Acoustic and Thermal Properties of Mycelium-based Insulation Materials Produced from Desilicated Wheat Straw - Part B

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The acoustic and thermal properties were determined for biodegradable insulation materials produced from desilicated wheat straws with two different fungi and three different incubation periods. *Ganoderma lucidum* (GL) and *Pleurotus ostreatus* (PO) fungi and wheat straw were exposed to fungal incubation for 10, 20, and 30 days to produce mycelium-based insulation materials. The sound absorption coefficients of mycelium-based insulation boards produced using PO fungus were higher than those produced with GL fungus. It was found that the acoustic absorption coefficients of insulation boards produced using PO fungus at 1,000 Hz were 87 to 99% according to the incubation periods. The sound transmission losses of mycelium-based insulation boards produced ranged from 46.4 to 59.7 dBa at 1000 Hz. The group of boards labeled as YP2 exhibited the lowest level of sound transmission loss, whereas GL2 revealed the highest degree of sound transmission loss at 1000 Hz. The lowest thermal conductivity coefficient was obtained in insulation boards produced with PO fungus and an incubation period of 20 days. The limiting oxygen index (LOI) value of mycelium-based insulation materials was considerably higher than the insulation boards commonly used today. Thermogravimetric analysis and derivative thermogravimetry curves of mycelium-based insulation materials were also determined.

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INTRODUCTION

The rapid growth of the global population has led to an increase in agricultural production, which has resulted in an increase in food demand. This consequently causes an increase in the generation of agricultural by-products and wastes including sugarcane bagasse, rice husks, cotton stalks, straw, and wood chips (Bhuvaneshwari *et al*. 2019). The vegetative growth of filamentous fungi (mycelia) has garnered interest from academic and commercial circles over the last decade as a new form of material for low-energy bio-fabrication and waste recycling (Jones *et al*. 2017; Nawawi *et al*. 2019). Mycelia bind organic matter through a network of hypha microfilaments in a natural biological process (Bhuvaneshwari *et al*. 2019). These can be used to produce higher-value composite materials from both low-value materials such as packaging and agricultural products and industrial byproducts that are problematic and have minimal or no commercial value (Pelletier *et al*. 2013; Jones *et al*. 2017; Islam *et al*. 2017; Haneef *et al*. 2017). The binding components of these mycelia interface with a dispersed agricultural waste phase (substrate filler) act as a load transfer medium between the typically fibrous agricultural waste within the composite materials, similar to the matrix phase of a polymer composite (Pelletier *et al*. 2013; Thakur and Siṅgha 2013).

Mycelium-based materials have several major advantages when compared with conventional synthetic materials, including reduced cost, density, energy consumption, biodegradability, and low environmental impact and carbon footprint (Arifin and Yusuf 2013; Islam *et al*. 2017; Abhijith *et al*. 2018). A wide range of available substrates combined with controlled processing techniques (*e.g.*, growth media and hot pressing) can enable mycelium-based materials to meet specific structural and functional requirements, including fire resistance and thermal and acoustic insulation (Pelletier *et al*. 2013; Haneef *et al*. 2017; Jones *et al*. 2017). Mycelium-based materials provide waste-derived environmentally friendly alternatives to synthetic-based materials (*e.g.*, plastic films and sheets) (Haneef *et al*. 2017) and larger-sized low-density products (*e.g.*, synthetic foams and plastics) (Holt *et al*. 2012; Pelletier *et al*. 2013; Travaglini *et al*. 2013; López Nava *et al*. 2016). Furthermore, mycelium-based materials are environmentally sustainable products (*e.g.*, panels, flooring, upholstery, furniture, decking) that can be used as semi-structural materials (Islam *et al*. 2017; Jiang *et al.* 2017). Owing to these features, mycelium-based materials can be used as renewable and environmentally friendly products in construction.

The low thermal conductivities are associated with better insulation characteristics and are primarily influenced by material density and to a lesser extent by moisture content (Uysal *et al*. 2004; Jerman *et al*. 2013; Collet and Pretot 2014). For example, a 67% increase in density has been reported to cause a 54% increase in thermal conductivity in hemp concretes (a biocomposite material containing hemp bark and lime), whereas a 90% increase in relative humidity (from 0 to 90%) causes only a 15 to 20% increase in thermal conductivity (Collet and Pretot 2014). The strong correlation between material density and thermal conductivity has been reported to result from the presence of large amounts of dry air in the interiors of low-density material, which has a very low thermal conductivity (26.2 $\times 10^{-3}$ W/m K at a pressure of 0.1 MPa and temperature of 300 K) (Kadoya *et al*. 1985). The large amounts of non-moving air indicate that low-density materials are typically excellent heat insulators.

Mycelium-based insulation boards containing high-performance natural insulators including straw and hemp fibers have been reported to have low density (57 to 99 kg/m^3) and thermal conductivity values (0.04 to 0.08 W/m K) (Jones *et al*. 2020). These materials have been reported as excellent insulation materials that can compete with other traditional commercial thermal insulation products such as glass wool (57 kg/m^3, 0.04 W/m·K), extruded polystyrene insulation material (XPS, 34 kg/m^3; 0.03 W/m·K) (Papadopoulos 2005), sheep wool (18 kg/m^3, 0.05 W/m·K), and kenaf (105 kg/m^3, 0.04 W/m·K) (Asdrubali *et al*. 2015), as well as other natural insulation materials.

