Use of Activated Charcoal Produced with Brewery Waste in Water Treatment

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Abstract

Activated charcoal (AC) was prepared from mixtures of dry malt bagasse (DMB) and coconut dust in different coconut: malt weight ratios of 100/0; 75/25; 50/50; 25/75; 0/100. Each mixture was activated with $ZnCl_2$ under a 100 mL/min influx at 550ºC during one hour. The characterization of AC was performed through moisture determination, volatile matter, ashes and calorific power. In order to assess efficacy, water from the well located in front of the Central Library of the Catholic University of Pernambuco – UNICAP, Recife, Pernambuco, Brazil was collected and 150 mg/L of AC was added to the samples. The samples were compared with three mL/L of aluminum sulfate (employed in Water Treatment Stations) in the same experimental conditions, using turbidity as parameter to compare the results. The data was submitted to statistical analysis, resulting in Box Plot graphics. The characterization result demonstrated that the 0/100 dose was the most indicated to produce activated charcoal. After the application in the water sample, 99% reduction in turbidity was achieved.

Keywords: Brewery Industry, Chemical Activation, Adsorption, Reutilizing, Waste

1. Introduction

Brazil is the third largest beer producer in the world, with an annual production volume of 13,2 billion liters (Kirin Holdings, 2015). The beer production, however, inevitably involves the generation of several wastes and byproducts that are yearly produced in large amounts by the breweries (Ferreira *et al.*, 2010). Malt's bagasse is the main byproduct of the brewery industry, representing around 85% of the total amount of byproducts generated. Such byproduct is available through the entire year and is generated not only by large companies, but also by small ones (Mussato *et al.*, 2010).

According to Amaya *et al*. (2007), the final disposal of the agro industrial waste is generally an environmental problem. The utilization of those wastes in the production of activated charcoal would add economic value, would help in reducing the cost of waste disposal and, most importantly, would provide a potentially cheaper alternative than the current commercial activated charcoals (Rafatullah *et al.*, 2010).

The activated charcoal (AC) is a very important industrial adsorbent because it possesses a well-developed porosity (micro, meso and macropores) along with great chemical and thermal stability (Rodríguez-Reinoso, 2006). It can be found in pulverized or granular forms (Rodríguez-Reinoso *et al.*, 2001). The AC can be prepared through two distinct industrial processes: physical and chemical activation (Marsh & Rodrígues-Reinoso, 2006).

Chemical activation is generally directed to the production of pulverized activated charcoals in which the lignocellulosic material is impregnated with a chemical agent (H_3PO_4, H_2SO_4, HNO_3, NaOH, KOH or $ZnCl_2$), carbonized between 400 and 800ºC under controlled atmosphere (Mohamed *et al.*, 2010) and the remaining chemical agents are removed from the charcoal through either water or acid washing (Yang, 2003). Physical activation consists of two steps: carbonization and activation. The carbonization process includes drying and heating to remove undesired byproducts such as tar or other hydrocarbons. Activation is thermally achieved through oxidation gases such as vapor above 800ºC or CO_2 at higher temperatures (Çeçen & Aktas, 2011).

The goal of this study was, therefore, to produce activated charcoal through waste from brewery industry aiming at the reduction of pollutants through the employment of alternate sources to charcoal production, targeting cost reduction and environmental preservation.

1. *Materials and Methods*

2.1. Preparation and qualification

The dried coconut shells waste (*Cocus nucifera*) was collected from the local coconut water commercial sites, rejecting those of brown color due to the increased difficulty of their processing. The brewery waste (malt bagasse) was acquired in a brewery close to the metropolitan area of the city of Recife, Pernambuco, Brazil.

The samples were dried in open air and grinded at the Agronomic Institute of Pernambuco – IPA located in Recife, Pernambuco, Brazil, and sieved in sieves of 60 and 14 mesh, respectively, in order to achieve a uniform granulometry, as stated by ABNT-NBR 6.923/81 and NBR 8112/83. The experimental design used was randomized blocks with five repetitions with a coconut/waste (treatment) equal to 100/0; 75/25; 50/50; 25/75; 0/100, as preliminary tests of work condition identification.

To perform the immediate analysis of the charcoal the following parameters were assessed: moisture rate, volatile materials and ash according to the ASTM D-1 762/64 and ABNT – NBR 9112/83 regulations and calorific power according to the ABNT– NBR 8633/84 regulation. The obtained data was submitted to statistical analysis in the Statistic 7.0 software, generating Box Plot graphics.

