Production of Activated Carbon from Waste Bamboo Biochar by Zinc Sulphate Activation

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Abstract

This study aimed to produce the activated carbon from agricultural waste which were bamboo scraps in order to promote agricultural waste utilization in community. In this study, bamboo biochar was prepared in conventional furnace. Then activated carbons were produced from bamboo biochar by chemical activation with zinc sulphate ($ZnSO_4$) at 500 °C under anaerobic condition and their absorption capacity was demonstrated with iodine number using ASTM D4607 standard. The bamboo biochar produced by the community in Rayong province had an iodine number of 202.84 (±71.99). When compared to the commercial activated carbon analyzed by the same method, which had an iodine number of 1121.90 (±4.96), it cannot be classified as activated carbon. For the chemical activation process, zinc sulphate was first used instead of commonly used zinc chloride. The carbonization was carried out at 500°C, under anaerobic condition. The modified biochar had an iodine number of 507.75 (±5.71), significantly higher than the biochar before activation, demonstrating its potential as an activated carbon.

Keywords: Activated carbon, Biochar, Charcoal, Activation, Bamboo

1. Introduction

Activated carbon is a porous carbon material with developed nano-sized pores and a high specific surface area (>1,000 m2g−1). Activated carbon can be produced from coal or environmental wastes with high carbon content followed by an activation step in order to improve its adsorption. The porous structure, along with the high surface area and the presence of free electrons on the surface and within the pores, enhances the adsorption efficiency of activated carbon, allowing it to effectively adsorb substances in both gas and liquid forms. Consequently, activated carbon is utilized in several application including adsorption, pollutant removal, water treatment and production of biofuels (Kayee, 2019, Paripinichai, 2021).

Biomass is regarded as carbon neutral since the carbon dioxide released from biomass is offset by the carbon absorption that takes place during photosynthesis. Thermochemical decomposition processes convert biomass materials to syngas, bio-oil, and biochar. Nowadays, sustainable circular bioeconomy has gained great attention, enabling the transformation of biobased sectors, including the agri-food sector, to support sustainable economic growth and development.

The carbon content of plants ranges from 35-70%. Bamboo has the ability to manufacture carbon raw materials because it contains 47.43% carbon. Bamboo grows quickly, which is a benefit when using it as a raw material for activated carbon. The old stems can be cut and used for burning charcoal continuously. It is appropriate for burning porous charcoal due to its high fiber content and porosity.

Agricultural waste in Thailand, including bamboo scraps, totals as high as 43 million tons. Using it to make activated carbon will increase the value of agricultural waste and decrease waste production. In this research, the production of activated carbon from waste bamboo scraps was investigated to improve the charcoal production process of community in Rayong province to produce more valuable products from agriculture waste.

Figure 1: (left) Waste bamboo scraps, (middle) conventional furnace at bamboo garden in Rayong province and (right) bamboo biochar

1.1 Research Objectives

1. Assessment of iodine number of bamboo biochar production from community in Rayong province

2. Preparation of activated carbon from bamboo biochar by chemical activation using Zinc sulphate

2. Methods

2.1 Preparation of bamboo biochar

The raw materials bamboo scraps were collected from bamboo garden in Rayong province, Thailand. For pyrolysis, the bamboo scraps were placed in conventional furnace overnight at around 500 °C under anaerobic condition. The produced biochar was grounded into fine particles and stored in storage bag.

2.2 Preparation of activated carbon

Bamboo biochar was ground and soak in 1%$ZnSO_4$ for an hour and dried an room temperature overnight. The modified charcoal was subsequently dried at 105°C for 1 h to remove moisture content. The dried charcoal was loaded in a clay pot and covered with rice husk before placed in a furnace. Carbonization step was carried out at 500°C for 3 h under anaerobic condition. Then the adsorption capacity of activated carbon for iodine was determined using ASTM D4607 standard.

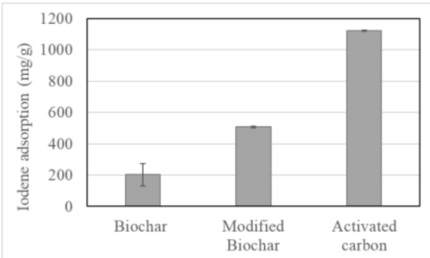
2.3 Result and Discussion

The adsorption capacity of community biochar, modified biochar and commercial activated carbon was shown in Table 1 and Fig. 2 as iodine numb

Table 1: The adsorption capacity of community biochar, modified biochar and commercial activated carbon determined by ASTM D4607 standard

Sample	**Iodine adsorption** (mg/g)
Biochar	202.84±71.99
Modified Biochar	507.75±5.71
Activated carbon	1121.90±4.96

Figure 2: Iodine adsorption value of community biochar, modified biochar and commercial activated carbon determined by ASTM D4607 standard

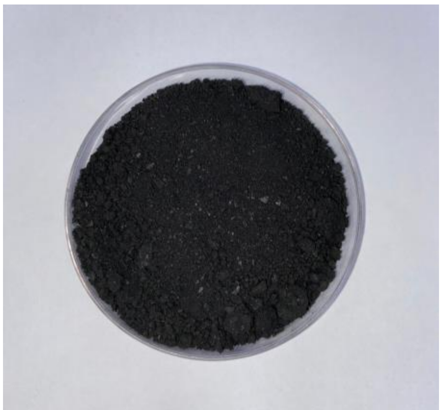


From the result, we found that the charcoal produced by the community in Rayong province had an iodine number of 202.84 (±71.99). The commercial activated carbon analyzed by the same method had an iodine number of 1121.90 (±4.96). Typically, the retention rate of iodine by activated carbon varies between 500 - 1200 mg/g which is approximately equivalent to an adherence surface of 900 to 1100m2/g and the standard criteria of activated carbon according to the industrial product standard for activated carbon (TIS 900-2547) is not less than 600, the charcoal produced by the community, therefore, has a comparatively low surface area.

The methods of activation can be categorized into chemical and physical activation. However, chemical activation is more cost-effective because it takes place at low temperatures and in a comparatively short time. In chemical activation, the carbonaceous material is mixed and impregnated with chemical agents such as phosphoric acid, zinc chloride, potassium tartrate, potassium hydroxide, etc. prior to one-step pyrolysis at temperatures of 400 °C to 600 °C under inert atmosphere.

Physical activation applies a pyrolysis at high temperature, ranging between 700 °C and 1000 °C under oxidizing condition in the presence of oxygen, steam and/or carbon dioxide. The decrease in surface area at higher temperature could be attributed to the expansion and collapse of micropores to mesopores, and the break of crosslinked structure under strong gasification (Yahya et al., 2015). In chemical activation, the liquid chemical is intercalated into the carbon matrix to create pores at temperatures beyond the melting point of the chemical agent. Hence, it can take place at lower temperature than physical activation to prevent the collapse of micropores (Hock, 2018). In this study, zinc sulphate was first used instead of commonly used zinc chloride. The carbonization was carried out at 500°C, under anaerobic condition. The modified charcoal had an iodine number of 507.75 (±5.71), significantly higher than the biochar before activation and meet the standard of activated carbon. The modified biochar has black color as shown in Fig.3.

Figure 3: $Zn(SO)_4$ modified Bamboo Biochar



3. Conclusion

In this study, the production of activated carbon from waste bamboo scraps was investigated. The result showed that the charcoal produced by the community in Rayong province had low adsorption capacity and cannot be classified as activated carbon. When activated using zinc sulphate, the modified charcoal had higher iodine number, demonstrating its potential as an activated carbon.

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