

CARBONIZATION TEMPERATURE EFFECT OVER ACTIVATED CARBON POROSITY DERIVED FROM INDUSTRIAL PROCESSING WASTE

Hasan Saygılı

Department of Petroleum and Natural Gas Engineering, Faculty of Engineering and Architecture, Batman University, 72100 Batman, Turkey

Abstract

The influence of carbonization temperature (CT) on pore properties of the prepared activated carbon using lentil processing waste product (LWP) impregnated with potassium carbonate was studied. Activated carbons (ACs) were obtained by impregnation with 3:1 ratio (w/w) K_2CO_3 /LWP under different carbonization temperatures at 600, 700, 800 and 900 °C for 1h. Activation at low temperature represented that micropores were developed first and then mesoporosity developed, enhanced up to 800 °C and then started to decrease due to possible shrinking of pores. The optimum temperature for LWP was found to be around 800 °C on the basis of total pore volume and the Brunauer-Emmett-Teller (BET) surface area. The optimum LWPAC sample was found with a CT of 800 °C, which gives the highest BET surface area and pore volume of 1875 m²/g and 0.995 cm³/g, respectively.

Key words: Lentil processing waste product, activated carbon, carbonization temperature, porosity

1. Introduction

ACs are carbonaceous nanoporous materials with a well-developed porous structure that are widely used for the adsorption of numerous environmental pollutants, gas separation, heterogeneous catalysis, gas storage, gas masks, and so on. [1, 2]. Although activated carbons are productive for industrial use, their production costs remain expensive. In recent years, researchers have focused on finding cost effective alternatives to the production of activated carbon [3]. In recent years, the development of environmentally friendly technologies and the concept of a circular economy have promoted the use of waste for the production of valuable materials. AC produced from organic waste can be competitive and perform better than commercial activated carbon (usually made from wood). In this context, LWP, the main manufacturing residue, could potentially be used to produce AC [4].

Worldwide, 4.9 million tons of lentil are produced each year, most of them from Canada, India and Turkey. According to the Ministry of Food, Agriculture and Livestock, about 400.000 tons of lentil are produced each year in Turkey. Lentil manufacturing involves various processing steps such as cleaning, peeling, splitting and grinding. During the production phase in amounts of 4 to 10% as impurities 8 to 12% are formed as lentil flour and 7 to 10% as lentil bran. Namely, from 100 kg of unprocessed lentil, a lentil having a content of 68-81% is obtained. With an optimistic estimate of 20% waste biomass, the projected lentil waste in Turkey alone can reach 80.000 tons. This high volume of waste creates an environmental problem and its reuse is useful. One of the

*Corresponding author: Address: Faculty of Engineering and Architecture, Batman University, 72100 Batman, Turkey. E-mail address: hasan.saygili@batman.edu.tr, Phone: +904882173770

ways to eliminate this large amount of waste is to use it as a source for the production of carbonaceous material, such as activated carbon, which is widely used in industry for many applications [5].

Typically, two different processes, physical activation and chemical activation, are used to produce activated carbon. Chemical activation has two major advantages over physical activation. First, the process of chemical activation is achieved at lower temperatures, while the physical activation process requires higher temperatures. On the other hand, the yield in the chemical activation is higher, since the burning of char is not required. During chemical activation, various chemicals were used, such as K_2CO_3 , $ZnCl_2$, H_3PO_4 , KOH , $CaCl_2$, Na_2SO_4 , and H_2SO_4 . Among the chemical reagents, K_2CO_3 was one of the most preferred chemicals in the production of activated carbon by chemical activation methods, since K_2CO_3 tends to improve the development of pores in the structure of activated carbon and a high carbon yield is achieved [6].

The purpose of this study is to investigate the influence of carbonization temperature to manufacture activated carbon from the agricultural byproduct LWP. Process parameter, such as carbonization temperature on system performance and the pore characteristics of resulting activated carbon are examined in this paper.

2. Materials and Method

2.1. Chemicals and biomass

Potassium carbonate (K_2CO_3) and hydrochloric acid (HCl) were purchased from Sigma-Aldrich, Turkey. LWP was donated by lentil factory at Batman in Turkey. LWP was used for this study due to its wide availability in Turkey.

2.2. Carbonization/Activation step

The LWP was washed with boiled water to remove impurities, dust and water-soluble substances, followed by washing with distilled water. The washed LWP is dried in an oven at 70 °C for 24 h. AC was prepared by activating LWP with K_2CO_3 at MW energy. Optimized conditions for alternating current from LWP were determined by studying the effect of the carbonization temperature on porosity at various temperature values (600, 700, 800, and 900 °C). At each stage, LWP mixed with K_2CO_3 (impregnation ratio (IR, 3:1, $w_{K_2CO_3}/w_{LWP}$)) was activated for 30 seconds at MW energy and then introduced into a horizontal stream of nitrogen. The inert nitrogen flow was set at a rate of 100 ml/min, and the heating rate for all samples was constant at 10 °C/min. After completion of the carbonization process (carbonization time (1 h)), the produced ACs were cooled to room temperature in an inert atmosphere, and the final products were refluxed with 0.2 N HCl, and then washed with distilled water until the pH of the filtrate reached 6-7. Finally, the washed ACs were stored in an oven at 105 °C for 24 h and stored in glass bottle.