Acoustic materials are typically fibrous and porous or are reactive resonators. Examples include nonwoven fabrics, fibrous glass, mineral wools, felt and foams (Seddeq 2009; Bell and Bell 2017). Sound absorbers convert the mechanical motion of air molecules moving in sound waves into low-grade heat that prevents sound accumulation in enclosed spaces and reduces the power of reflected noise (Bell and Bell 2017). All tested mycelium-based composites were reported to have lower perceived road noise (45.5 to 60 dBa) than conventional acoustic materials including commercial ceiling tiles (61 dBa), urethane foam board (64 dBa), and plywood (65 dBa) (Pelletier *et al*. 2019). The best individual lignocellulosic materials used in the production of mycelium-based insulation boards for acoustic absorption were rice straw (52 dBa), hemp extract (53 dBa), flax stalk (53.5 dBa), sorghum fiber (54 dBa), and turnip (55 dBa) (Pelletier *et al*. 2019). However, even better acoustic absorption was achieved with mixtures of materials (50% and 50% by weight), with the best combinations being rice straw-sorghum fiber (45.5 dBa), rice straw-cotton milling fiber (47 dBa), and sorghum fiber-switchgrass (47 dBa) (Pelletier *et al*. 2019).

Mycelia themselves are excellent sound absorbers, exhibiting strong natural low-frequency absorption (< 1500 Hz) and outperforming cork and commercial ceiling tiles in reducing road noise (Pelletier *et al*. 2019).

Many researchers have produced mycelium-based insulation boards using different lignocellulosic materials, including wheat straw and different fungi, and investigated their acoustic and thermal properties (Jones *et al*. 2017; Pelletier *et al*. 2013; Haneef *et al*. 2017; Pelletier *et al*. 2019; Jones *et al*. 2020). However, although silica is known to limit fungal mycelium growth (Jones *et al*. 2020), no known study has attempted to elucidate how it affects the acoustic and thermal properties of mycelium-based insulation boards, especially those produced from raw materials known to have high silica content, such as wheat straw. Therefore, mycelium-based insulation boards were produced from desilicated wheat straw and their acoustic and thermal properties were investigated.

The aim of this study was to produce biodegradable mycelium-based insulation materials using desilicated wheat straw incubated with two different fungi for 10, 20, and 30 days and to determine the acoustic and thermal properties of the produced mycelium-based insulation boards. The effects of incubation time and fungal species on the acoustic and thermal properties of the biodegradable materials produced were determined and the most suitable fungi species and incubation time were determined for each variation on the basis of the findings obtained.

EXPERIMENTAL

Materials

The materials used in this present study were given in another study conducted by the authors (Kuştaş and Gezer 2024).

Method

Production of mycelium-based insulation materials

The production process and parameters of mycelium-based insulation boards were described in another study conducted by the authors (Kuştaş and Gezer 2024).

Determination of technological properties of mycelium-based insulation material

The determination of sound absorption coefficient (α) and sound transmission loss (TL) was conducted in accordance with the TS EN ISO 10534–2 (2003) standard, with certain adjustments implemented using an impedance tube instrument. Before the measurements, the speaker was operated for 10 min to stabilize the temperature. The environment where the experiment was to be conducted was measured to be 23 °C, 58 to 60% relative humidity, and 100 kPa of pressure. For the tests, each group of samples with a diameter of 30 mm and 100 mm was prepared. After the connection between the signal generator and the impedance tube was established, a signal was created at the center frequency of each 1/3 octave band in the frequency range of 100 to 6300 Hz, and the results were obtained through the appropriate software. A total of 3 test samples were utilized for each test, ensuring replication.

The limiting oxygen index (LOI) of each group of insulating boards was measured using samples with dimensions of 150 mm × 35 mm × 10 mm, following the guidelines outlined in ASTM D 2863 (2000). LOI values were obtained using the Dynisco LOI analyzer instrument (Franklin, USA). A total of 5 replicate test samples were utilized for each test.

The values for the thermal conductivity coefficient were obtained in accordance with the ASTM C518 (2003) standard, with certain adjustments made during the testing process using a Laser Comp Fox 314 machine. The Laser Comp Fox 314 device upper plate (cold plate) temperature was set to 20 °C and the lower plate (hot plate) temperature was set to 40 °C. The thermal conductivity coefficient experiments were conducted on square specimens with dimensions of 300 mm × 300 mm × 40 (mm). For each test, three replicate test samples were used.

Thermogravimetric (TGA) and derivative thermogravimetric (DTG) analyses were performed using a PerkinElmer STA 6000 Thermogravimetric Analyzer. The device was set to 900 °C with increments of 10 °C per min from room temperature. Mycelium-based insulation boards samples were ground to a size of 1 mm in a laboratory-style IKA mill for analysis, and they were then dried to a constant weight in an oven at a temperature of 103 ± 2 °C. The weight change of the samples over time was measured by heating them at a constant rate in a nitrogen gas environment. The Origin 2021b (OriginLab Corporation) program was used to create TGA/DTG graphics. For these tests and analyses, three replicate samples were used for each variation.

