Investigation of Sound Absorption Ability of *Acanthopanax senticosus* Wastes

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ABSTRACT

This study aims to investigate the sound absorption ability of *Acanthopanax senticosus* wastes as an eco-friendly sound-absorbing material. The sound absorption coefficient was examined with different heights of *A. senticosus* wastes filling (40, 60, 80, and 100 mm) in impedance tubes. The sound absorption peaks shifted to a lower frequency as the height of *A. senticosus* wastes inside the tubes increased. The sound absorption ability at filling heights of 80 and 100 mm was obtained as 0.3M and 0.5M grades, respectively, based on KS F 3503. The results suggest that *A. senticosus* wastes exhibit good sound absorption ability and can therefore be used as an efficient, eco-friendly sound-absorbing material.

**Keywords:** *Acanthopanax senticosus*, eco-friendly sound-absorbing material, sound absorption peak, sound absorption performance

1. INTRODUCTION

Forests are excellent carbon sinks. Trees store carbon as they grow, and harvesting trees for wood products can contribute to reduce greenhouse gas emissions (Ahn et al., 2021; Galih et al., 2020; Yang et al., 2020). Because the most widely used building materials, such as steel and concrete, store very little carbon, whereas wood can store half its weight as carbon dioxide (Churkina et al., 2020). Also, carbon dioxide emissions from wood can be postponed until after it has completely decomposed (Kim et al., 2019).

Wood is the most widely used material for the preparation of structures, floors, and interiors of a building. In addition, wood is one of the most eco-friendly materials in various application areas such as furniture, sports equipment, musical instruments, art, and pulp (Ahn et al., 2021; Fortin-Smith et al., 2019; Ghani and Lee, 2021; Han et al., 2021; Jamaludin et al., 2020; Kim and Kim, 2020; Lee et al., 2021a, 2021b; Sedliačiková et al., 2021; Yoo et al., 2021).

Not only that, extracts of some tree species are used as herbal medicine. Especially, the extracts of the species such as *Kalopanax pictus*, *Praunus sargentii*, *Cudrania tricuspidata*, *Aralia eleta* Seemann, and *Acanthopanax senticosus* are widely used as herbal medicines and food products in Korea (Hong and Hong, 2015; Jia et al., 2021; Kang, 2018; Lee et al., 2001). The present study focuses on *A. senticosus*. *A. senticosus* which has been classified as an adaptogen (anti-
stress natural substance that improves adaptability to various stresses) herbal medicine candidate by the European Medicines Agency (Lee, 2020). In addition, Korean (red) ginseng, *Rhodiola sachalinensis*, and *Schizandra chinensis* are few other adaptogen herbal medicine candidates; however, only *A. senticosus* is material from wood (Lee, 2020). Thus, *A. senticosus* is widely used in herbal medicine or a functional food in Korea. About 21.7 hectares of *A. senticosus* are cultivated in Gangwon-do. Recently, the cultivated area has been increasing in Jeollabuk-do, and Chungcheongnam-do (GNARES, 2020).

The extracts of *A. senticosus* have been widely used. However, their by-products have been rarely studied for any applications. The by-products of *A. senticosus* store carbon dioxide even after the extraction of their active ingredients. Therefore, in this study, the recycling method of *A. senticosus* wastes was reviewed in terms of using wood by-products that contribute to carbon neutrality.

Wood and forest-by products have been suggested as a natural sound-absorbing materials (Iswanto *et al.*, 2020; Jang, 2022a, 2022b, 2022d; Jung *et al.*, 2020; Jung *et al.*, 2021). Previous studies have reported that the pore structure of wood has a sound-absorbing effect (Jang and Kang, 2021a, 2021d, 2021e; Jiang *et al.*, 2004; Taghiyari *et al.*, 2014). When wood is subjected to heat treatment such as high-temperature oven-drying, microwave, or steam explosion, the pores are converted into an open-pore structure, and the sound absorption performance can be further improved (Jang and Kang, 2021b; Jang and Kang, 2022; Kang *et al.*, 2021). *A. senticosus* is boiled at a high temperature for a long time to obtain the extract for herbal medicine. The porosity of *A. senticosus* increases after the removal of the extract; accordingly, the sound-absorption performance improves (Jia *et al.*, 2021).

