WINDMILL PALM NONWOVEN FABRICS WITH POTENTIALSOUND ABSORPTION PROPERTY

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***ABSTRACT**: In this paper, alkali oxygen treatments under different conditions were used to extract windmill palm fiber and fiber bundles from windmill palm sheath meshes. Then the palm fiber nonwoven fabrics were prepared by different process parameters with palm fiber and fiber bundles. The effects of surface density, content of palm fiber bundles and bulk density on sound absorption performance were studied, in order to utilize the new cellulose fiber resource. A compared study had been done between the windmill nonwoven fabrics and the commercially available sound absorbing materials. The results showed that: sound absorption performance of windmill palm nonwoven fabrics were enhanced with its increasing surface density. The average absorption coefficient was 0.35, when surface density reached 320g/m^2. The best content of palm fiber bundle was 40%, which can improve the sound absorption performance at the low and middle frequency ranges. The increases of bulk density could improve the sound absorption performance, and the best range was from 1289 to 1542g/m^3. When the content of palm fiber bundles was 40%, surface density reached 320g/m^2 and the bulk density was 1542g/m^3, the palm nonwoven material had a highest average absorption coefficient of 0.43.*

***KEYWORDS**: windmill palm fiber; nonwoven fabrics; sound absorption; bulk density; fiber bundle content; surface density*

1 INTRODUCTION

The introduction will contain the general aspects of the research, the objectives and the methodology. The text style is Normal, written in Times New Roman font, 11 points, justified and with a 5-mm indentation on the first line.

Since the 21st century, the rapid development of economic led to a series of environmental problems. The urban construction, transportation, and industrial modernization make the noise pollution worse and worse which cause the common concern of the world (Cheng, Penbo et al. 2016, Rwawiire, Tomkova et al. 2017, Xu, Li et al. 2017, Yilmaz, Banks-Lee et al. 2011). Large numbers of studies show that noise can seriously affect human health, such as hearing loss, dizziness, insomnia, and other issues which induce high blood pressure and heart disease(Yilmaz, Banks-Lee et al. 2011). The methods to reduce noise pollution are mainly divided into two ways: positive or negative way. The positive way reduces the generation of noise by the means of source control. While the negative way is related to the use of high-performance materials which can reduce noise hazards. The negative way also can be divided into two different parts, one is to prevent the spread of sound insulation and one is weaken the transmission of acoustic energy through materials' porous, absorbent resonance action or film action to absorption the incident sound energy. Porous material is one of the most widely used sound absorbing materials (Yang and Yan, et al. 2009).

Nonwoven fabrics are typically porous sound absorbing materials. Uniformly distributed holes communicate with each other and extend to the surface. A large number of branches increase the vibration resistance and the friction of air molecules when the internal air passes through the cell walls, which can effectively transform the sound energy into heat to reduce noise (Huang, Lin et al. 2013). Nonwoven materials have high strength, low density, low energy consumption, biodegrade able, renewable, better chemical stability and other advantages (Hao, Zhao et al. 2013, Ganesan and Karthik 2015, Zheng, Wang et al. 2015). Windmill palm fiber as a new natural cellulose fiber has a large lumen in the middle of the cross section, and a thin cell wall (Chen, Changjie et al. 2016, Chen, Zhang et al. 2017). The hollowness of windmill palm fiber is about 47.1% (Changjie, et al. 2014). This particular structure has a potential use in acoustic field to increase the friction between sound and fiber. The global source of palm fiber is abundant, only the production of date palm fiber reached 4,000,000 tons per year (Al-Oqla and Sapuan, 2014). Wind mill palm fiber as raw material for preparing a nonwoven fabric can take full advantage of the porous structure, improve the sound absorption performance.

