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Use of empty fruit bunch as a potential raw material for the production of activated carbon

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ABSTRACT

Activated Carbons (ACs) are widely used as adsorbents for purification, separation and recovery purposes. The potential of AC in the removal of heavy metals such as Lead, Cadmium, Cobalt and Iron from industrial effluents is currently receiving a global attention without much consideration for the characterization and synthesis method due to their high adsorptive power. Empty Fruit Bunches (EFBs) contribute a greater percentage of solid waste and consequently become an environmental problem in palm oil producing area. These Empty Fruit Bunches tested positive as a potential raw materials for AC production. However, the best production method is not yet established. Various methods of activated carbon production and the effect of these methods on agricultural waste specifically EFB were understudied in this article. Suggestions were made based on the identified problems and finally, Empty Fruit Bunch is recommended for use in the production of activated carbon to reduce its effect as environmental pollutants.

KEYWORDS

Empty fruit bunches;
Activated carbon;
Toxic heavy metals;
Adsorption;
Contamination.

INTRODUCTION

Increases in waste matter generation caused by expansion of human activity pose a continuous growing in environmental pollution and contamination. Among the solid waste that is contributing to this problem is empty fruit bunches (EFB). EFB is a waste material obtained from oil palm after removal of the seeds. It is compose of 50% cellulose, 25% hemicellulose and 25% lignin. The composition of FEB which is carbon base has made it a good candidate for activated carbon production. There are currently a large number of studies regarding the use of several agricultural wastes to produce AC. Most of them focus on the use of waste materials of considerable rigidity, such as the shells and/or stones of fruits like nuts, peanuts, olives, dates, almonds, apricots and cherries; however, wastes resulting from the production of cereals such as rice, coffee, soybean, maize and corn as well as olive cakes, sugar cane and sugar beat bagasse, coirpith, oil-palm shell (from oil-palm processing mills) and various seed wastes were already used. The preparation of AC from these materials has been made using both physical activation and chemical activation. In a study by Ioannidou and Zabaniotou[11] an extensive revision regarding AC preparation from agricultural residues was made and the effects of different parameters regarding activation procedures are presented in TABLE 1. Effort is made in this work to study the application of EFB in the production of activated carbon so as to exploit its potential as a carbon source. This will in turn address its problem as a solid waste and environmental pollutant. Activated carbons are materials with high surface area and complex pore structure resulting from physical or chemical activation processes. The structure of an activated carbon is composed of pores classified into three groups, namely micropores, mesopores and macropores. Micropores usually account for over 95% of the total surface area of activated carbons. The volumes of the micropores range from 0.15 up to 0.6 cm^3 g^{-1}. Conventional activated carbons are tridisperse, having all three types of pores present within their structure. Adsorb-ate molecules penetrate through the wider pores and into the micropore structure. Activated carbon can be produced from different raw carbon resources ranging from industrial waste, agricultural and at times biomass. These include materials like lignite, peat, coal, and biomass resources such as wood, sawdust, bagasse, and coconut shells[11]. Activated carbons are widely used as industrial adsorbents for separation, purification, and recovery processes due to their highly porous texture and large adsorption capacity[7,15,23].

Toxic heavy metal contamination of the environment is a significant worldwide problem and conventional methods for removing toxic metals from contaminated water include chemical precipitation, chemical oxidation or reduction, ion exchange, adsorption, filtration, membrane technologies, and evaporation recovery[13,16,17,20,21]. These methods are highly expensive and the materials used sometimes have residual effect on the final product. Hence, application of activated carbon on removal of heavy metals is receiving global attention.

EMPTY FRUIT BUNCHES

Generally, Palm oil industry creates almost 14 million tonnes oil palm empty fruit bunches (EFB) per year. Empty fruit bunches (EFBs) (Figure 1) is a waste after the seeds are removed from oil palm fresh fruit bunch (Figure 2), and it is contributing a lot to solid waste and hence causes environmental pollution. In their raw state, EFBs are both fibrous and wet[26]. At present, the biomass is either left at the plantation to provide organic nutrients to the oil palm trees or burned illegally or used as solid fuel in the boiler to generate steam or electricity at the mills[14]. EFB has significant potential as a raw material to produce activated carbon[1].