This study expected that the porous structure of *A. senticosus* and the gap between *A. senticosus* could produce a sound absorption effect. The primary purpose of this study was to investigate whether *A. senticosus* wastes from which valuable components have been removed can be utilized as a natural porous sound-absorbing material. Furthermore, this study intends to increase the application value of *A. senticosus* wastes.

2. MATERIALS and METHODS

2.1. Sample preparation

Fig. 1 shows a schematic of the preparation of the one-year-old *A. senticosus* samples used in this study. The samples were supplied by a Korean herbal medicine shop (Jecheon, Korea). Their diameter and length were approximately 5–10 mm and 50–60 mm, respectively. The samples were boiled at 100°C for 2 h and then cut.
into 10–15 mm lengths followed by drying in an oven at 90°C for three days.

The shorter lengths of the *A. senticosus* wastes enhance the exposed cross-sectional area and number of open pores to the incident sound wave. The samples were then stored in a laboratory at a temperature of 20°C and a humidity of 50% for approximately two weeks. Then, 100 g of wastes was dried at 105°C for approximately seven days to measure the moisture content (MC) in the samples (Korean Standards Association, 2016). The final weight of the dried wastes was measured as 91 g, which indicates that the MC was approximately 9%.

### 2.2. Scanning electron microscopy (SEM)

The pore structure of the *A. senticosus* wastes was observed by SEM (Genesis-1000, Emcraft, Gwangju, Korea). Prior to SEM imaging, the samples were dried in a laboratory oven at 50°C for approximately 2 h to remove the surface moisture. Then, a thin layer of gold was deposited on the samples to prevent the surface charging during SEM imaging. Then, the cross-sections and thorn surfaces of the wastes samples were observed at magnifications of 200 × and 500 ×.

### 2.3. Sound absorption coefficient

The sound absorption coefficients of *A. senticosus* wastes were evaluated using an impedance tube (type 4206, Brüel & Kjær, Nærum, Denmark) designed in accordance with the ISO 10534-2 (International Organization for Standardization, 2001) same as the author’s previous studies (Jang, 2022b, 2022c, 2022d). *A. senticosus* wastes were filled to a height of 40, 60, 80, and 100 mm in two different impedance tubes with diame-

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**Fig. 2.** Schematic of the experimental setup for sound absorption coefficient measurement using impedance tubes of 29 mm and 99 mm diameter.
ters of 29 and 99 mm (Fig. 2). The absorption coefficient was measured in the frequency ranges of 500–
6,400 Hz and 100–1,600 Hz for the small diameter (29 mm) and large diameter (99 mm) impedance tubes, respectively.

The sound absorption coefficient of a material varies with different frequencies. In the industrial setting, the sound absorption ability of a material is evaluated as a single-number index using noise reduction coefficient (NRC). In this study, NRC was computed using the following Equation (1).

$$\text{NRC} = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4}$$

where, $\alpha_{250}$, $\alpha_{500}$, $\alpha_{1000}$, and $\alpha_{2000}$ are the sound absorption coefficients at 250 Hz, 500 Hz, 1,000 Hz, and 2,000 Hz, respectively.

Originally, NRC should be calculated using the reverberation chamber method (Korean Standards Association, 2012). However, many researchers also apply NRC to the sound absorption coefficient through the impedance tube (Gokulkumar et al., 2019; Jang and Kang, 2021b; Voronina and Horoshenkov, 2004). Accordingly, this study calculated NRC as the sound absorption coefficient value from the impedance tube.

The values of the sound absorption coefficients at 250, 500, and 1,000 Hz were collected from the 99 mm diameter impedance tube, and those at 2,000 Hz were collected from the small-diameter impedance tube (Jang, 2022b, 2022c, 2022d).