2.2. *Charcoal Production*

In order to produce charcoal, 10 grams of each different treatment was impregnated with $ZnCl_2$ (zinc chloride) at a 1:1 ratio (waste mixture/$ZnCl_2$), using a mortar and pestle to crush and putting the result in a stove at 100ºC for 24 hours (Ramos *et al*., 2009).

The samples were then put into a porcelain crucible and activated using a muffle furnace, LF00613 model, raising the temperature to 550ºC, at a 15ºC/min and maintaining it for one hour, under an inert gas inflow of 100 mL/min of N_2. After the samples were taken out of the muffle furnace and naturally dried, washing with a NaOH/H_2O solution at 50% with filtration was repeated thoroughly until pH stabilized around seven. All of the previously described procedures were performed with five repetitions for each treatment.

2.3. *Application of Activated Charcoal*

The assessment of the activated charcoal was performed using a Jar Test with five repetitions in which 150 mg of activated charcoal per liter of water collected from the tank in front of the Central Library of the Catholic University of Pernambuco – UNICAP, city of Recife in the State of Pernambuco, Brazil. The mixture was mixed at 15 rpm during 15 seconds and laid to rest for 15 hours and soon after 500 mL of the supernatant was retrieved to assess turbidity by nephelometry in accordance to ASTM D6698-14 (ASTM, 2014). With a view to compare the efficacy of the activated charcoal three mL of aluminum sulfate (employed in Water Treatment Stations – ETA’s) per liter of water under the same experimental conditions was used.

2. *Results and Discussion*

3.1. *Qualification*

The results obtained to ashes, moisture, volatile materials and calorific power from the mixtures of coconut/malt bagasse (treatments) equal to 100/0; 75/25; 50/50; 25/75; 0/100 are presented in Figures 1 to 4.