RESULTS AND DISCUSSION

Investigation of Thermal and Combustion Properties of Mycelium-Based Insulation Boards

Limiting oxygen index test results of mycelium-based insulation boards

Limiting oxygen index (LOI) values of mycelium-based insulation boards are given in Fig. 1. Mycelium-based insulation boards produced within the scope of the study had similar LOI values, regardless of the fungi species used and the incubation durations. YP3 mycelium-based insulation boards produced from wheat straw inoculated with PO fungus and incubated for 30 days had the highest LOI values. YP1 mycelium-based insulation boards produced with wheat straw inoculated with PO fungus and incubated for 10 days had the lowest LOI values.

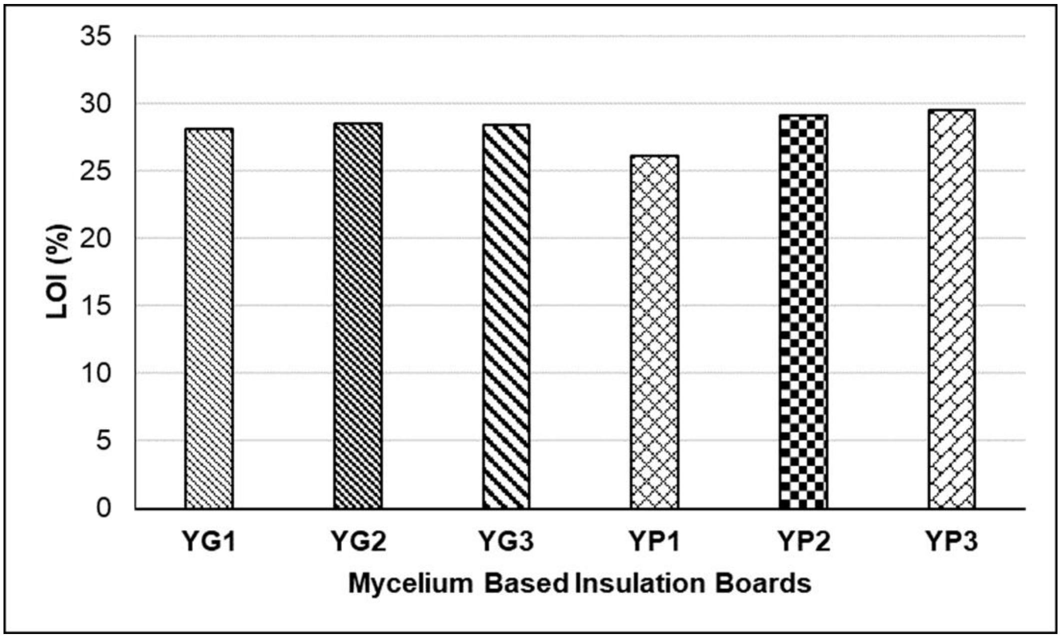

Fig. 1. Limiting oxygen index (LOI) values of mycelium-based insulation boards

Thermogravimetric and derivative thermogravimetric analyses results of mycelium-based insulation boards

The TGA and DTG curves of the mycelium-based insulation board groups are presented in Figs. 2 and 3, respectively. In Fig. 2, thermal degradation began at a lower temperature in mycelium-based boards produced from wheat straw treated with fungus than in default samples. As the incubation time increased, the temperature at which degradation occurred decreased. *Ganoderma lucidum* fungal inoculation resulted in lower thermal degradation temperatures compared with PO fungal inoculation. In the second thermal degradation stage, the percentages of weight loss decreased as the fungal incubation time increased. Weight loss was higher in mycelium-based insulation materials produced with GL fungus than those produced with PO fungus.

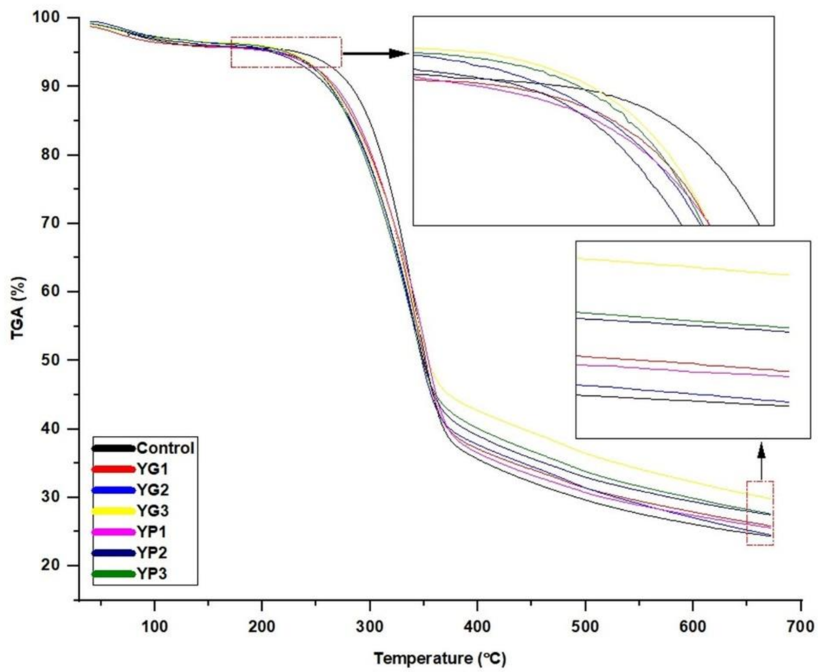

Fig. 2. TGA curves for mycelium-based insulation boards

The increase in residual mass of mycelium-based insulation board groups after the thermal degradation process was completed was proportional to the increase in the incubation time.