In this paper, windmill palm fiber and palm fiber bundle were used to prepare nonwoven fabrics. The impact of surface density, the content of fiber bundles and bulk density on sound absorption performance were explored. The optimal process of palm nonwoven fabrics were obtained. And the sound absorption performance of optimal materials was compared with commercially available sound absorbing cotton (AC) and melt blown polypropylene (MP) nonwoven materials. (Bere; Berce and Nemes, 2012)

2 MATERIALS AND METHODS

2.1 Materials

Windmill palm meshes were collected from Huangshan in Anhui province.

2.1.1 Preparation of palm fibers

Windmill palm fibers were treated with hydrogen peroxide (H_2O_2) 40mL/L and sodium hydroxide solution (NaOH) 20g/L with a 1:75 fiber-to-extracting agent ratio (g/mL) at 90°C for 2.5h. The residue was filtered with two layers of gauze and then oscillated to prepare separated single fibers. After washing with running water to neutral, the fiber was dried naturally.

2.1.2 Preparation of palm fiber bundle

Windmill palm mesh was treated with $H_2O_2$20mL/L and NaOH10g/L with a 1:50 fiber-to-extracting agent ratio (g/mL) at 75°C for 2h to obtain the fiber bundle then washed and dried naturally.

2.1.3 Preparation of palm fiber nonwovens.

The amount of windmill palm fiber was changed from 10g to 40g in 10-g intervals to obtain samples which were denoted WPFW-10, WPFW-20, WPFW-30, and WPFW-40, respectively. 500mL of water and fibers with different mass were added into the blender and stirred for about 40s to mix uniformly. Then, the mixture was poured into a 200-mesh sieve. After the excess water was filtered, the sub-mesh sieve was placed in an oven at 75℃ about 6h to obtain nonwoven materials with different surface density. And the surface density was calculated as the mass per unit area.

16g, 12g and 8g palm fiber was mixed with 500mL water into the blender and stirred for about 30s, separately. Then 4g, 8g and 12g palm fiber bundle was one-to-one correspondence to 16g, 12g and 8g. After stirring another 10s, the fiber and fiber bundles were mixed uniformly in the water. The mixture was filtered dried in an oven at 75℃ for about 6h to prepared samples with fiber bundle content were 20%, 40% and 60%, which were denoted WPFB-20, WPFB-40, and WPFB-60.

20N, 40N, 60N and 80N metal plates were placed on the surface of four wet sample WPFW-20. After dried in an oven at 75℃ for 8h, the samples with different bulk density which were denoted WPFD-1290, WPFD-1420, WPFD-1540, and WPFD-1620 were prepared. And the bulk density was defined as the weight of the material divided by the total volume it occupied. According to the optimum process obtained from the research before, the optimum sample was 16g fiber mixed with 24g fiber bundles under the pressure of 60N, numbered WPFO.

2.1.4 Comparative commercial materials

The high-density sound absorbing cotton which contained sound absorbing layer, the honeycomb layer and aluminum layer were obtained in Shandong, referred to as AC. Melt blown polypropylene nonwoven materials were obtained in Hainan, a production company, referred to as MP.

2.2 Methods

The surfaces of nonwoven samples after placed in a constant temperature and humidity chamber for more than 24h were observed using scanning electron microscopy, SEM (S-4800, HITACHI®, Japan).

2.2.1 Sound absorbing property

The normal incidence absorption coefficient was measured by means of two microphone impedance tubes SW477 and SW422 (Beijing, Shengwang® Co., Ltd.), according to GB/T1869.2-2002. The test frequency was 80-6300Hz with the set temperature of 25℃ and relative humidity of 65 %.

3 RESULTS AND DISCUSSIONS

3.1 Morphological properties of different types palm fiber nonwoven fabrics

The surface morphology of three typical types of palm fiber nonwoven fabrics were shown in Fig, 1. The windmill palm fiber nonwoven fabric (Fig.1(a)) had a roughness surface, loose structure and pores through a large scale. The windmill palm fiber nonwoven fabric under pressure (Fig.1(b)) had a relatively smooth surface, dense structure, and fine pores. The windmill palm fiber/fiber bundle nonwoven material (Fig. 1(c)) with a rougher surface, large-scale prose. However, the fibrillation of windmill palm fiber bundles formed some irregular tiny pores distributes in the fiber/fiber bundles nonwoven fabrics.