3. Results and Discussion

The effect of CT from 600 to 900 °C on specific surface area (S_{BET}) and total pore volume (V_T) is shown in Figure 1 and discussed in Table 1. S_{BET} increased rapidly from 562 to 1875 m^2/g when the temperature was increased from 600 to 800 °C. This increase can occur due to the decomposition of hemicellulose, cellulose and lignin in LWP with increasing temperature, which leads to the opening of previously inaccessible pores and to the formation of new pores. However, a tendency to decrease above 800 °C was also observed. It can be assumed that the decrease in S_{BET} from 1875 to 1766 m^2/g is due to the accumulation of an activating agent in the pore walls, causing a reduction or collapse of the pores at high CT. In addition, we noted that V_T followed the same trend. V_T rapidly increased from 0.257 to 0.995 cm^3/g and raised the temperature from 600 to 800 °C. This finding shows that the pore opening and pore widening effects occur in pores with an increase in CT [7]. However, as CT increases above 800 °C, high molecular weight volatiles are liberated from LWP at high temperatures, resulting in sintering and shrinkage of the pores, leading to a decrease in V_T [8]. Therefore, a temperature of 800 °C was chosen as optimal CT.

Table 1. The experimental runs and obtained pore characteristics results of ACs produced from LWP

Run	Production conditions			Pore characteristics						
	IR ^a (g g ⁻¹)	CT ^b (°C)	Ct ^c (h)	S_{BET} (m ² g ⁻¹)	V_T (cm ³ g ⁻¹)	V_{mic} (cm ³ g ⁻¹)	V_{mic} (%)	V_{mes} (cm ³ /g)	V_{mes} (%)	D_p (nm)
<i>Effect of carbonization temperature (°C)</i>										
1	3:1	600	1.0	562	0.257	0.212	82.5	0.045	17.5	1.80
2	"	700	"	1034	0.468	0.375	80.1	0.093	19.9	1.80
3	"	800	"	1875	0.995	0.300	32.0	0.636	68.0	1.97
4	"	900	"	1766	0.936	0.160	41.6	0.835	83.9	2.24

^aIR: Impregnation ratio; ^bCT: Carbonization temperature; ^cCt: Carbonization time

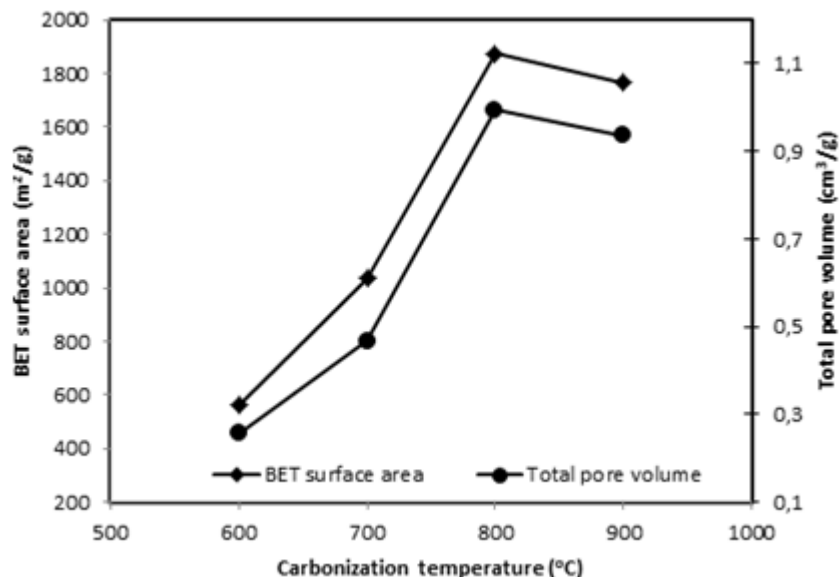


Figure 1. Effect of carbonization temperature on AC porosity.

Conclusions

In the present work the biomass waste product of lentil was used as precursor for AC production. The activation process was performed using impregnation ratio 3:1 and carbonization time 1 h at different temperatures (600-900 °C). The results showed that varying of the carbonization temperature from 600 to 800 °C had a significant influence on pore properties of AC.

References

- [1] Marsh H, Rodriguez-Reinoso F. Activated Carbon. 3st ed. Elsevier Science, 2006.
- [2] Bandosz TJ. Activated Carbon Surfaces in Environmental Remediation. Elsevier Science, 2006.
- [3] Üner O, Bayrak Y. The effect of carbonization temperature, carbonization time and impregnation ratio on the properties of activated carbon produced from *Arundo donax*. Microporous Mesoporous Mater 2018;268:225-34.
- [4] Gonçalves M, Castro CS, Boas IKV, Soler FC, Pinto EC, Lavall RL, Carvalho WA. Glycerin waste as sustainable precursor for activated carbon production: Adsorption properties and application in supercapacitors. J Environ Chem Eng 2019;7:103059-69.
- [5] Saygılı H, Saygılı GA. Optimized preparation for bimodal porous carbon from lentil processing waste by microwave-assisted K₂CO₃ activation: Spectroscopic characterization and dye decolorization activity. J Clean Prod 2019;226:968-76.
- [6] Yahya MA, Al-Qodah Z, Ngah CZ. Agricultural bio-waste materials as potential sustainable precursors used for activated carbon production: A review. Renew Sustain Energy Rev 2015;46:218-35.
- [7] Lua AC, Lau FY, Guo J. Influence of pyrolysis conditions on pore development of oil-palm-shell activated carbons. J Anal Appl Pyrolysis 2006;76:96-102.

- [8] Zhou L, Yu Q, Cui Y, Xie F, Li W, Li Y, Chen M. Adsorption properties of activated carbon from reed with a high adsorption capacity. *Ecol Eng* 2017;102:443-450.