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To cite this article: S Muzarpaar *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **877** 012030

IOP Conf. Series: Materials Science and Engineering **877** (2020) 012030 doi:10.1088/1757-899X/877/1/012030

Reliable Method and Multistage Process Involved in the Production of Activated Carbon Based on Raw Material- A Systematic Review

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Abstract. Activated carbon AC) has versatile usage in the modern days for water treatment, air filtration and for multipurpose adsorption. Carbonaceous material with highly developed porosity known as AC after some process took place. AC also known as artificial materials characterized by the high surface area and the extensive surface chemistry. Significant adsorptive properties of the materials according to extensive surface chemistry which are responsible for the surface properties. Nowadays, AC are widely used in a large range of applications, for example medical uses, catalysis, gas storage, removal of pollutants and odors, gas separation and purification. Important Character for based materials of AC, it must accessible, affordable price, and with valorization potential in agricultural residues and industrial base. The most important raw materials for the production of AC is lignocellulosic materials. Over the time researcher around the world conducting research to improvised and perfecting the method for producing the AC. The aim of this paper is to critical review the reliable method for AC production. The process involved in the production of activated were pre- carbonization process (PCP), carbonization process (CP), and activation process (AP). Carbonization either using furnace or microwave. For AP, there are two main activation used namely chemical activation CA) and physical activation (PA). However there also combination of chemical and physical activation which called physiochemical activation (PCA).

1. Introduction

Activated carbon (AC) has versatile usage in modern days for water treatment, air filtration and also for multipurpose adsorption applications. AC is a carbon-based material that undergoes several types of process which eventually develop high porosity that could be function as adsorbent and catalyst [1]. João M. Valente Nabais et al. stated that, AC are materials which characterized by mean of high surface area with weak van der waal's forces surrounding them [2]. Nowadays, AC become the high significant usage and widely used especially in the area of medication, pollutant and odour removal, catalysis, gas storage, separation of gas and purification. Characteristic for based materials of AC must affordable, accessible

and with valorization potential, such as agricultural residues and industrial [3]. The production of 300,000 tons/year of AC were reported, as the result of corresponding usage of this material. General domestic application, metal ore processing, and removal of both organic and inorganic trace contaminants makes AC considered as one of the best available technology for this particular area [4].

2. Production flow process of activated carbon

There is a lot of technique to make an AC, but the common process is shown in Figure 1.

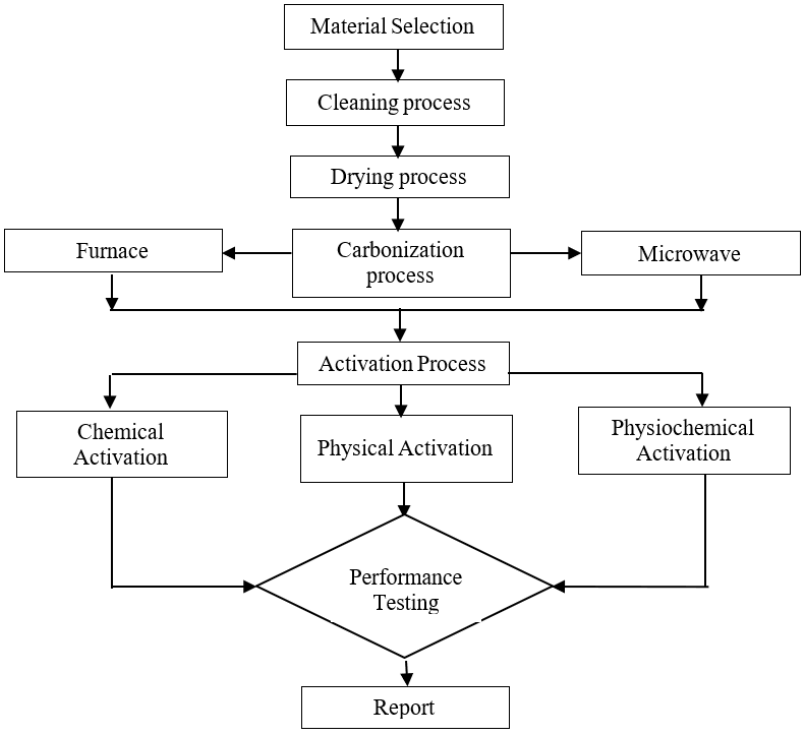

Figure 1. The general flow process of activated carbon production.