The DTG curves in Fig. 4 revealed that mycelium-based insulation boards exposed to fungal incubation had shortened peak lengths (indicating a slowing down in weight loss rates) during thermal degradation compared to wheat straw default samples. The lowest weight loss was observed in YG3 samples, and the highest weight loss was observed in YG1 samples.

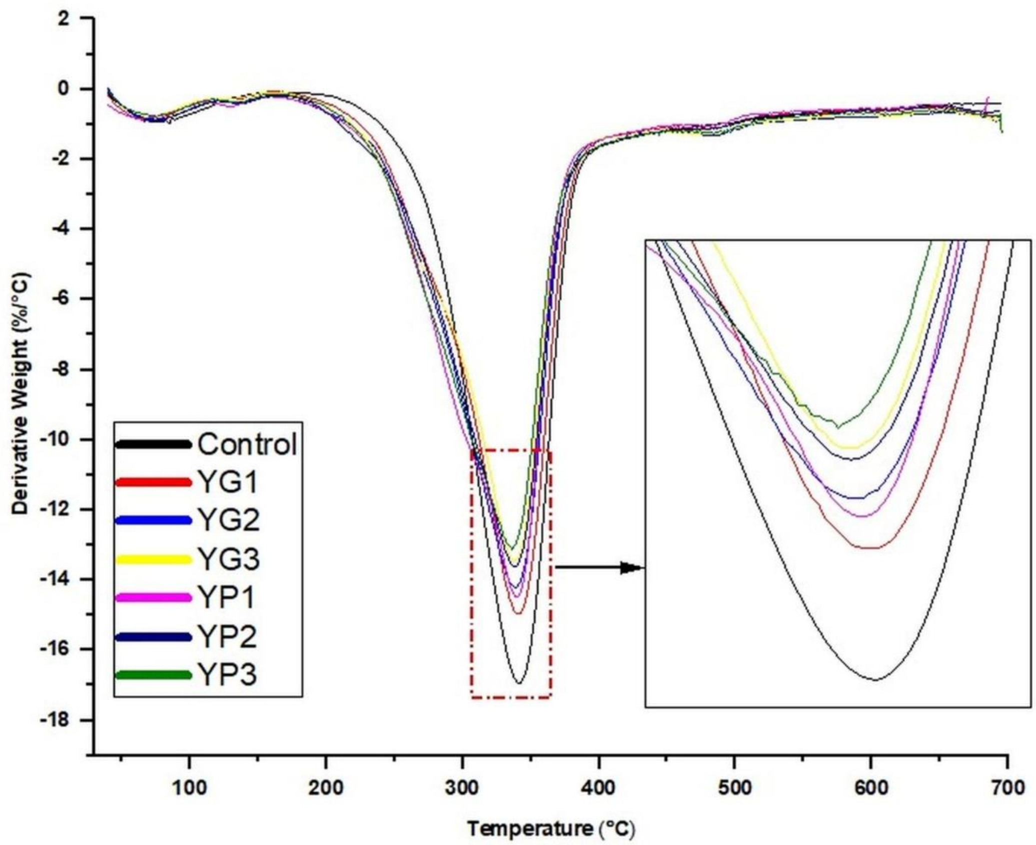

Fig. 3. Derivative thermogravimetric (DTG) curves for mycelium-based insulation boards

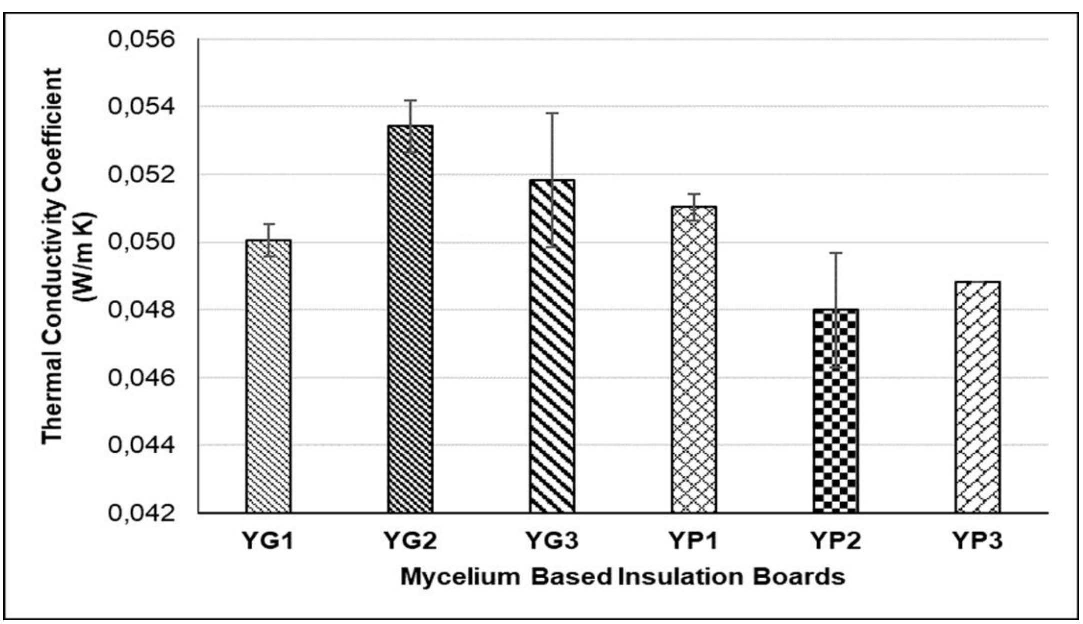

Fig. 4. Thermal conductivity coefficients of mycelium-based insulation boards

Investigation of thermal conductivity coefficient of mycelium-based insulation boards

Data obtained for the thermal conductivity coefficient values of mycelium-based insulation boards are presented in Fig. 4. The thermal conductivity coefficients of mycelium-based insulation boards produced within the scope of the study were remarkably similar regardless of the fungal species used and the incubation time.

