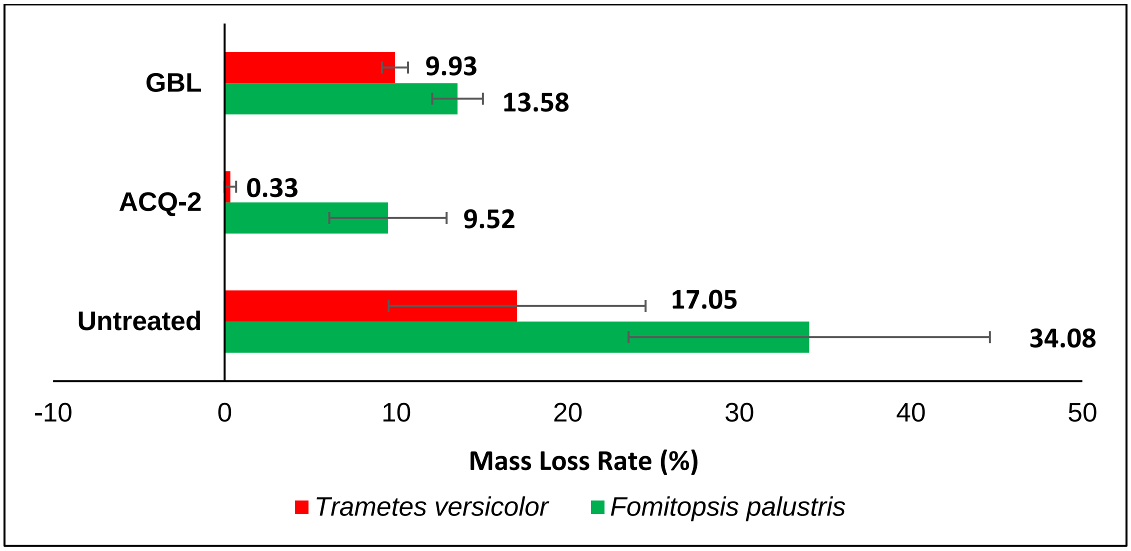


Fig. 4. Natural decay resistance tested samples according to KS F2213

In addition, future studies could help determine which components of GBL extracts are the most valuable as wood preservatives and which concentrations are the most effective. In conclusion, this study proposes GBL extract as a candidate material for sustainable eco-friendly wood preservatives. In future studies, better preservation performance can be expected if various additives or oils with antibacterial function are added to GBL.

CONCLUSIONS

1. The *Ginkgo biloba* leaf (GBL) extract resulted in mass loss rates of 13.6 and 9.9%, respectively, after culturing with *Fomitopsis palustris* and *Trametes versicolor*. By contrast, the corresponding mass loss in the absence of treatment was 17.0 and 34.1%, respectively.
2. Although GBL did not reach the performance of ACQ-2, a commercial preservative, it was graded "resistant" according to KS F 2213 (2018), signifying a significant wood preservation effect. Also, GBL had the advantage of not changing the natural color of the wood.

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Author Contributions

Conceptualization: ESJ, Methodology: ESJ, Formal analysis: ESJ, Writing - original draft: ESJ, Writing - review & editing: ESJ, CWK, Correspondence: CWK, Supervision: CWK. All authors read and approved the final manuscript.

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