2.1. Pre- Carbonization process

Pre carbonization process (PRB)is an optional process. The process include in pre carbonization process were, raw material selection, material cleaning, and drying the material before proceed with the carbonization process. To remove the excessive dirt that stick to the material surface, the raw materials were cleaned intensively by using distilled water. The precursor then heated at 110 ºC until dried, with sized of 4 mm [5] For material selection, certain criteria should be followed such as the availability of material and cost of material. Meanwhile drying of the material before carbonization process will helps in reducing the moister content [6].

2.2. Carbonization/ burning process of activated carbon

Carbonization process (CP) was describe by many researchers as the process of burning the raw materials with specific temperature to convert them into charcoal. CP could be done either using furnace, microwave or any device that generate heat. Carbonization of any biomass will produce charcoal, that later on be activate using chemical reagent to obtain AC [7]. Charcoal or the carbon based can be retrieved throughout carbonization process in electrical tubular furnace at 450 ºC with a ramp temperature 10 ºC/min, after that it will be cooled to room temperature, washed and dried under vacuum at 70 ºC for the period of 24 hours [8].

2.2.1. Carbonization using furnace. The process of carbonization using furnace were the most dominant method for converting the raw material to charcoal. Usually this method involved in high

temperature usage under controlled environment. Continuous flow of nitrogen gas with the temperature of 700°C using vertical furnace were used to carbonize the agricultural wastes [9]. Before activation process, the precursor will leaved for a while in the furnace for cooling purposed. Hence, the carbon or charcoal were soak into activated agents such as H_3PO_4, HNO_3, K_2CO_3, NaOH or KOH [10].

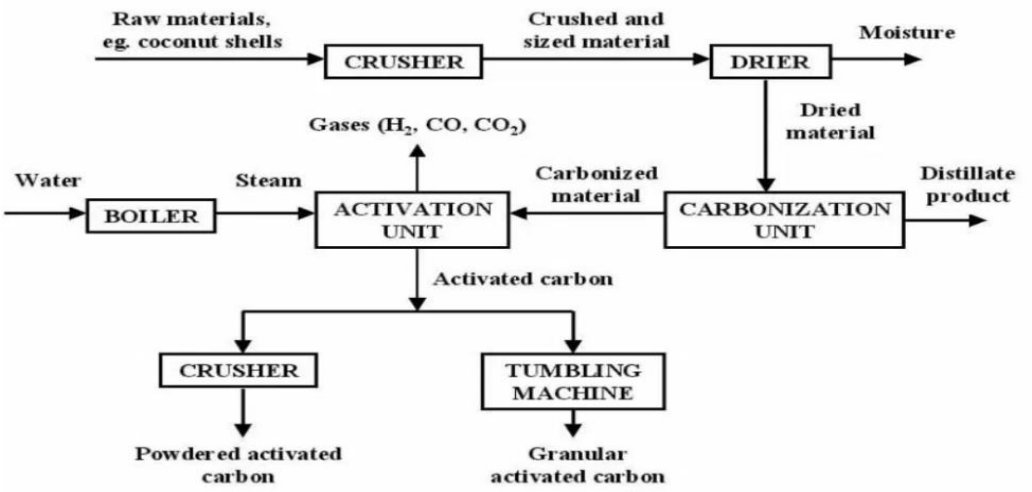

Figure 2. The process of AC using furnace with physical activation [13].

These processes were supported by other researcher which mention in production of AC the CP of the bamboo particles were heated to 500 ◦C [11]. Furthermore, to obtained large amount of charcoal, CP must be conducted with the absence of oxygen in temperature range between 600–900 °C, with the absence of oxygen. The absence of oxygen surrounding can be achieve by purging the inert gas such as argon or nitrogen inside the furnace [12]. Figure 2 show the process of AC furnace with physical activation.

