



Comparative study on microstructure and surface properties of keratin- and lignocellulosic-based activated carbons



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ABSTRACT

The paper probed the preparation of activated carbon by potassium silicate (K_2SiO_3) activation from keratin waste (cowhair waste, CW) and lignocellulosic materials (*Cyperus alternifolius*, CA) and the comparisons of physicochemical properties of the resulting carbons. These impregnation conditions were as follows: one impregnated at room temperature for 12 h then dipped at high temperature for 30 min; the other was only impregnated at room temperature for 12 h, producing four activated carbons CWAC-1, CWAC-2, CAAC-1, and CAAC-2. The influence of activation time, K_2SiO_3 /precursor weight ratio, and the pre-process on properties of activated carbons was discussed. The CWAC-1 produced at 700 °C with the K_2SiO_3 /precursor weight ratio of 2:1 possessed the Brunauer–Emmet–Teller (BET) surface area of 1965 m²/g and total pore volume of 1.345 cm³/g, while CAAC-1 prepared at the same conditions attained the BET surface area of 1710 m²/g and total pore volume of 0.949 cm³/g. The surface area and total pore volume of CAAC increased with the impregnation ratio. Moreover, CWAC-1, CWAC-2, CAAC-1, and CAAC-2 exhibited high portion of micropores, illustrating the role of K_2SiO_3 . The analysis with a Fourier transform infrared spectrometer indicates that CWAC has more functional groups than CAAC, as well as CWAC-1 and CWAC-2 which possess similar functional groups.

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1. Introduction

Activated carbon (AC) is well known as an effective adsorbent which is widely applied in the separation and purity process for wastewater and exhaust gas operation [1,2]. It is also used as a catalyst carrier, raw material of capacitor and solid-phase extractors from aqueous solutions [3]. ACs have many advantages, including large surface area, various oxygen-containing functional groups and stable chemical properties. It can be prepared by any carbon-rich substances, and its properties depend on the raw materials and methods of preparation.

Generally, in the process of AC preparation, the activation methods contain chemical, physical and the combination of both of them. For chemical method, the precursor is mixed with compounds such as phosphoric acid [4], potassium hydroxide [5], zinc chloride [6] and potassium carbonate [7,8], and then activated at various temperatures. The previous studies [9] have been reported that carbon activated by potassium hydroxide could possess high specific surface area and large number of micropores, but the apparatus would be corroded and the life of which lowers due to the strong basicity. Actually, silicone material is widely employed as a catalyst and fire retardant to prevent the flame of material in origin [10], and potassium silicate (K_2SiO_3)

has lower alkalescency than potassium hydroxide. In general, carbon prepared by potassium hydroxide consists of the pyrolysis of the precursor material and activation of the char using activating agent. However, ACs activated by K_2SiO_3 can be prepared in one step, which is favorable to make the steps simple and reduce energy consumption.

Presently, lignocellulosic materials are composed of sugar, which have been found to be suitable for the preparation of AC due to its low cost and high carbon content, such as *Zizania latifolia* [11], cattail [12], lotus stalks [13], cotton stalks [14], and oil palm shell [15]. Cowhair waste (CW), a kind of keratin waste, is abundant in tanneries, slaughterhouses, and textile factories. It has biological structures of unity and abundant keratin which provides nitrogen-containing functional groups. Converting the natural fibers into fine powders can be used into the adsorption in aqueous solution. Chen et al. have reported the characteristics of wool-based carbons activated by H_3PO_4 , $ZnCl_2$, and K_2CO_3 [16]. However, to our knowledge, there is no study comparing the properties of keratin and lignocellulose-based ACs activated by potassium silicate. In this sense, the main aim of this paper is to study the preparation of keratin AC by K_2SiO_3 activation with different preparation condition, and the comparison of keratin AC with lignocellulose-based ACs. Regarding the preparation method of AC, we have studied (i) how variables such as activation temperature and impregnation ratio affect the formation and properties and (ii) the effect of K_2SiO_3 on the formation of pores. Regarding the precursors, cowhair waste

