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Corn husk for noise reduction: Robust acoustic absorption and reduced thickness

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ABSTRACT

Corn husk extracted from maize is a potential candidate for the application of noise reduction. The overall goal of this study is to investigate the acoustic absorption properties of corn husk. The effects of multi-layer structure on the acoustic absorption coefficient were studied. The results indicated that acoustic absorption was not improved with the increase of layers, while the acoustic absorption peak gradually moves to lower frequency direction. Furthermore, it has been observed that the increase of back cavity distance can also increase the absorption coefficient at low frequency range.

1. Introduction

Corn is one of the most widely planted crops in the world, and China is the second largest producer and consumption market. It has been produced mainly for daily food, animal feed, and starch production, etc. [1]. Corn husk is an important byproduct of maize, which has been either used as animal feeding stuffs or plant fuels. Currently, the exploration towards this kind of agricultural residues for various applications is gradually rising. As shown in Table 1, the reported studies for corn husk are listed. It can be seen that corn husk is good raw materials for chemical reagent extraction, such as soluble sugar [2], anthocyanins [3], and polyelectrolytes [4]. The preparation of silver-based nanoparticles [5] and nanocrystalline cellulose [6] through corn husk has also been reported. In addition, cellulose nano-fibers were successfully extracted from corn husk by alkaline treatment, oxidation and followed homogenization process [7].

Corn husk has also been utilized in composites recently. Kwon et al. [8] reported that using corn husk reinforcement is a positive approach to improve the mechanical properties of poly(lactic acid) hybrid biocomposites. Micro-slit plate was also fabricated by degummed corn husk fiber reinforced thermoplastic polyurethane [9]. Youssef et al. [10] investigated the suitability of low density polyethylene board, and the preparation without any treatment for both low density polyethylene as well as corn husk fiber. The results indicated that the increase of corn husk fiber loading is beneficial to improve the mechanical, water absorption and swilling properties of composites. It has been further reported that the obtained nano-fibrillated cellulose from corn husk can improve the strength and thermal stability of poly(vinyl alcohol) films [11]. Additionally, activated carbon of corn husk was utilized for methylene blue purification [12]. Corn husk was also directly crushed and sieved into micro-scale powder. The corn husk powder was used as alternative bio-adsorbent for dyestuff removal from aqueous solutions [13].

Recently, the application of natural fibrous materials in noise reduction is gradually rising. As shown in Table 2, the acoustic absorption properties of various natural fiber were investigated, including tea-leaf fiber, jute fiber, coir fiber, kapok fiber, date palm fiber, fique fiber and kenaf fiber, etc. It can be seen that natural fibrous materials has good acoustic absorption properties. However, most of the reported fibrous materials in noise reduction applications are loose fiber felts. Therefore, the fabrication process is necessary to produce fibrous acoustic absorber, such as the commonly used non-woven fabric and fiber felts. Corn husk has the unique advantage of extremely low production cost. It can be directly utilized as noise reduction materials just by air-drying process. Furthermore, the thickness of corn husk is thinner than conventional fiber felts, as shown in Fig. 1. The thickness of corn husk is much thinner than natural fiber felts, such as fique fiber, kapok/hollow polyester fiber, coconut fiber and mineralized fiber. Bark cloth has the similar thickness with corn husk. However, the acoustic absorption coefficient of corn husk is higher than bark cloth, which can be attributed to the groove structure of corn husk surface [17]. The acoustic absorption of corn husk is also better than natural fiber/polypropylene hybrid felts and luffa fiber reinforced composites. In addition, corn husk can be easily fabricated into multi-layer structure by facile layering process. Therefore, it can be concluded that corn husk is a potential candidate for noise reduction applications.

In the present work, the potential of corn husk as acoustic absorption materials has been studied. The corn husk used in this study was

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Table 1
Typical examples on the studies of corn husk.

No.	Key findings	Methods	References
1	Rapidase Pomaliq is proper enzyme source for the enzymatic production of soluble sugars from corn husks	Alkali treatment and enzymatic saccharification	Hang and Woodams [2]
2	Corn husk is a potential source of anthocyanins	Chemical extraction	Li et al. [3]
3	Potential at industrial scale for biotechnological production	Solid state fermentation	Mahalaxmi et al. [14]
4	Activated carbon of corn husk for methylene blue purification	High temperature carbonization	Khodaie et al. [12]
5	Polyelectrolytes produced by corn husk in sewage treatment	Hemi-celluloses extraction	Landim et al. [4]
6	Corn husk reinforced biodegradable kenaf/corn husk/PLA bio-composites	Compounding and extrusion	Kwon et al. [8]
7	High absorption towards water and saline solutions	Blending corn husk with acrylic acid	Li et al. [15]
8	Corn husk is an alternative adsorbent for color wastewater treatment	Kinetic and thermodynamic studies	Paska et al. [13]
9	Sound absorption of corn cob fiber husk reinforced polyurethane micro-slit plate	Degumming and mastication-hot processing	Lv et al. [9]
10	Nanocrystalline cellulose extracted from corn husk	Chemical extraction and spray-drying process	Mendes et al. [6]
11	Green synthesis of silver-based nanoparticles from corn husk extracts	Bio-synthesis	Villanueva-Ibáñez et al. [5]
12	Corn husk fibers reinforced low-density polyethylene	Melt compounding and compression molding	Youssef et al. [10]
13	Cellulose nanofibers prepared by the oxidation of corn husk	Alkaline-treatment and oxidation	Du et al. [7]
14	Corn husk taken as solid fuel	Liquid and vapor hydrothermal carbonization	Minaret and Dutta [16]
15	Nanofibrillated corn husk cellulose is benefit to improve the strength and thermal stability of poly(vinyl alcohol) films	Chemical pretreatment and ultrasonication	Xiao et al. [11]

Table 2
Comparison of noise reduction properties for various natural vegetable fibrous materials.