3. RESULTS and DISCUSSION

3.1. Scanning electron microscopy (SEM) analysis

Fig. 3 shows SEM images of the cross-section and

![Fig. 3. SEM images of Acanthopanax senticosus cross-section and thorn. (a) Sapwood and pith (200 ×), (b) sapwood (500 ×), (c) pith (500 ×), (d) the tip of thorn (500 ×), (e) the middle of thorn (500 ×), (f) the thorn attached to the bark (500 ×). SEM: scanning electron microscopy.](image)
thorn surface of the *A. senticosus* wastes. Fig. 3(a) shows the sapwood and pith together. The SEM images indicated that the cross-section of *A. senticosus* was significantly different from that of the sapwood and pith. The distribution of vessels in the sapwood [Fig. 3(b)] indicates the characteristics of ring-porous wood, and vessel clusters are abundant. This structure is advantageous for absorbing sound (Jang and Kang, 2021e). Fig. 3(c) shows a pith. The core has more large cells and less developed through-pores compared with the sapwood. The surfaces of the pith are found to be rough.

Fig. 3(d–f) shows the surface of the thorn of *A. senticosus*. Fig. 3(d) and (e) show the tip and the middle part, respectively. The thorn surfaces were found to be smooth. Fig. 3(e) shows a thorn connected to the bark of *A. senticosus*, showing a rougher texture than that of the middle and tip. The rough surfaces of the material can contribute to improved sound absorption at low frequencies (Chung et al., 2017).

### 3.2. Sound absorption ability

The sound absorption coefficient curves are shown in Fig. 4. When the filling height of the *A. senticosus* wastes inside the impedance tube was 40 mm, the maximum sound absorption coefficient was 0.387 at 1,540 Hz; when the filling height was increased to 100 mm, the maximum sound absorption coefficient increased to 0.535 at 714 Hz [Fig. 4(a)]. As the filling height of *A. senticosus* wastes increased, the maximum sound absorption coefficient shifted towards a lower frequency.

The sound wave incident on the porous material is converted into thermal energy as it collides with the material’s pores or void space between materials, and the sound energy is lost. As the thickness of the sound absorber increases, the sound absorption performance improves in the low-frequency region, as it provides more space for sound waves to convert thermal energy (Bhingare et al., 2019). However, the thickness of the sound-absorber needs to regulate within the optimum range. The efficiency of transferring sound energy into thermal energy significantly may decline as the sound absorber's thickness exceeds the ideal values (Taban et al., 2021).

As shown in Fig. 4(b), the sound absorption coefficient’s curves fluctuated. As the hollow space between the granules acts as a resonator, the sound absorption curve has oscillated in the high-frequency region above

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![Fig. 4](image_url) **Fig. 4.** Sound absorption curves of *Acanthopanax senticosus*. (a) Measured sound absorption coefficients for different filling heights of *A. senticosus* wastes using an impedance tube of dimeter 99 mm. (b) Measured sound absorption coefficients for different filling heights of *A. senticosus* wastes using an impedance tube of dimeter 29 mm.
1,000 Hz (Voronina and Horoshenkov, 2004). This phenomenon is observed in most of granular type sound-absorbing materials (Jang, 2022b, 2022c, 2022d; Maderuelo-Sanz et al., 2014; Vašina et al., 2006).

In addition, the number of sound absorption peaks increased as the filling height was increased in the high-frequency region. There were only two sound absorption peaks at a filling height of 40 mm. The number of sound absorption peaks increased by one, three, four and five as the filling height was increased by 40, 60, 80, and 100 mm, respectively.