The thermal conductivity coefficients of mycelium-based insulation boards produced in this study ranged from 0.048 to 0.0534 W/m K.

Although the thermal conductivity coefficients of mycelium-based insulation boards were very similar regardless of fungi species and incubation duration, the thermal conductivity coefficients of the boards produced with GL fungus were higher than that of PO fungus.

Investigation of sound transmission loss and sound absorption coefficients

The sound transmission loss and sound absorption coefficients of mycelium-based insulation boards produced within the scope of the present study are shown in Figs. 5 and 6. The sound transmission losses of mycelium-based insulation boards produced ranged from 46.40 to 59.69 dBa at 1000 Hz. The group of boards labeled as YP2 exhibited the lowest level of sound transmission loss, whereas GL2 revealed the highest degree of sound transmission loss at 1000 Hz. A 20-day incubation time was optimal for the PO fungus, while a 10-day incubation period was optimal for the GL fungus in terms of sound transmission loss. In addition, the mycelium-based insulation boards produced with PO fungus were found to be superior to those produced with GL fungus.

The acoustic absorption percentages of mycelium-based insulation boards produced using PO fungus at 1000 Hz varied between 87 and 99% depending on the incubation periods. In contrast, acoustic absorption percentages of mycelium-based insulation boards produced with GL fungus at 1000 Hz ranged between 37 and 53%, depending on the incubation periods.

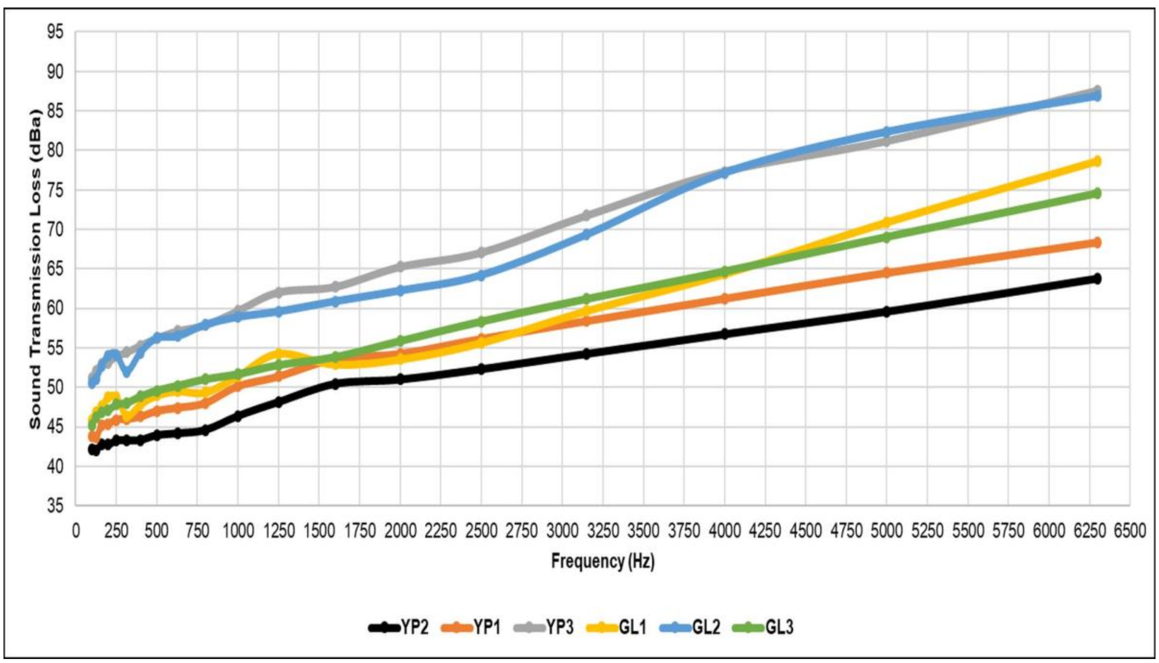

Fig. 5. Sound transmission loss values of mycelium-based insulation boards (dBa)