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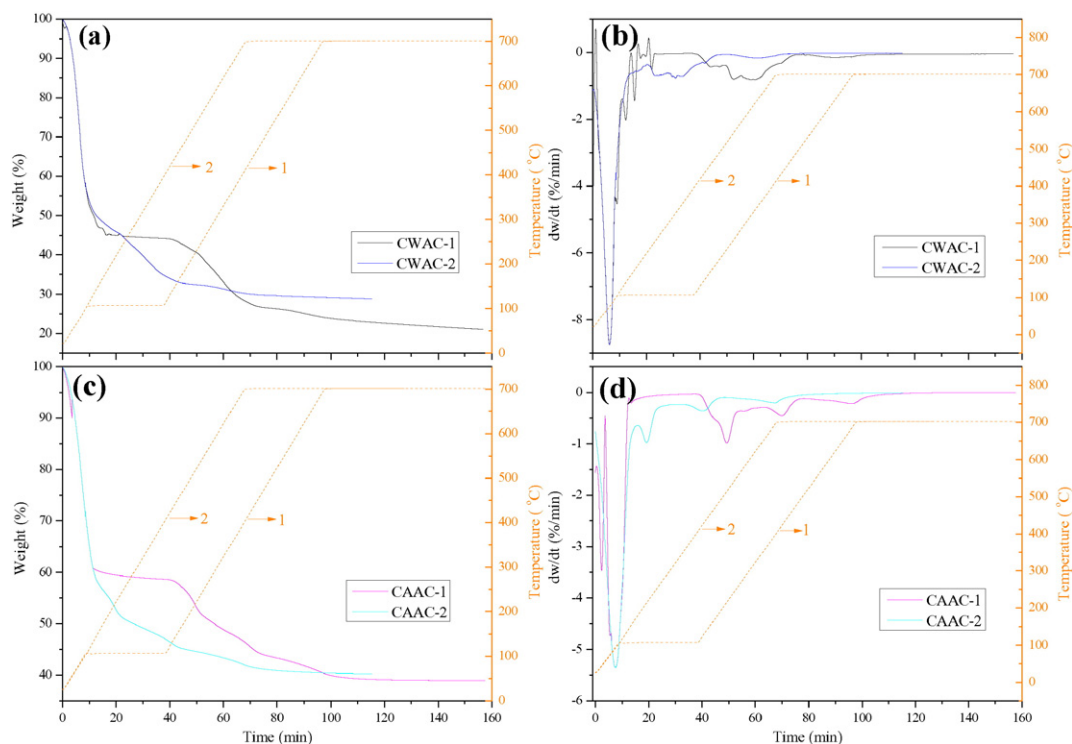


Fig. 1. TGA and DTG diagrams for CW- K_2SiO_3 and CA- K_2SiO_3 in N_2 atmosphere.

(CW) and *Cyperus alternifolius* (CA) on developing functional groups for both ACs, textural properties of ACs were analyzed and probed.

2. Materials and methods

2.1. Synthesis of the AC

All the chemicals used in this study were analytical reagents, and deionized water was used as the experimental water. CW used in this study was obtained from a local leather factory, and cut into 5 mm length for further study. CA was acquired from artificial wetlands in Weishan, Shandong Province, China. Before preparing AC, CA was first

washed with distilled water and then grounded into particle size in the range of 0.25–0.425 mm.

Two different kinds of ACs were produced by K_2SiO_3 activation with varying impregnation ratios (IR) of 1:1–3:1 (g K_2SiO_3 :g CW/CA). One sample was impregnated at room temperature for 12 h, then heated from room temperature to 105 °C and maintained for 30 min. The samples were placed into a tube furnace, then heated to the desired temperature (400–800 °C) at a same heating rate (15 °C/min) under N_2 atmosphere (100 mL/min) and kept at that temperature for 1 h. The ACs are referred to as CWAC-1 and CAAC-1, and the best preparation condition was determined by acquiring the properties of ACs. Thus, another mixture of K_2SiO_3 and CW/CA with the best impregnation ratio (2:1) was only dipped for 12 h at room temperature, and then activated

Table 1
Surface areas and pore volume of ACs produced by CW under different conditions.

AC	Activation temperature (°C)	Impregnation ratio (IR)	S_{BET} (m ² /g)	S_{mic} (m ² /g)	V_{tot} (cm ³ /g)	V_{mic} (cm ³ /g)	V_{mic}/V_{tot} (%)	D_p (nm)
CWAC	400	2:1	8		0.072	0.0024	3.33	14.749
	500	2:1	657		0.337	0.2837	84.18	2.046
	600	2:1	802	632	0.494	0.315	63.77	2.460
	700	2:1	1965	1462	1.345	0.7954	59.14	2.646
	800	2:1	4		0.039	0.0016	4.10	35.617
CWAC	700	1:1	33		0.099	0.0109	11.01	10.005
	700	1.5:1	1566		0.855	0.6609	77.30	2.145
	700	2:1	1965	1466	1.345	0.7954	59.14	2.646
	700	2.5:1	1820	1462	1.176	0.7462	63.45	2.488
	700	3:1	339	205	0.594	0.1373	23.11	6.980
CWAC-2			419	269	0.394	0.162	41.12	3.649

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