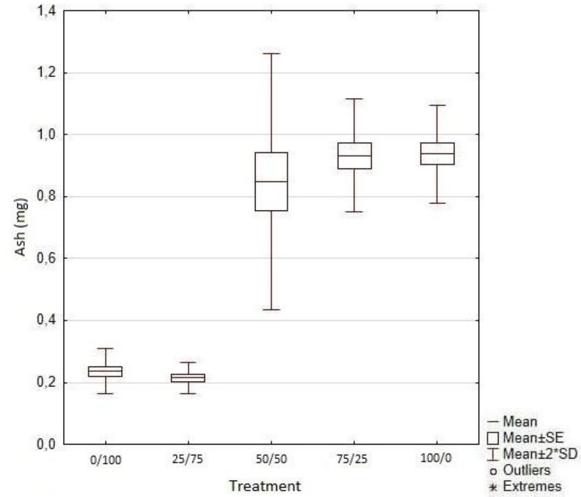

Figure 1: Ash content in the employed treatments

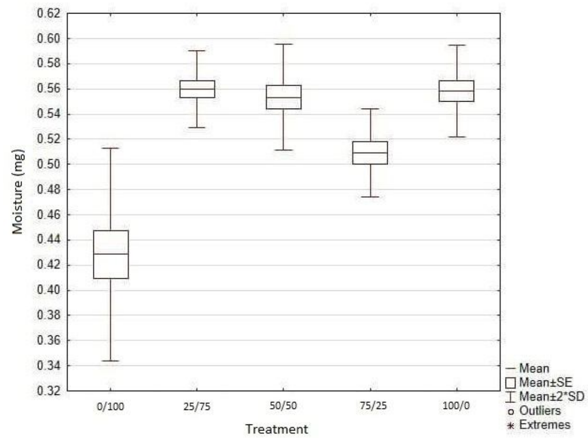

Figure 2: Moisture content of the employed treatments

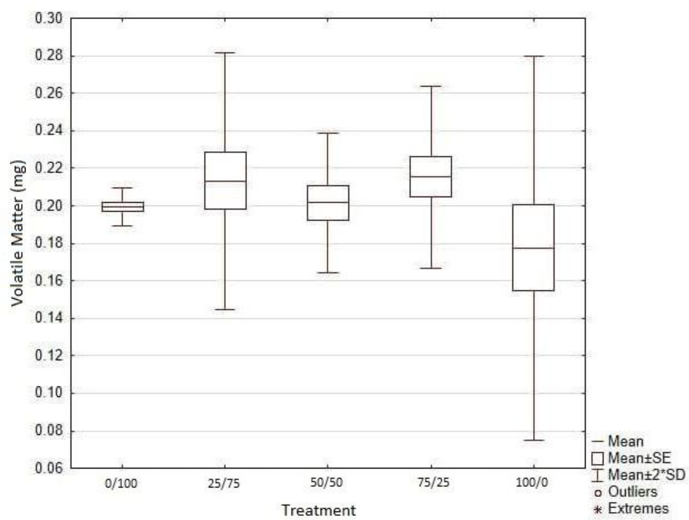

Figure 3: Volatile materials determined from the employed treatments

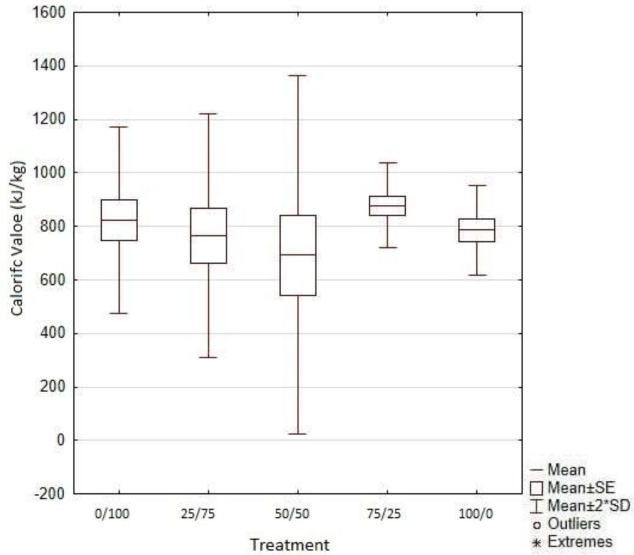

Figure 4: Calorific power determined in the employed treatments

It can be perceived by Figures 1, 2 ,3 and 4 that the 0/100 treatment (malt bagasse) presented results contained within the acceptable limits in all determinations as follows: 0,2358 mg in ashes (avoiding high levels of impurities and an inferior quality of the charcoal); 0,4284 mg in moisture content (which contributes to avoid the production of a frail charcoal); 0,1994 mg in volatile materials (to allow gas expansion and adequate porosity avoiding low quality and performance of the final product) and 823,3081 kJ/kg in calorific power (energy released in the form of heat).

Therefore, this treatment (0/100 malt bagasse) was selected to the production of activated charcoal for presenting high calorific power and low ash concentration, which favors the chemical quality of the charcoal according to Amodei (2008).

3.2. ***Results of the application of the produced Activated Charcoal***

Table 1 presents the values obtained in turbidity for the corresponding dose of 0/100 (malt bagasse) in comparison with the standard value of aluminum sulfate for the water sample from the tank in front of the Central Library of the Catholic University of Pernambuco, in Recife, Pernambuco, Brazil.

The value found for turbidity of the water sample from the tank in front of the Central Library was of 161,76 NTU (Table 1). According to Guimarães, Carvalho & Silva (2015), only in water whose turbidity is inferior to 20 UNT directing straight to slow filtration, dismissing chemical coagulation (with aluminum sulfate), is recommended. As it can be seen in Table 1, the low turbidity of the water proves a good performance of the produced charcoal. Further looking at Table 1 it can be verified a possible lower cost solution when comparing the results with the turbidity value of water treated with aluminum sulfate, which enforces that water treated with activated charcoal produced from malt bagasse lowers the content of particles in suspension in its medium up to 99%. The obtained results are in consonance with Silva *et al*. (2012) who found a turbidity removal of over 95% working with granular commercial activated charcoal in three different assays with tank water. In a similar experiment, Selhorst Filho *et al*. (2011) has achieved a turbidity removal of 88% working with optimization of parameters of water classification from the water treatment system of the city of Ponta Grossa in the State of Paraná using adsorption of water in commercial activated charcoal.

Table 1: Results of the turbidity assessment of crude water in comparison with the application of activated charcoal and aluminum sulfate

Sample	Turbidity (NTU)
Crude tank water	161,76
Aluminum sulfate	7,58
Activated charcoal	1,31

3. *Conclusions*

The tests performed to choose a better treatment of coconut and brewery waste were effective for the treatment of 0/100 (100% of brewery waste = malt bagasse) for presenting higher calorific power and lower ash content.
As to the application, the charcoal produced from the 0/100 treatment (malt bagasse) has proven to be highly efficient in removing 99% of water turbidity, with enough potential to replace aluminum sulfate in water treatment stations.

According to the performed study, it was possible to demonstrate the aptitude of the brewery waste in the production of activated charcoal. Therefore, breweries could aggregate value to their wastes and contribute to the maintenance of the environment, providing a more suitable destination to malt bagasse

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