Study on Preparation and Filtration Effect of Plant Polysaccharide Aerogel Filter Rod

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Abstract—Environmental friendly and biodegradable plant polysaccharide aerogel filter rods were prepared, and their degradation rate and influence rule under different environmental conditions were investigated. Micro morphology observation and mechanical properties research were carried out. The results showed that Konjac Glucomannan (KGM) had a significant effect on the micro morphology of gelatin aerogel. When KGM was added, the structure of aerogel changed obviously, and the pore size decreased and better pore structure appeared. The optimal ratio of KGM and gelatin is 1:2. The filtration efficiency of K1G2 aerogel is 45.35% for particles with a particle size of 0.3 μm and above. With the increase of particle size, the filtration efficiency of aerogel for particles increases. The filtration resistance is 30 Pa. The permeability of K1G2 aerogel is better.

1. INTRODUCTION

At present, cellulose acetate, which is used as cigarette filter material, is difficult to degrade in the natural environment, resulting in a large number of urban garbage, river, lake and marine pollution. The severity of the damage to the global ecological environment has also increasingly attracted social attention[1-8]. At present, there are few reports about the degradation of acetate fiber. The conventional treatment methods include burying, composting and combustion[9-12]. However, these treatment methods not only cause air, water and soil pollution, but also waste a lot of energy[13-17].

Due to its unique porous structure, large specific surface area, high porosity and low density, plant polysaccharide aerogel has the potential to be used as air filtration material, and it is a natural plant polysaccharide with rich sources, renewable resources, good biological safety and biodegradability[18-24]. Therefore, in this paper, environmental friendly and biodegradable plant polysaccharide aerogel filter rods were prepared, and their filtration efficiency were investigated.

2. EXPERIMENTAL

2.1. Preparation of plant polysaccharide aerogel

The specific preparation process is shown in Fig.1. The preparation method is as follows: weigh Konjac Glucomannan (KGM), gelatin, starch and other raw materials according to a certain mass ratio, place
gelatin and starch in a 250 ml beaker, add 100 ml distilled water, disperse evenly under normal temperature, then place the beaker in a 90 °C water bath, add KGM while stirring under 500 rpm, seal with a fresh-keeping film after adding to reduce water evaporation, stir for 5m After in, increase the speed to 1000 rpm. After stirring for 60 min, inject 20 ml syringe into a cylindrical mold with an inner diameter of 8 mm to gel at room temperature, then transfer it to a 4 °C refrigerator for aging and forming, and transfer it to an ultra-low temperature refrigerator for pre-freezing after 2 h. After the water is completely frozen, transfer it to a vacuum freeze dryer with a temperature of - 50 °C and a vacuum degree of 10 Pa for drying. Take it out after 24 h to obtain plant polysaccharides aerogel. Cut off both ends and trim them into a cylinder with a length of 120 mm and a diameter of 7 mm. After the moisture absorption reaches equilibrium in the constant temperature and humidity phase with a temperature of 25 °C and a humidity of 80%. At this time, the samples can be processed into filter rods in batches on the cigarette machine.

2.2. Micro morphology observation
Jsm6390lv scanning electron microscope (SEM) of Japan Electronics Co., Ltd. was used to observe the micro morphology of the filter rod before and after degradation, and to investigate the damage of biodegradation on the microstructure of the filter rod. The dry filter rods before and after degradation were cut into small pieces with the length × width × height of 5 × 5 × 1 mm with stainless steel blades.

2.3. Mechanical properties research
The effect of biodegradation on the mechanical properties of filter rod material was studied by texture analysis (TPA). Tms-pro texture analyzer of FTC company is adopted. Parameter setting: test speed is 60mm / min, compression ratio is 30%, minimum force is 1N, and trigger type is automatic. The diameter of the sample is 7 mm and the height is 5 mm. The significance of data was analyzed by DPS software.

2.4. Filter performance test
Filtration efficiency η refers to the percentage of particles trapped by the sample under certain test conditions. The filtration efficiency is calculated by measuring the number of particles in the upstream and downstream of the sample to be measured by a counter. The formula is as follows,

\[ \eta = \frac{M_u - M_d}{M_u} \times 100\% \]  \hspace{1cm} (1)

where, \( M_u \) - particle number upstream; \( M_d \) - particle number downstream.