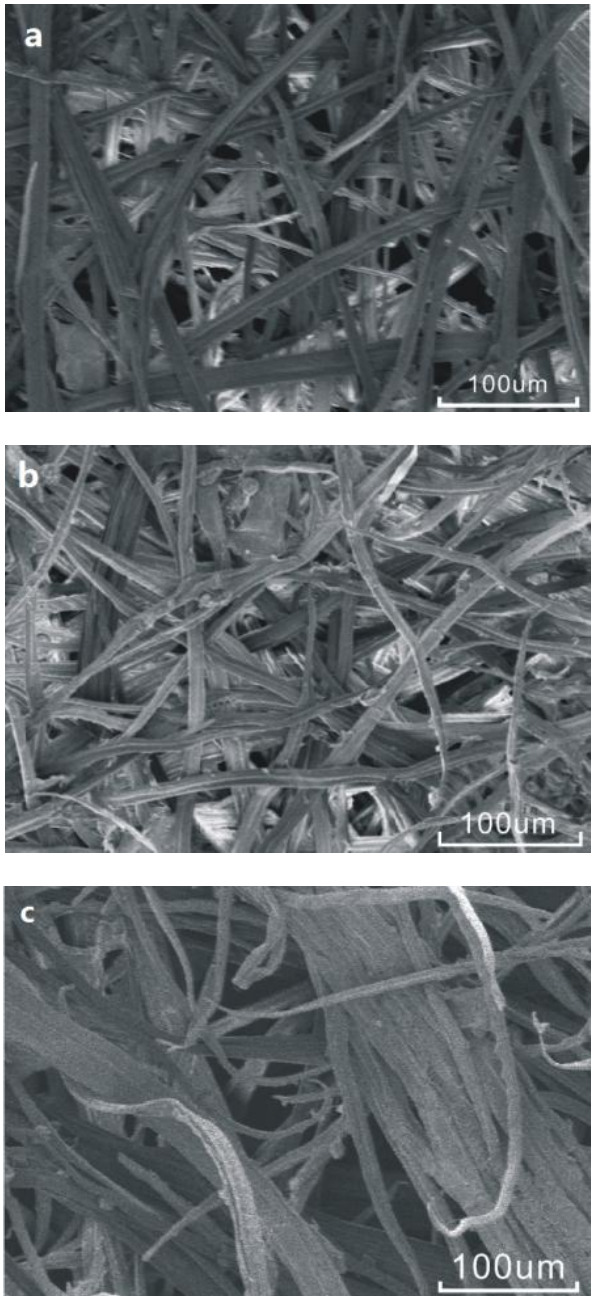

Fig. 1 Morphology of typical types of (a) windmill palm fiber nonwoven fabric, (b) windmill palm fiber nonwoven fabric under pressure, (c) windmill palm fiber/fiber bundle nonwoven fabric

3.2 Optimization of surface density

The thickness of windmill nonwoven materials with different surface density were shown in Table 1. And the sound absorption properties of each sample were shown as Fig.2. The comparison among these samples showed that increasing the surface density can affect the sound absorption properties only for the frequency above 500Hz. The acoustic absorption property increased with the increasesof surface density, especially between the frequencies at 1000~4000Hz.

Table 1. Thickness of palm fiber nonwoven materials with different areal density.

