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Optimization and characterization of sliced activated carbon prepared from date palm tree fronds by physical activation

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ABSTRACT

Sliced activated carbons were prepared from palm tree fronds, a biomass material, using a single step physical method. Effect of the synthetic parameters on the surface area, pore size and pore volume of the activated carbon were studied, pursuing by the optimization of studied parameters. The activation temperature, heating ramp rate, reaction vessel pressure and the CO_2 flowrate were found to be the influential parameters for the synthesis of sliced activated carbon with larger porosity and surface area. The optimum conditions to synthesize the porous activated carbon bearing high pore volume and surface area were studied and identified. Highest surface area of 1094 $m^2\ g^{-1}$ was achieved under the optimum conditions. Scanning electron microscopy (SEM) for the porosity and Fourier transform infrared spectroscopy (FTIR) for surface functional groups and transmission electron microscopy (TEM) confirms the presence of uniform nanoparticles of 2.1385 nm.

1. Introduction

Kingdom of Saudi Arabia produces15% of the total date production and is considered as a major date producer in the date producing countries. Around 75,000,000 Kg of date tree residues in the form of fronds, foliar and thorns were produced during pruning of the trees [1].

Variety of carbonaceous materials has been used for the synthesis of activated carbon using agricultural waste [2–7]. Two methods for the activation of biomass has been reported; physical and chemical activation procedure, however the chemical activation procedure is considered inefficient procedure as far as economical and environmental aspects are concerned. There are very few research papers published to date on the physical activation of biomass using the CO_2 and steam. Physical activation method is considered as cheaper and eco-friendly compared to chemical activation because of the disposal issues of toxic chemicals. In this study, a single-step carbonization and physical activation method was used. Initially the raw date palm tree fronds (precursor) are carbonized using grade N-5.0 Nitrogen (inert atmosphere) to produce chars, the resulting chars are than subjected to a mixture of grade N-5.0 nitrogen and carbon dioxide at high temperature to produce the sliced activated carbon (SAC) with well-developed porous structures. This physical activation method is widely used in industries to produce effective adsorbents. The important synthetic parameters like the activation temperature and the dwell time has already been studied and reported by using different precursors [8–10]. Variety of oxidizing gases like steam and carbon dioxide

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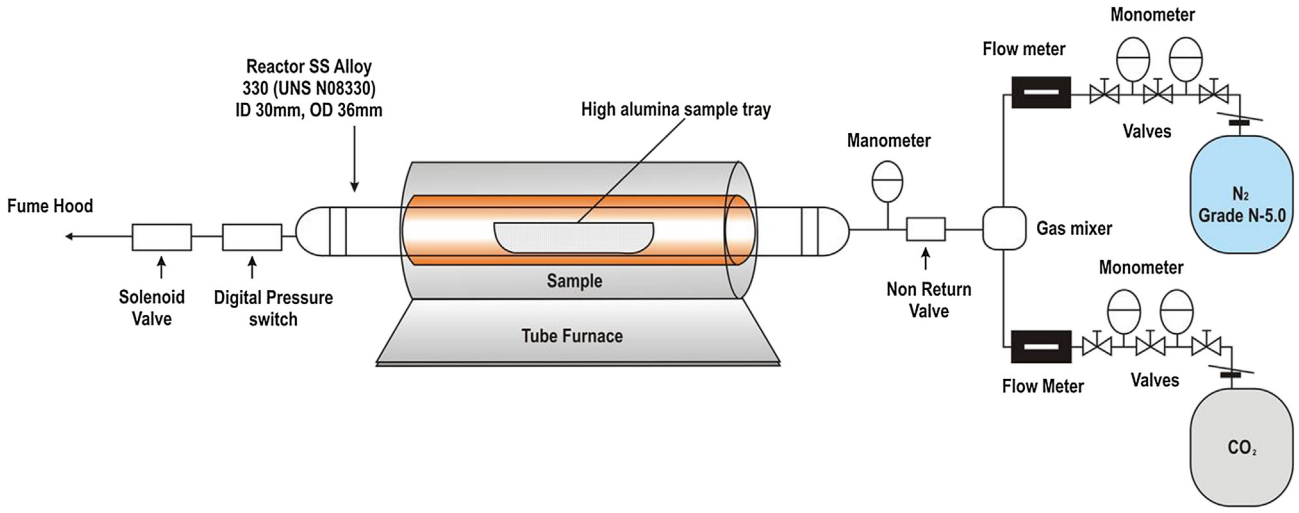

Fig. 1 – Scheme of activated carbon synthesized from date palm tree fronds by physical activation.

during activation of chars would have different impacts on the pore structures of the synthesized adsorbent. However, very limited research articles have studied the optimization of physical activation conditions parameters like activation temperature, dwell time, heating ramp rate, activation gas flow and reaction vessel pressure.

In continuation with the previous work carried out by our group [11–13], the objective of the study was to optimize different parameters for the synthesis of SAC from date palm tree fronds. Different parameters like activation dwell time, activation temperature, heating ramp rate, CO_2 flow rate and the reaction vessel pressure were studied and optimized to get the maximum pore volume and surface area.

2. Material and methods

Date palm tree fronds are used as raw materials for preparation of sliced activated carbons. The date palm trees are harvested in Agricultural Research farm of College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia. The geographical coordinate is 24°42′41″ N Latitude 46°37′15″ E Longitude. The site is characterized by hot desert climate, the overall climate is arid, and the city experiences very little rainfall, especially in summer, but receives a fair amount of rain in March and April. It is also known to have many dust storms. Sampling was made from Khudri cultivar having uniform vigor with a planting distance of 7 * 7 m. The soil was sandy-clay loam in texture with electrical conductivity (EC) 1,400,000 μ S m^{-1} and pH 7.6. Sampling was made from fourteen years old plant in the month of November–December 2013.

The pruned date tree fronds are dried under the sun and then the sufficiently dried fronds, are sealed in the plastic bag. In order to get rid from the moisture content present in the date palm tree fronds, the precursor was dried at 110 K in an oven for 8 h. Slicing were carried out by holding the dried fronds in a vice mounted on table followed by the cutting through the Power Tools Forward Professional JIGSAW FJS-80/900 JIGSAW cutter. The built-in gauge in JIGSAW cutter facilitates to the even size slices of 2–3 mm thickness. The sliced pieces are then stored in desiccator. Pyrolysis and physical activation of the dried/sliced precursor were carried out in a horizontal stainless-steel (S.S) tube alloy 330 reactor (UNS N08330) having ID 30 mm, OD 36 mm from Sandmeyer steel company, which was placed in a Carbolyte tube furnace MTF 12/38/250. Four g of sliced precursor was placed in high alumina sample tray to prepare the chars. 150 cm^3 min^{-1} Grade N-5.0 nitrogen gas (99.999%) was purged through the reactor right from the start of the pyrolysis process. The furnace temperature was raised from room temperature to a specified temp, when the furnace temperature was achieved the activation gas carbon dioxide was introduced as shown in the Fig. 1. After activation the furnace was cooled down to room temperature using Grade N-5.0 (99.999%) nitrogen gas.

3. Results and discussion

3.1. *Proximate analysis and chemical composition of date palm tree fronds*

Proximate analysis of date palm tree fronds was conducted as per the method [14]. The method was effectively applied to

Table 1 – Properties of the date palm tree fronds.

Proximate analysis (mass%)				Chemical composition (%)		
Volatile	Moisture	Ash	Fixed carbon	Cellulose	Hemicellulose	Lignin
74.6	9.1	6.0	10.3	44	29.8	26.2