3. RESULTS AND DISCUSSION
The effect of different KGM and gelatin content on the mechanical properties of the composite polysaccharide aerogel is shown in Fig.2. When KGM content is low (less than 0.5%), the compressive strength of aerogel increases significantly with the increase of gelatin content. When KGM content is higher (higher than 0.5%), the compressive strength of aerogel first increases and then decreases with the increase of gelatin content. In addition, when the content of gelatin is 1%, the compressive strength increases with the increase of KGM, while when the content of gelatin is 2%, the compressive strength of aerogel increases first and then decreases with the increase of KGM, and reaches the maximum value when the content of KGM is 1%. When the content of gelatin is 3%, KGM can reduce the compressive
strength of aerogel. This may be because in the same system, when KGM and gelatin content are high, phase separation occurs, which leads to the destruction of aerogel structure, thus reducing its compressive strength. When KGM is not added, the elasticity of aerogel is the largest and increases with the increase of gelatin content, while when KGM is combined with gelatin, the elasticity of aerogel decreases. This may be because when there are only gelatin molecules in the system, after gelatin dissolves in hot water, the triple helix molecular chain opens, and after cooling, the molecular chain reconstructs into triple helix structure, which makes the aerogel have good elasticity. When KGM and gelatin molecules exist in the system at the same time, KGM and gelatin molecules cross each other, which hinders the molecular chain reconstitution of gelatin, thus reducing the material’s elasticity.

Fig. 2. Variation of compressive strength and elasticity of aerogel with content of KGM
The macro picture of KGM / gelatin composite polysaccharide aerogel is shown in Fig. 3. When KGM content is low, the aerogel appearance is uniform as a whole. With the increase of KGM content, when KGM content is 1%, gelatin content is 3%, aerogel and KGM content is 1.5%, gelatin content is 1% ~ 3%, the outer layer is translucent and the middle layer is opaque white. This may be due to phase separation in the gel process.

In order to better understand the distribution of the internal structure of the aerogel, the aerogel was observed by SEM, and the results are shown in Fig. 4. KGM has a significant effect on the micro morphology of gelatin aerogel. When KGM content is 0%, the pure gelatin aerogel has porous structure, larger pore size and more open pores. With the increase of gelatin content, the pore size did not change, and the change of gelatin concentration did not affect the microstructure of gelatin aerogel. When KGM was added, the structure of aerogel changed obviously, the pore size became smaller, and more fine pore structure appeared. However, it can also be seen that when KGM or gelatin content is high, the aerogel structure appears partial agglomeration, local areas are dense, local areas are sparse, and the overall homogeneity is poor.
The filtration performance of aerogel filter rod is also an important index. The filtration performance of filter rod material mainly includes physical adsorption and chemical adsorption. Among them, physical adsorption is mainly a process that filter materials catch particles from polluted gas by mechanical or electrostatic principle. Physical adsorption is mainly realized by inertial collision, Brownian diffusion, direct interception and electrostatic effect occur.

![Fig.5. Correlation between filter efficiency and particle size.](image)

Fig.5 shows the filtration efficiency of K1G2 aerogel for particles with different sizes. It can be seen from Fig.5 that the filtration efficiency of K1G2 aerogel for particles with particle size of 0.3 μm and above is 45.35%, and with the increase of particle size, the filtration efficiency of aerogel for particles increases. The filtration test results also show that the filtration resistance of K1G2 aerogel is 30 Pa. It shows that the permeability of K1G2 aerogel is better, that is, the optimal ratio of KGM and gelatin is 1:2. However, the aerogel containing only KGM and gelatin as the filtration material, its filtration efficiency and compressive strength still need to be improved.

4. CONCLUSION
Konjac Glucomannan (KGM) has a significant effect on the micro morphology of gelatin aerogel. KGM has a significant effect on the micro morphology of gelatin aerogel. When KGM was added, the structure of aerogel changed obviously, the pore size decreased and more fine pore structure appeared. However, when the content of KGM or gelatin is high, the structure of aerogel is partially agglomerated, local areas are dense, local areas are sparse, and the overall homogeneity is poor. The optimal ratio of KGM and gelatin is 1:2. The filtration efficiency of K1G2 aerogel is 45.35% for particles with a particle size of 0.3 μm and above. With the increase of particle size, the filtration efficiency of aerogel for particles increases. The filtration resistance is 30 Pa. The permeability of K1G2 aerogel is better.

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