Figure 1 : Oil palm empty fruit bunch

Figure 2 : Oil palm fresh fruit bunch

PRODUCTION OF ACTIVATED CARBON

Activated carbons are prepared by either physical or chemical activation[5,8]. Physical activation required suitable activating agent such as oxygen, steam, and carbon dioxide but steam and CO_2 are commonly used[24], while chemical activation involves impregnation of carbonaceous material with dehydrating agent prior to activation. The chemical agents used in the chemical process are normally alkali and alkaline earth metal containing substances and some acids such as KOH, K_2CO_3, NaOH, Na_2CO_3, $ZnCl_2$, $MgCl_2$ and H_3PO_4[22]. The raw materials are either source from agricultural (TABLE 1) or industrial waste. However, due to the abundance of agricultural waste, their low economic value combined with high percentage of carbon with low ash content has enriched their potential as a raw material for activated carbon when compared to industrial waste. Mostly waste from wood industries constitute the major industrial wastes used in the production of AC. Due to their particular porous characteristics, woody materials are very relevant and challenging raw materials to prepare AC, mainly for the adsorption of solutes in the liquid phase[28]. The waste from woody materials of different types such as cedar, fig, oak, as well as from tropical trees have already been used to produce activated carbon by either physical or chemical activation. Various reports on the use of woods and other agricultural wastes as raw materials for AC are presented in TABLE 2.

TABLE 1 : Preparation of activated carbons using agricultural wastes as raw material by physical activation

Raw Material	Activation Agent -Physical activation-	Relevant Issues	Reference
Cherry stone	Steam, CO2	Steam activation more effective than CO2 activation. Surface area: 1200m2 g-^{1}.	[19]
Corn cob	Steam, CO2	Microporosity was obtained using both agents. Surface areas of 1315m2 g_1 could be reached.	[6]
Corn stover	Steam	Corn stover activated carbons; there is no linear relationship between activation time and BET surface area. However, activation burn-off of and activation time appear to relate in a linear manner for the activated carbons produced from corn stover char.	[9]
EFB	CO2	The activated carbon produced from empty fruit bunch at 800°C showed a good adsorption capacity for phenol removal.	[1,2]
Oat hulls	Steam	Both activation burn-off and Brunauer–Emmett–Teller (BET) surface area appear to exhibit a linear relationship with respect to activation time of oat hulls. Oat hull is better than corn stover as a raw material for the production of activated carbon.	[9]
Olive cake	Steam	The best AC was obtained activating for 68 min at 1095 K.	[3]
Walnut shell	CO2	The best activation was at 800 1C, 2.5 h, and CO2 flow rate of 100 cm3 min_1. Surface area: 1064.2m2 g-^{1}.	[29]

TABLE 2 : Preparation of activated carbons using agricultural wastes as raw material by chemical activation

Raw Material	Activation Agent -Chemical activation-	Relevant Issues	Reference
Cassava peel	KOH	Activation time showed no significant effect on the pore structure. Maximum surface area and pore volume were Obtained using: impregnation ratio of 5:2 and carbonization temperature of 750 1C.	[25]
Coffee bean husk	H_3PO_4	Characteristics could be easily controlled by varying H3PO4 impregnation ratio. High impregnation ratios yielded essentially mesoporous carbons with high surface areas and pore volumes.	[4]
Corn cob	ZnCl2	High-surface area (about 1400m2 g_1) and microporosity was obtained using the following conditions: 175% (w/w) ZnCl2, 773K for pyrolysis, 0.5–1.0 h for soaking time.	[27]
Date pit	H_3PO_4	Iodine number increased with increasing activation temperature. Impregnation ratio increase caused an oscillation in the iodine number. Iodine number varied in average 710% for all particle sizes used.	[10]
Cedar wood and its shavings	CO_2 (H_2O_2 PT)	Pre-treatment with H2O2 positively influenced porous development, probably due to the elimination of surface complexes produced during the activation step.	[18]
Oak wood	CO_2	The longer the duration of activation, the greater was the adsorption capacity.	[30]
Teak sawdust	Steam	AC with a surface area of 1150m2 g_1 and pore volume of 0.43 cm3 g_1 was obtained.	[12]

CONCLUDING REMARK

Empty fruit bunches due to its chemical composition has been found to be a good candidate for the production of activated carbon using either physical or chemical activation. This will control the illegal disposal of the EFBs and therefore protect the environment.

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