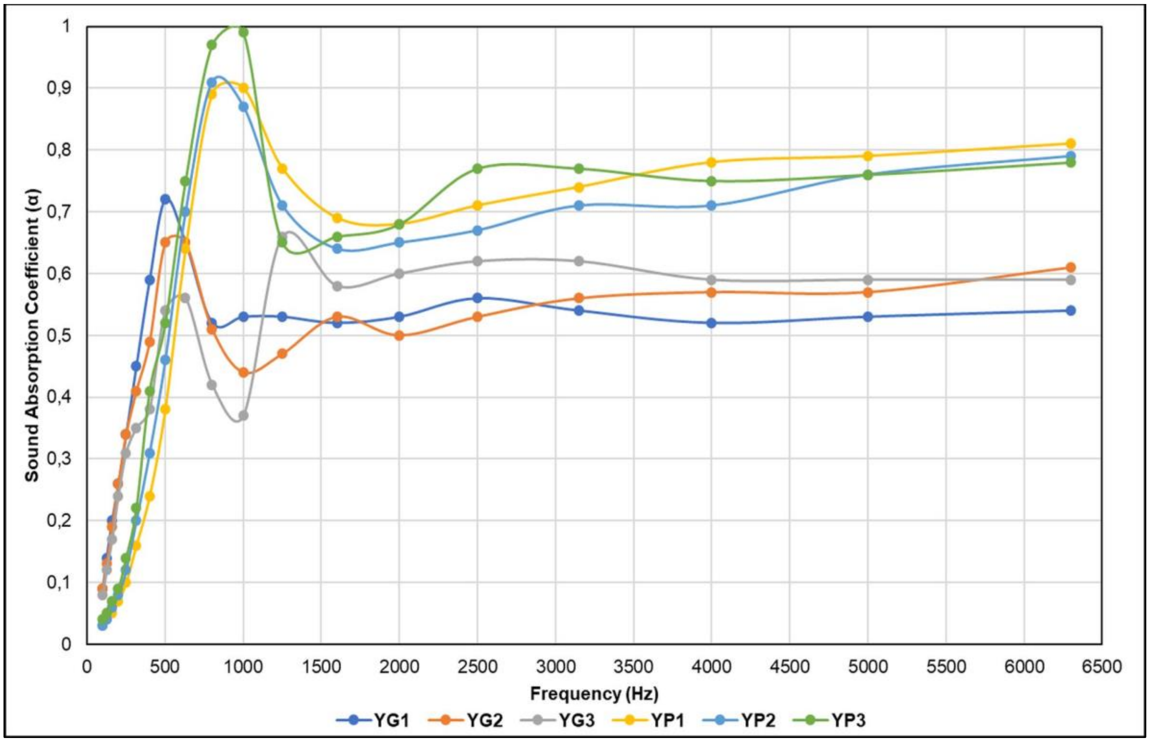

Fig. 6. Sound absorption coefficients of mycelium-based insulation boards

Discussion

Limiting oxygen index test results of mycelium-based insulation boards

The LOI values increased with increasing incubation time, albeit at a low rate. This was attributable to the further development of the mycelia/hyphae network of the fungi with prolonged incubation, resulting in an increase in the amount of oxygen required for the combustion of the boards. Most of the insulation boards used today are petroleum-based products, and their highly flammable nature poses a risk to buildings and inhabitants. For example, expanded polystyrene (EPS) has an LOI of < 13 and can continue to burn even at very low oxygen levels. In addition, mycelium-based insulation boards have several advantages. They are completely natural, do not contain any chemical substances, and are completely degradable. Thus, it is evident that mycelium-based insulation materials are considerably superior to the insulation boards commonly used today, with respect to being natural, degradable, fire resistant. Using different substrates, mycelium-based insulation boards can be produced for specific functions and purposes (*i.e.*, structural support, fire resistance, and acoustic insulation). For example, adding rice husks and thin glasses to the substrates was reported to significantly increase the fire resistance of mycelium biocomposite because large amounts of char and silica ash were released during combustion to tolerate the high temperature (Bansal *et al*. 2006; Jones *et al*. 2018a).

Thermogravimetric and derivative thermogravimetric analyses results of mycelium-based insulation boards

In the TGA curves, thermal degradation occurs due to the evaporation of free and chemically bound water in the first stage of degradation. The second stage of degradation most likely includes the thermal degradation of chitin (acetylated and non-acetylated chitin in the mycelium), amino acids, lipids, and polysaccharides. Reportedly, large molecular weight polymers begin to thermally decompose by breaking down into low molecular weight volatiles (Paulino *et al*. 2006; Jones *et al*. 2018a,b). Only a small amount of mass is reportedly lost in the samples due to the formation of CO, CO_2, and H_2O. This is attributable to the formation of charcoal in the last stage of thermal degradation (Iqbal *et al*. 2011). Thermal degradation of wheat straw occurs in the following sequence: moisture evaporation at 30 to 100 °C; decomposition of hemicellulose, cellulose, and lignin components at 200 to 450 °C; and lignin pyrolysis and charring of the residue at 450 to 700 °C (Lazdovica *et al*. 2017).

The mycelium-based boards showed thermal degradation at lower temperatures than the default samples. This is believed to occur owing to the presence of degraded lignin, hemicellulose, and cellulose.

Gou *et al.* produced bio-composite material by incubating a mixture of cotton stalk, wheat bran, and reinforced natural fibers for 28, 31, and 37 days using three different fungi *(PO*, *Oudemansiella radicata*, and *Acremonium* sp) (Gou *et al*. 2021). Thermogravimetric analysis results of the produced biocomposite materials showed that thermal degradation occurred at 150 to 500 °C, and the degradation rate was low. The authors stated that the reinforced natural fibers are rich in $CaCO_3$ (95.85%), and an endothermic reaction occurs at high temperatures, which may reduce the degradation rate of mycelium-based biocomposites (Gou *et al*. 2021).

Jones *et al.* produced mycelium-based composites using silica-rich rice husk and grass and *Trametes versicolor* fungus (Jones *et al*. 2018a). The high silica content in the produced mycelium-based biocomposite reportedly improved the thermal degradation properties, indicating that mycelium-based biocomposites rich in $CaCO_3$ or SiO_2 can improve resistance to thermal degradation.