2.2.2. Carbonization using microwave. Method for carbonization of carbon can be done using microwave [14]. Dipolar and interfacial polarization effect resulting from the material receiving energy. The process will determine the successful rate of dielectric mechanism. Dipolar polarization occurs when water molecule rotates and align in both permanent at certain frequency cause by the electric component of microwave. Microwave heating and heat loss were the result from molecular rotation and moving throughout the increase of friction and collision generated by molecule. Indication of volumetric characteristic and uniformity of microwave were generally describe as the higher of the induced polarity. It is the main and important characteristic for the influence of microwave [15, 16]. From the preliminary experiment the performance of different microwave heating time and temperature condition were selected. Recently, Microwave assisted pyrolysis for AC preparation commonly reported as a reliable process [17]. Shorter treatment time which is less than 10 minutes show the microwave heating advantages as compared to conventional heating, simultaneously reduce the energy consumption and expenses during the pyrolysis process [18,19]. The biomass will never have direct contact with the radiation sources using microwave heating [20]. Figure 2 show the Activated carbon Preparation conventional and microwave technique [21]. Figure 3 show the AC preparation using conventional and microwave technique.

3. Activation process

Activation of AC is a process whereby the enhancement of pore structure in AC, this pore will determine the adsorption of the AC. The higher the pore formation the higher the adsorption power. Activation process will highly determine the dependency of pore structure and adsorption properties of

AC [22]. Physical activation (PA) and chemical activation (CA) were the common method to produce AC. PA of AC consists of two steps. Elimination of oxygen and hydrogen content through carbon base pyrolysis material at high temperature with the absence of oxygen were the first step in PA. The second step involved is activation process.

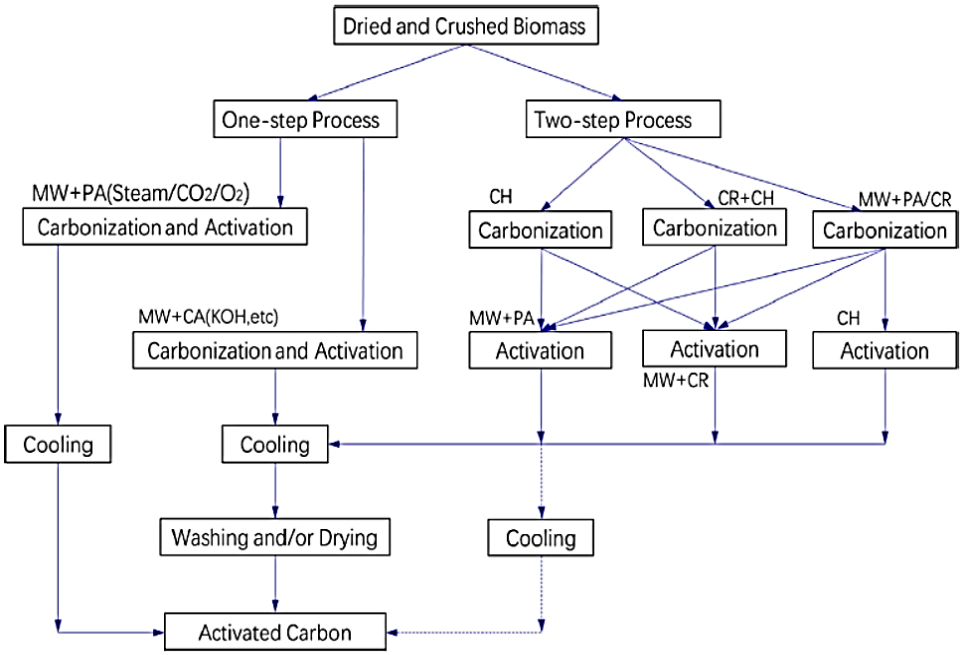

Figure 3. AC preparation using conventional and microwave technique [21].