No.	Materials	Thickness	Key findings	References
1	Tea-leaf fiber	10 mm, 20 mm, 30 mm	Compared the acoustic absorption of tea-leaf with woven textiles	Ersoy and Kucuk. [18]
2	Corn husk, polyethylene	3.2 mm	Corn husk can increase acoustic absorption	Huda and Yang [19]
3	Bamboo, banana, and jute	4.28 mm, 4.93 mm, 6.43 mm	Bamboo/polypropylene has good acoustic absorption	Thilagavathi et al. [20]
4	Coir fiber	20 mm, 50 mm	The absorption coefficient is 0.8 for $f > 1360$ Hz at 20 mm thickness	Fouladi et al. [21]
5	Ramie, flax and jute	40 mm	The hollow lumen contributes to acoustic absorption	Yang and Li [22]
6	Kapok fiber	60 mm	Kapok fiber has better acoustic absorption than glass wool and degreasing cotton	Xiang et al. [23]
7	Date palm fiber	25 mm	Acoustic absorption coefficient of date palm fiber is small at low frequency	Khidir et al. [24]
8	Fique fiber	5 mm, 10 mm, 15 mm	Fique fiber has the advantages of low weight, low cost and biodegradability	Navacerrada et al. [25]
9	Bark cloth	0.7–1.4 mm	Sound absorption of natural bark cloth	Rwawiire et al. [26]
10	Kenaf, hemp and coconut	50 mm, 100 mm	Natural fibrous sound absorbing panels	Berardi and Iannace [27]
11	Kapok fiber	5 mm, 10 mm, 20 mm	Kapok fiber has better acoustic absorption than polypropylene at low frequency	Liu et al. [28]
12	Kapok and milkweed	2.3–13.5 mm	Cotton/milkweed nonwoven has better sound reduction than cotton/kapok	Ganesan and Karthik. [29]
13	Luffa fiber reinforced epoxy	4.5 mm	Alkaline treatment can decrease the sound absorption coefficient	Jayamani et al. [30]
14	Corn husk	0.652–2.916 mm	Robust acoustic absorption due to the groove structure	This study

just washed with distilled water and then dried in air. The manufacturing process is green and environmental-friendly, which without any chemical modification. Furthermore, multi-layer structured corn husk was fabricated for the improvement of acoustic absorption. The effects of back cavity with various distance for acoustic absorption efficient and peak frequency were also investigated. The aim of this paper is to characterize the acoustic absorption properties of natural corn husk for noise reduction applications.

2. Experimental

2.1. Materials

The corn husk is a natural product which has been extracted from corn in the local farmland of Tanglou village, Shangqiu, Henan province, China. As shown in Fig. 2(a) and (b), mature corn cob was picked from the corn field. Corn husk was obtained from the corn cob, as seen from Fig. 2(c). Then corn husk was air dried and cut for specified size, as shown in Fig. 2(d). Especially, the raw corn husk was repeatedly washed with distilled water to remove dust, dirt and impurity, etc.

2.2. Methods

The schematic illustration of acoustic absorption measurement as shown in Fig. 3. The test of acoustic absorption coefficient was based on the method of ASTM E 1050 (Standing Test Method for Impedance and Absorption of Acoustic Properties Using a Tube, Two Microphones and a Digital Frequency Analysis System). The fixed loudspeaker at the end of impedance tube which generates broadband acoustic waves within stationary frequency. The specimen of corn husk is placed at the opposite end. Incident acoustic signals propagate as plane waves in the impedance tube, where incident and reflected wave signals are picked up and analyzed. The mechanical properties are measured by fabric strength tester (HD026N-300, Hongda Instrument Co., Ltd., Nantong, China). The test procedure was based on ISO 13934-1-2013 (Part 1: Determination of maximum force and elongation at maximum force using the strip method). In this study, con husk sample with 80 mm diameter was used to test acoustic absorption properties. The schematic illustration to set test sample in impedance tube as shown in the inserted image of Fig. 3. The specimen was fixed with moving a backing plate in the impedance tube. In details, two condenser microphones with the separation of 17 cm and 4.5 cm were taken to measure the acoustic absorption coefficient of 100–800 Hz and 400–2500 Hz, respectively. Then VA-Lab system (BSWA Technology Co., Ltd., Beijing, China, complying with the standard of ISO 10534-2:2001) was utilized to fit the data of two frequency range, thus obtain the acoustic absorption coefficient from 100 to 2500 Hz. These measured results including acoustic absorption and mechanical properties were repeated at least 3 times and the average values were reported.