Table 1 depicts the sound absorption coefficient at 250, 500, 1,000, and 2,000 Hz and the NRC of A. senticosus wastes. As the filling height of A. senticosus wastes inside the impedance tube was increased from 40 to 100 mm, the sound absorption coefficient at 250 Hz increased by 1.56 times, at 250 Hz by 2.97 times, at 500 Hz by 1.83 times, and at 2,000 Hz by 2.09 times. The NRC also increased by approximately 2.1 times, from 0.214 to 0.446, as the filling height was increased from 40 to 100 mm. The improvement of NRC is due to improving the sound absorption effect depending on the increase in thickness. This trend is typical of porous or granular sound-absorbing materials (Jang, 2022b, 2022c, 2022d; Jang and Kang, 2021c).

The KS F 3503 (Korean Standards Association, 2012) classifies the sound absorption performance into four grades (0.3M grade: 0.21–0.40, 0.5M grade: 0.41–0.60, 0.7M grade: 0.61–0.80, and 0.9M grade: Above 0.81) depending on the NRC of the sound absorption material. The sound absorption rating of A. senticosus wastes investigated in this study is 0.3M and 0.5M grade for filling heights of 80 and 100 mm, respectively. Therefore, our results confirm that A. senticosus wastes can be considered as an eco-friendly sound-absorbing material. The rough surfaces of the pith and thorn of A. senticosus and the vessel structure of the cross-section have a favorable effect on sound absorption. Furthermore, a large number of thorns complicated the paths of empty spaces between A. senticosus wastes, which would have created a practical path for sound absorption.

According to the previous study, the NRC of boards made of natural materials such as coir, corn, banana, bamboo, and bagasse was 0.21–0.40 (Sim et al., 2014). In addition, the NRC of peanut shells investigated in the author’s previous study was 0.23–0.53 (Jang, 2022c), and that of pine pollen corns was 0.30–0.52 (Jang, 2022d). The sound absorption ability investigated in this study was approximately similar to these. In the future, if the A. senticosus wastes is compressed more to increase the density and the path of the void space between materials is made more complicated, it is estimated that the sound absorption performance can be further improved.

This study is meaningful because it is the first approach to investigate the sound absorption ability of A. senticosus wastes. However, there is a limit to the conti-

Table 1. Sound absorption coefficients at 250, 500, 1,000, and 2,000 Hz frequency, and NRC for different filling heights of Acanthopanax senticosus wastes inside the impedance tubes

<table>
<thead>
<tr>
<th>Filling height (mm)</th>
<th>Sound absorption coefficient (Hz)</th>
<th>NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>40</td>
<td>0.103</td>
<td>0.124</td>
</tr>
<tr>
<td>60</td>
<td>0.114</td>
<td>0.169</td>
</tr>
<tr>
<td>80</td>
<td>0.134</td>
<td>0.244</td>
</tr>
<tr>
<td>100</td>
<td>0.161</td>
<td>0.367</td>
</tr>
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NRC: noise reduction coefficient.
nous supply of materials to produce commercial sound-absorbing materials. Therefore, it is necessary to investigate whether all medicinal plants (e.g., herbal medicines), including *A. senticosus* wastes, can be used as sound-absorbing materials. In the future, if their excellent sound absorption performance is revealed, it will be a more meaningful study from a practical point of view.

4. CONCLUSIONS

This study investigated the sound absorption ability of *A. senticosus* wastes. The main conclusions are as follows:

1. As the filling heights of *A. senticosus* wastes inside the impedance tube were increased, the sound absorption peaks shifted to a lower frequency.
2. The sound absorption performance at 80 and 100 mm filling heights corresponded to 0.3M and 0.5M grades based on KS F 3503 (Korean Standards Association, 2012), respectively.
3. *A. senticosus* wastes is an efficient eco-friendly sound-absorbing material.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES


Jang, E.S., Kang, C.W. 2021c. The pore structure and sound absorption capabilities of Homalium (Homalium foetidum) and Jelutong (Dyera costulata). Wood Science and Technology 56(1): 323-344.


Jang, E.S., Kang, C.W. 2022. An experimental study on changes in sound absorption capability of spruce (Picea sitchensis), Douglas fir (Pseudotsuga menziessii), and larch (Larix kaempferi) after microwave treatment. Journal of Wood Science 68: 2.