Sample	WPFW-10	WPFW-20	WPFW-30	WPFW-40
Surface density($g.m^{-2}$)	80	160	240	320
Thickness(mm)	2.07	3.81	7.31	10.26

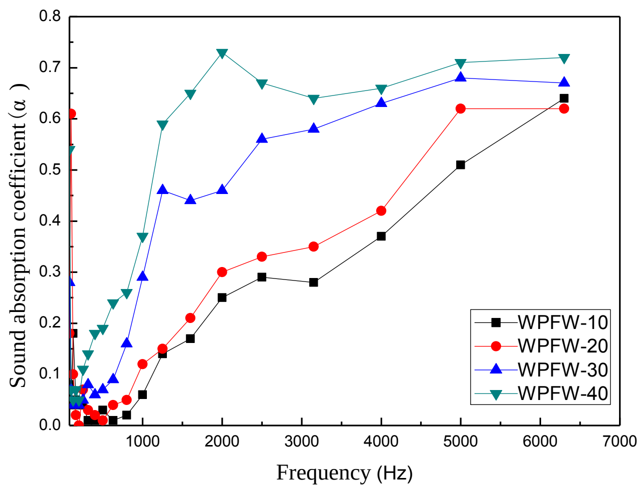

Fig. 2 Sound absorption performance of palm nonwoven materials with different surface density

Sound absorption performance tested covering frequency range of 80~6300 Hz, but the average sound absorption coefficient at 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz are often used to represent the average sound absorption coefficient $\bar{\alpha}$ in engineering (Huang, Tang et al. 2007). And the average sound absorption coefficient was calculated as Eq.1.

$$\bar{\alpha} = \frac{\sum \alpha_f}{6} (f = 125, 250, 500, 1000, 2000, 4000) \quad (1)$$

The surface density of the nonwoven increased from 80g/$m^2$to 160, 240 and 320 g/m^2, the average absorption coefficient of the material increased from 0.16 to 0.17, 0.26 and 0.35. When the surface density of palm fiber nonwoven material reaches 320g/m^2, the absorption coefficient reached the highest 0.7 at the frequency of 6300Hz.

3.3 Optimization of windmill palm fiber bundle content

The effect of fiber bundle content on the sound absorption properties of palm fiber nonwoven material were shown in Fig. 3.

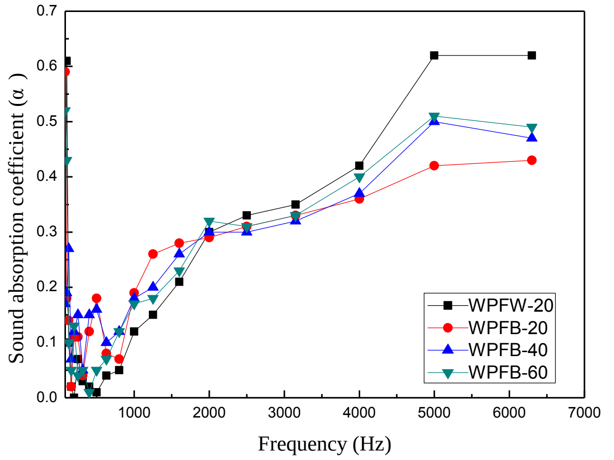

Fig. 3 Sound absorption performance of palm nonwoven materials with different palm fiber bundles content

Table 2. Analyses of 6 octaves for windmill palm fabrics with different content of fiber bundles

Samples	subset		
	N	1	2
WPFW-20	6	0.17	
WPFB-60	6	0.18	0.18
WPFB-20	6	0.212	0.212
WPFB-40	6		0.238
Sig.		0.178	0.066

The sound absorption property of nonwoven fabrics contains fiber bundle was superior to the windmill palm fiber nonwoven fabrics at the frequency range of 500~2000Hz. Palm fiber bundleswith amount of lignin and hemicellulose around the surface had a large diameter than the windmill palm fiber. The large diameter, to some extent, improved the sound absorption performance of low frequency. Xi Zhengping studied the effect of fiber diameter on the sound absorption properties of metal fiber, also found the material contains large diameter fiber had better sound absorption property at low frequency (Zhengping, Jilei et al. 2011). However, with the continued increase in the fiber bundle content for more than40%, the large scale pores as well as through-holes will increase rapidly in the material. As a result, the friction between the cell wall was greatly reduced, which decreased the sound absorbing property. In the high frequency region above 2000Hz, windmill palm fiber nonwoven fabrics had a better sound absorption property than the windmill palm fiber/fiber bundle nonwoven fabric. The increased fiber bundle will decrease the sound absorption property at the frequency above 2000 Hz.