Although mycelium-based biocomposite materials have low thermal degradation, the high residual mass at temperatures of > 400 °C was reported to provide an advantage as insulation material (Bansal *et al.* 2006; Jones *et al*. 2018b; Gou *et al*. 2021).

Investigation of thermal conductivity coefficient of mycelium-based insulation boards

The thermal conductivity coefficients of mycelium-based insulation materials reportedly depend on the density, moisture content, and lignocellulosic materials used in the insulation boards rather than the fungal species and incubation time (Uysal *et al*. 2004; Jerman *et al*. 2013; Collet and Pretot 2014). Although the density values of the mycelium-based insulation boards produced within the scope of the present study were quite similar, the boards with lower density with a higher void ratio had lower thermal conductivity coefficients.

Straw and hemp are widely recognized as natural thermal insulation materials, which owe their advantageous insulating characteristics to their permeable structure and low mass density of bundled fibers. These attributes facilitate the accumulation of significant quantities of air between the fibers inside the insulation material (Kymäläinen and Sjöberg 2008; Wall *et al.* 2012). The thermal insulation characteristics were found to mostly differ based on the density, amount of moisture, and type of fiber present in the board (Bainbridge 1986). In a previous study, the thermal conductivity coefficient of mycelium-based composites with a density of 94.4 kg/m^3 produced using *Trametes versicolor* fungus and wheat straw was determined as 0.04 W/m K (Elsacker *et al*. 2019). In another study, thermal conductivity coefficients of mycelium-based composites with a density of 51.1, 62.0, and 57.5 kg/m^3 respectively produced from wheat straw using *Oxyporus latermarginatus*, *Megasporoporia minor*, and *Ganoderma resinaceum* fungi were determined as 0.078, 0.079, and 0.081 W/m K, respectively (Xing *et al*. 2018). The thermal conductivity values (mean, 0.05 W/m K) of the insulation boards produced in this research were within the values obtained in these two different studies (Xing *et al*. 2018; Elsacker *et al*. 2019). The density of the mycelium-based insulation boards produced in this study ranged from 131 to 142 kg/m^3. As a result of the implementation of the desilication treatment on the wheat straw within this study, the thermal conductivity coefficients of the mycelium-based insulation boards manufactured were expected to exhibit higher values compared to the thermal conductivity coefficients observed in the mycelium-based insulation boards produced by Elsacer *et al.* (2019), who did not apply desilication treatment on wheat straw. Considering the density properties (higher than those boards produced by Elsacer *et al.*) of mycelium-based insulation boards produced from desilicated wheat straw in this study, the desilication process did not appear to have a dramatic negative effect on thermal conductivity properties. Although it is already known that mycelium alone does not possess notable fire-retardant characteristics, the incorporation of substrates or fillers abundant in natural phenolic polymers, such as lignin, and naturally occurring or artificially synthesized silica (SiO_2) in mycelium composites can result in considerably enhanced thermal degradation, fire reaction, and safety properties (Jones *et al*. 2018a, 2020). While the thermal conductivity coefficients of the boards derived from desilicated wheat straws in this research were determined to be higher than the thermal conductivity coefficients observed in the mycelium-based insulation boards produced by Elsacer *et al.*, it is important to acknowledge that this disparity can be attributed not only to the removal of silica but also to the higher density of the boards manufactured in this study compared to the study conducted by Elsacer *et al.* (2019). Mycelium-based composites produced using hemp fiber were reported to have significantly lower thermal conductivities (0.04 W/m K) (Elsacker *et al*. 2019) than hemp concrete (0.1 W/m K (Elsacer *et al.* 2019). The thermal conductivity coefficient values of the boards produced in this study were much lower than mycelium-based composites produced using lignocellulosic materials. These exhibit poorer thermal insulation properties including those containing cotton carpel (0.10 to 0.18 W/m K) (Holt *et al*. 2012), gypsum (0.17 W/m K), high-density particleboard (0.15 W/m K), plywood (0.12 W/m K), and both deciduous wood (0.16 W/m K) and coniferous wood (0.12 W/m K) (Bergman *et al*. 2011). This renders mycelium-based insulation materials as practical, affordable, and sustainable options to conventional building insulation materials.

The apparent density (fractional pore volume) and pore size distribution of mycelium boards are critical factors that influence their acoustic absorption properties. Mycelium boards with low apparent density often have higher porosity, meaning there are more open spaces or pores within the material. This characteristic is advantageous for sound absorption because it allows sound waves to penetrate the material and get trapped within the porous structure. A high porosity, associated with low apparent density, enables mycelium boards to absorb a greater amount of sound energy, especially in the mid to high-frequency range. Lower-density materials generally perform better in absorbing higher-frequency sounds. Having a diverse range of pore sizes is beneficial for absorbing a broad spectrum of frequencies. Different frequencies of sound waves interact with materials in distinct ways, and a diverse pore size distribution allows mycelium boards to effectively absorb sound across various frequency ranges. Larger pores are generally more effective in absorbing lower-frequency sounds. If mycelium boards have a distribution that includes larger pores, they can contribute to the absorption of bass frequencies. Smaller pores are effective in absorbing higher-frequency sounds. A well-distributed range of smaller pores in the mycelium board may enhance its performance in absorbing treble frequencies. Mycelium boards with an optimized combination of low apparent density and a diverse pore size distribution may provide broadband sound absorption. This is desirable in applications where a material needs to perform well across a wide range of frequencies. Depending on the intended use, mycelium boards can be engineered with specific pore size distributions to target absorption in particular frequency ranges. This is crucial in applications like acoustic panels in recording studios or concert halls, where different frequencies need to be controlled effectively. In conclusion, the apparent density and pore size distribution of mycelium boards are intricately linked to their acoustic absorption capabilities. Understanding and manipulating these factors allow for the customization of mycelium-based materials to meet specific acoustic requirements in diverse applications.

