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Short Communication

Production and Characterization of Activated Carbon Using Indigenous Waste Materials

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Abstract. Activated carbon was produced from shisham wood and coconut shell through chemical activation, using phosphoric acid and low temperature carbonization. Proximate analysis and characterization of the product were carried out and Brunauer Emmett Teller (BET) surface area, total ash content, moisture content, pH value and iodine number were determined. The product characteristics were well comparable with those of the commercially available activated carbon.

Keywords: waste material, activated carbon, chemical activation, carbonization

Activated carbon can be produced from different raw carbon sources such as lignite, peat, coal, wood, sawdust, bagasse, and coconut shells. Earlier researchers utilized eucalyptus bark (Patnukao and Pavasant, 2008), flax shive (Marshall *et al*., 2007), date stone (Haimour and Emeish, 2006), hardwood (Lima *et al*., 2004), almond shell, pecan shell (Bansode *et al*., 2003) and coal (Jagtoyen *et al*., 1992) as precursor for production of activated carbon. Despite many related studies, there is little information available on the preparation of activated carbon using shisham wood as the precursor.

In principle, the methods for preparing activated carbon can be divided into two categories: physical activation and chemical activation (Narbaitz and Karimi-Jashni, 2009). In the physical activation, the raw material is first carbonized and then activated by steam or carbon dioxide, air or their mixture. The carbonization temperature ranges between 400 and 850 ºC, and the upper limit being sometimes 1000 ºC, whereas the activation temperature ranges between 600 and 900 ºC. In the chemical activation method, the raw material is impregnated with an activating agent and then heat-treated under inert atmosphere. The carbonization step and activation step are carried out simultaneously in the chemical activation process, with the precursor being mixed with chemical activating agents as dehydrating agents and oxidants (Moreno-Piraján *et al*., 2010). Investigations have been extensively conducted to elucidate the mechanism of phosphoric acid activation (Al-Qaessi and Abu-Farah, 2010; Lim *et al*., 2010). In the present study, activated carbon was produced from locally available waste materials i.e., coconut shell and shisham wood through chemical activation method. The product was characterized and characteristics were compared with the activated carbon commercially available in the market.

Initially, raw samples were washed with the hot water (50-60 ºC), dried in oven and then soaked in 30% phosphoric acid (H_3PO_4) overnight (Saleem *et al*., 2010; Masood-ur-Rehman, 2008). Later the samples were again dried in oven, poured in steel cylinders and placed in furnace for 45 min. The resulting material was cooled, washed with hot water to neutralize, dried in oven and stored in air-tight bottles for further characterization.

Characterization was carried out on the basis of volatile matter,fixed carbon, total ash content (ASTM D2866-94), moisture content (ASTM D4933-99), pH value (ASTM D3838-05) and iodine number (ASTM D4607-94). Surface area of the activated carbon was characterized by a physical technique involving nitrogen adsorption at 195.6 ºC, Brunauer Emmett Teller (BET) surface area.

Results of the proximate analysis of both the types of activated carbon are presented in Table 1, which show that properties of both are comparable with those supplied commercially at international level (Zakwan, 2010). Especially, low values of moisture content and volatile matter endorse the good quality of the produced activated carbon. The results of the product relating to BET surface area, Iodine number, moisture content, ash content and pH value and typical values of powdered activated carbon (PAC) and granular activated carbon (GAC) are also shown in Table 1 and are compared with the characteristics of activated carbon reported in

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Table 1. Characteristics and comparison of produced activated carbon (AC) with commercially available activated carbon and with typical values available in literature

Parameters	Proximate analysis (dry basis)			Detailed analysis			
	Shisham wood AC	Coconut shell AC	Commercial coconut AC	Shisham shell[a] wood AC	Coconut shell AC	Typical values[b] PAC	GAC
Volatile mater (%)	0.4	1.9	12.0	-	-	-	-
Fixed carbon (%)	88.4	82.8	75.0	-	-	-	-
Ash content (%)	7.1	8.7	3.0	-	-	≤ 6	≤ 8
Moisture content (%)	4.1	6.6	12.0	-	-	3-10	2-8
BET surface area (m^2/gm)	-	-	-	812	735	800-1800	700-1300
Iodine number (mg/g)	-	-	-	940.7	819.7	800-1200	600-1100
pH value	-	-	-	7.9	8.3	6 - 8	6 - 8

[a] = CV. Zakwan, 2010; [b] = specific values will depend on the source material used for the production of activated carbon (Metcalf and Eddy, 2003).

Table 2. Comparison of indigenous coconut shell GAC with commercial coconut shell AC

Parameters	Indigenous coconut shell AC	Commercial coconut shell AC[a]				
		QAC-400	QAC-600	QAC-800	QAC-1000	QAC-1200
BET surface area (m^2/g)	735	400	600	800	1000	1200
Iodine number (mg/g)	819.7	400	600	800	1000	1200
pH	8.3	9-10	9-10	9-10	9-10	9-10
Ash content (%)	8.7	6	6	5	5	5
Moisture content (%)	6.6	5	5	5	5	5

[a] = Quantum Activated Carbon Pvt Limited (manufacturer and exporters of activated carbon), New Delhi, India.

the literature. A detailed comparison of GAC produced from indigenous coconut shell is also made with the five commercially produced activated carbon in Table 2 (a commercial product of Quantum Activated Carbon Pvt. Limited, India).

BET surface areas of coconut shell and shisham wood was found to be 735 m^2/g and 812 m^2/g, respectively. The values are comparable with those reported in the literature. Activated carbon produced from shisham wood and coconut shell had ash content of 7.1% and 8.7%, respectively (Table 1), which are slightly higher than the typical values reported in the literature. This may be attributed to higher heating rate (i.e. 600 ºC) and impregnation ratio (i.e. 1:1.7), as depolymerization reactions between the volatile materials and phosphoric acid during the carbonization are affected. However, this parameter may be improved by lowering the heating rate and adjusting the impregnation ratio (Masood-ur-Rehman, 2008). The moisture content of shiham wood and coconut shell samples (i.e. 4.1% and 6.6%, respectively) are comparable with the typical values of PAC and GAC found in the literature. Furthermore, these values are also comparable with the PAC available in the market (Table 2). The final pH of the products was within the range of pH of commercially available activated carbon (i.e. 8.3 and 7.9). Similarly values of iodine number in the present study for coconut shell and shisham wood activated carbon were 819.7 mg/g and 940.7 mg/g, respectively, as compared to the typical values mentioned in Table 2 (600 to 1200 mg/g) and with the values of commercial grade activated carbon (400 to 1200 mg/g).

Thus both the products meet the typical values for powdered and granular activated carbon. Moreover, values of the indigenous coconut shell activated carbon compare well with the commercial coconut shell activated carbon available in the market. The results suggest that shisham wood is a suitable precursor for activated carbon production with higher BET surface area than that from the coconut shell. The conversion of shisham wood and coconut shell to activated carbons offers significant potential for reducing the cost and the environmental damage, resulting from uncontrolled disposal of these residues.

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