The charcoal in the present of CO_2 or steam which will act as oxidizing agent at a certain high temperature. Throughout endothermic reaction, structure of porous of the carbon were extracted by these agents. The usage of gas phase entirely in these activation methods formally known as thermal or PA [23]. The example of PA reactions are as follow:

$$C + CO_2 \rightarrow 2CO \quad (1)$$

$$C + H_2O \rightarrow CO + H_2 \quad (2)$$

CA will generate porosity of carbon by mean of the treated of the material base with chemical reagent. It was followed by heat treatment during CP. For lignocellulosic and cellulosic ACs precursor, most common dehydrating agent were phosphoric acid and zinc chloride [24].Single step activation process at low temperature can be accomplish by carrying out thermal decomposition normally using dehydration agents. Among the necessary process for the ACs preparation were base and acid washing at first and last process respectively. Surface area and pore volume could be improved effectively by the base-leaching procedure. Residual activating agent could be cleaned using the acid-washing procedure [25]. Example of the reaction for chemical activation are as follow:

$$C + 2KOH \rightarrow 2K + H_2 + CO_2 \quad (3)$$

$$C + 2KOH \rightarrow 2K + H_2O + CO \quad (4)$$

$$CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O \quad (5)$$

Physiochemical activation (PCA) were the correlation process between PA and CA. These complex processes encourage formation of AC with different chemical characteristics and textural t from single activation method [26]. Pore blockage after washing due to eliminated chemical agent can be solved through PCA process. In order to promote the pore formation, present of steam and CO_2 was important using further gasification. The combination reaction are as follow:

$$CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O \quad (6)$$

$$H_2O + C + 2KOH \rightarrow K_2CO_3 + H_2 \quad (7)$$

3.1. Physical activation (PA)

PA of AC was conducted without using any chemical reaction there were many techniques for these types of activation. Due to low reactivity at high temperature PA make easier, the usage of CO_2 was preferred among researcher. $CO_2$and steam play different role in PA, CO_2 will excite the formation of microporosity whereas, the steam will encourage microporosity widening. Gasifying agent in PA plays a major role in development of the micropores structure depending on partial pressure and activation condition. For high grade of AC produced, both carbon dioxide and steam can be acting as suitable activation agent. [27]. Removing the oxygen during carbonization process at specific temperature by purging the inert gas can also be classified as PA].

3.2. Chemical activation (CA)

CA process were the most recognized among researcher in activating the carbon, this process occurs after the CP and involved the usage of chemical agent. Carbon containing materials usually activated using CA [28]. Process in CA begin with blending the precursor with chemical agent, then the material were heated to desired temperature for carbonization process with inert atmosphere. Dehydration and degradation of AC with the present of chemical agent helps to promote and develop the AC porosity. There were several types of chemical agent that can be used for activating the carbon such as KOH, NaOH, and $ZnCl_2$. Normally, considering the lower activation temperature the CA was preferable compared to PA. BET (Brunauer Emmett Teller) method determine that AC produce using CA exhibit high specific surface area with good pore formation and carbon yield [29]. Among the CA process, using KOH as chemical reagent will produce high micropore as compared to $ZnCl_2$ or H_3PO_4 activation.

3.3. Physical and chemical activation (PCA)

Combination of PCA would produce a better AC. Moreover, the complicated process makes these methods much difficult to produce the AC. However, this process proven to be the best method for producing the AC. It was reported that for methane adsorption, the efficient method was activating the palm oil shell using ZnCl2 followed by CO_2 stream for extra PA [30]. Alternatively, conventional method either PA or CA can be improvised by involving the CA raw material followed by PA process for better result. With using the horizontal furnace sample was activate under CO_2 at 800 ^oC in range of 1 to 5 hours and finally collected sample were cleaned with ionized water and dried at 100^oC for another period of 24h.

4. Conclusion

After review from the various source in, the information of reliable method of activated carbon production has been summarized. The process involved in the production of activated were pre-carbonization process, carbonization process, and activation process. Carbonization could be either using furnace or microwave. There are two main activation process respectively, physical activation (PA) and chemical activation (CA). Other than that there also combination of physical and chemical activation (PCA) which called physiochemical activation.

Acknowledgement
The authors express thanks to Faculty of Engineering Technology, University of Tun Hussein Onn Malaysia and UTHM Center for Graduate Studies (CGS). Also to Green Design and Manufacture Research Group, Center of Excellence Geopolymer and Green Technology (CEGeoGTech), UNiMAP.

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