When the content of fiber bundles increased from 0% to 20, 40, and 60%, the average absorption coefficient was 0.17, 0.21, 0.24 and 0.18, respectively. In order to further study, the sound absorption property of the windmill palm fabric samples, ANOVA method had been used to statistic the date of the 6 octaves for windmill palm fabrics with different content of fiber bundles, and the results had been shown in Table 2. WPFB-40 had a significant higher sound absorption property than the other fabrics. It indicated that the adding of fiber bundle could improve the sound absorption property at low frequency and increased the average absorption coefficient. The test results showed that the optimum content of palm fiber bundle was 40%.

3.4 Optimization of bulk density

Different pressures had been added to the windmill palm fiber nonwoven fabrics to obtain samples with different bulk density. The specific specifications were shown in Table 3.And the sound absorption property of palm fiber nonwoven material with different bulk density were shown in Fig. 4. With the increases of the bulk density, the sound absorption properties of the material increased.

Table3. Specification parameters of palm nonwoven materials under different pressure

Samples	WPFW-20	WPFD-1290	WPFD-1420	WPFD-1540	WPFD-1620
Area(cm^2)	100	100	100	100	100
Thickness(mm)	3.81	3.52	3.27	3.04	2.93
Weigh(g)	4.5479	4.5381	4.629	4.688	4.753
Bulk density(g/m^3)	1190	1290	1420	1540	1620

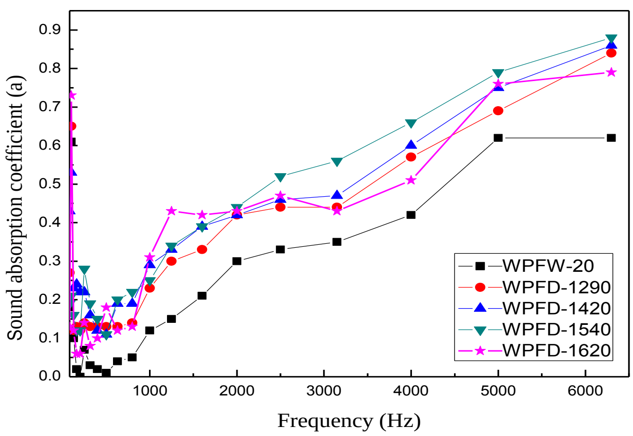

Fig. 4 Sound absorption performance of palm nonwoven materials with different volume density

When the bulk density of palm fiber nonwoven material increased from 1190g/m^3 to 1290,1420,1540 and 1620g/m^3, the average absorption coefficient of the material was 0.17,0.27,0.31,0.32 and 0.29. Adding pressure could make the nonwoven fabrics more compact, increase the bulk density and decrease the porosity. And the main pore size became smaller and smaller (Yu, Yao et al. 2006). So that the air path through the material became narrow and distorted, and lead to a longer way to go through. As a result, more acoustic sound energy was transformed into heat loss waves when going through the material. It could enhance the sound absorbing properties of the material. But with the increasing of pressure, the bulk density increase rapidly, which at last made a decrease of the porosity. The open pores become narrow until disappeared, reduced the absorption properties of the material. So, there was an optimum range of the bulk density of the sound absorbing material. As the experimental results showed that the optimum range of the bulk density of palm fiber nonwoven material was1540 g/ m^3.