Investigation of sound transmission loss and sound absorption coefficients

The sound transmission losses of mycelium-based insulation boards ranged from 46.40 to 59.69 dBa, while their acoustic absorption efficiencies ranged from 37 to 99% at 1000 Hz. The mycelium-based insulated boards produced in this study with PO fungus showed better acoustic properties than those produced with GL fungus. The disparity in acoustic absorption between mycelium-based insulation boards manufactured with PO fungus and those manufactured with GL fungus can be attributed to the contrasting characteristics of the mycelia/hyphae and network structure of the GL fungus. Furthermore, it was observed that the boards manufactured using GL fungus exhibited increased rigidity/stiffness, leading to the propagation of sound to the opposite side and thereby yielding lower values of sound absorption coefficients.

Pelletier *et al*. (2019) tested the effects of different substrates used in the production of mycelium-based foam and reported that the acoustic absorption rate exceeded 70 to 75% at 1000 Hz even in the worst samples tested. The sound absorption rate was highest when the substrate consisted of 50% turnip and 50% sorghum. The results of this investigation indicated that the sound absorption coefficients of boards formed from desilicated wheat straws with PO fungus were higher compared to the boards produced by Pelletier *et al.* (2019). In contrast to the findings of Pelletier *et al*. (2019), the sound absorption coefficients of boards manufactured using desilicated wheat straws with GL fungus were significantly lower.

The mycelia themselves are recognized as outstanding acoustic absorbers, demonstrating significant inherent absorption capabilities in the low-frequency range (< 1500 Hz). They surpass cork derived from oak trees and commercial tiles for ceilings in their ability to attenuate road noise (Pelletier *et al*. 2019). The presence of this distinctive characteristic implies that mycelium-based foam or insulation boards have the potential to enhance low-frequency absorption capabilities when utilized in conjunction with other materials. In addition, a mycelium-based composite consisting of residue from agriculture bound to mycelia can provide a wider range of acoustic absorption with 70 to 75% absorption or improved accessibility for perceived road noise (Pelletier *et al*. 2013).

The permeable, fibrous character of mycelium-based composites is responsible for their superior acoustic absorption properties. The airflow resistance of a material has a significant impact on the impedance and propagation constants used to describe a material's acoustic properties and higher airflow resistance has been linked to increased acoustic absorption (Ren and Jacobsen 1993). In mycelium-based composites, the fibers act as friction elements that resist acoustic wave motion and reduce their amplitude as sound waves attempt to pass through the material's curved passages, being converted into heat in the process (Ren and Jacobsen 1993). Fine fibers provide better acoustic absorption because they can move more easily, and a larger number of fibers per unit volume results in more tortuous paths and greater airflow resistance (Sun *et al*. 1993; Koizumi *et al*. 2002). Surface pore concentration and geometry are also important, with porosity required for sound waves to enter the material and tortuosity required for efficient damping (Seddeq 2009). Porosity and airflow resistance affect the height and width of sound wave peaks, while tortuosity affects the high-frequency acoustic properties of porous materials (Seddeq 2009). Less dense, more open structures absorb low-frequency sound in nonwoven fibrous materials (500 Hz), while denser structures are reported to be better for frequencies higher than 2000 Hz (Sun *et al*. 1993).

CONCLUSIONS

1. The thermal conductivity coefficients of the mycelium-based insulation boards ranged between 0.0480 and 0.0534 W/m K. The lowest thermal conductivity coefficient was observed in YP2 samples produced with PO fungus and incubated for 20 days. It was found that the desilication process did not have a dramatic negative effect on thermal conductivity properties.
2. Limiting oxygen index values of mycelium-based insulation boards produced from desilicated wheat straw using two different fungal species and three different incubation periods were higher than 21. The highest LOI value was found in YP3 samples inoculated with PO fungus and incubated for 30 days, whereas the lowest LOI value was observed in YP1 samples inoculated with PO fungus and incubated for 10 days.
3. The thermal degradation of mycelium-based insulation boards produced using two different fungi species and three different incubation periods started at lower temperatures compared with wheat straw default samples. This was attributable to the desilication process and fungal degradation.
4. The weight loss rates of mycelium-based insulation boards during the thermal degradation phase decreased with the increase in the incubation period extended. The highest weight loss rate was observed in YG1 samples inoculated with GL fungus and incubated for 10 days, and the lowest weight loss rate was noted in YG3 samples inoculated with GL fungus and incubated for 30 days.
5. The residual mass after the thermal degradation process increased with the increase in the incubation period. The highest residual mass was observed in YG3 samples inoculated with GL fungus and incubated for 30 days and the lowest residual mass was observed in YG2 samples inoculated with GL fungus and incubated for 20 days.

6. Sound transmission loss and sound absorption coefficients of mycelium-based insulation boards produced within the scope of the study were determined. The desilication of wheat straw enhanced the acoustic properties of mycelium-based insulation boards manufactured with PO fungus.

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