3.5 Comparison of sound absorption properties

Sound absorbing cotton AC and melt blown polypropylene nonwoven composite material MP were two main kinds of commercially sound absorbing material. Different specifications of these samples as well as WPFO were shown in Table 4. The mass weight of WPFO (9.36 g) was extremely slighter than AC (29.69 g). And the thickest sample was MP of 8.97mmamong these samples.

Table 4. Specifications of different material parameters

Samples	Thickness (mm)	Surface density (g.m^{-2})	Mass weight (g)
WPFO	7.06	388	9.36
AC	7.68	942	29.69
MP	8.97	128	3.98

Absorption properties of different materials were shown in Fig.5. It indicated that absorption properties of WPFO are significantly better than the AC and MP. The sound absorption coefficients of these samples of 6 octaves were shown in Table 5.When the frequency was greater than 500Hz, the sound absorption coefficients of AC and WPFO were above 0.2. While the sound absorption coefficient of MP reached 0.2 at 1000Hz. The average absorption coefficient of WPFO, AC and MP samples were 0.43, 0.34 and 0.24, respectively. The absorption properties of WPFO increased by 26.5% and 79% compared with AC and MP. The price of AC was 40CNY/m^2, while the price of WPFO was about 25CNY/m^2. The better sound absorption property combines the slighter mass weight and the cheaper price made windmill palm fiber was potential materials that can be used as function material.

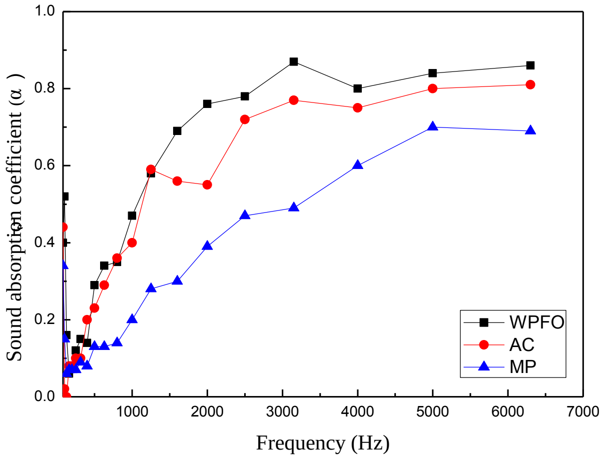

Fig.5 Sound absorption performance of different sound absorbing material

Table5. Average sound absorption coefficient of different nonwoven materials

Freque--ncy (Hz)	α_{125}	α_{250}	α_{500}	α_{1000}	α_{2000}	α_{4000}	$\bar{\alpha}$
WPFO	0.16	0.12	0.29	0.47	0.76	0.8	0.43
AC	0.01	0.1	0.23	0.4	0.55	0.75	0.34
MP	0.06	0.07	0.13	0.2	0.39	0.6	0.24

4 CONCLUSIONS

From the macroscopic appearance of the nonwoven material, the exert pressure made the samples tight, smooth and with finer pores. While the added fiber bundles made the sample rough and with large-scale pores.

The acoustic absorption property increased with the increases of surface density, especially between the frequencies at 1000 ~ 4000Hz. When the surface density reached 320g/m^2, the average absorption coefficient of samples was 0.35, and the maximum absorption coefficient was 0.72 at 6300Hz. Adding an amount of fiber bundles in the nonwoven material can improve the sound absorption property at the low frequency, while with a slightly decrease at the high frequency. The optimum content of the added fiber bundles was 40%.Sound absorption property increased at the beginning with the increased of the bulk density and then had a tendency of decrease. The optimum range of the bulk density was1540g/m^3.

When the surface density of windmill palm fiber nonwoven material containing 40% fiber bundle, with a surface density of 320 g/m^2 and the bulk density of 1540g/m^{3}had the best sound absorption property. And the average absorption coefficient was 0.43, much higher than the 0.34 of AC and 0.24 of MP.

5 ACKNOWLEDGEMENTS

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