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# THERMODYNAMIC EVALUATION OF PROCESS TO OBTAIN CHARCOAL FROM THE SLOW PYROLYSIS OF BABASSU COCONUT

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**Abstract.** *The demand for energy has been increasing with the technology development. As a result, there is a need to seek energy alternatives that are competitive and have low environmental impact. One of the alternatives is the pyrolysis technology, which produces bio-oil, charcoal and gas. These products have a high lower calorific value and a low impact on the environment. This work has investigated the development of a pyrolysis process for charcoal production from the endocarp of babassu coconut and tested its feasibility as a biosorbent to treat industrial effluents. The results of the research shows that the slow pyrolysis process studied presents an efficiency of 24.54%, with values close to the ones found in the scientific literature. Regarding the performance of the biosorbent, all the samples containing the heavy metals were influenced by the adsorption and desorption processes.*

**Keywords:** *Pyrolysis, charcoal, thermodynamic efficiency, activated charcoal, biomass*

## 1. INTRODUCTION

The use of biomass has always been present throughout human history and has varied considerably under the influence of two main factors: population density and the availability of resources. The annual photosynthetic production of biomass is 8 times greater than the total energy used in the world, so this stored energy potential must always be taken into account in any discussion of current and future energy supply (MESA et al, 2003).

According to Carioca and Arora (1984), biomass is all biological organisms that can be used as sources of energy: firewood and charcoal, some vegetable oils (peanuts, soybeans, palm oil), sugar cane, beet (of which are extracted alcohol), biogas (produced by the anaerobic biodegradation existing in the waste and organic waste) and so on.

Mesa (2004) define biomass as a material that has the capacity to store the sun's energy in the form of chemical energy or bioenergy due to the photosynthesis process of the plants. Thus, the bioenergy contained in biomass of plant or animal origin can be recovered through several thermochemical processes.

The pyrolysis process has been extensively studied because it is a simple and low cost energy technology. This is due to two factors: first, fossil fuels (derived from petroleum and coal), when burned release gases that contribute to global warming, and second, they are not renewable. Moreover, this process allows the use of vegetable waste, originating from agroindustrial processes to generate energy and biosorbent production.

The pyrolysis is a thermo-conversion process of biomass, which is characterized by the thermal cracking of an organic material in the partial or total absence of an oxidant agent, and it occurs in a temperature range of 400-800 °C (Gómez et al, 2000).

This thermo-conversion process uses biomass in nature as its source, and it can be divided into slow pyrolysis and fast pyrolysis. The main parameters influencing the results of the process are: heating temperature; residence time; heating rate; pressure; type of atmosphere; and the use of catalysts (Cortez et al, 2008).

Thus, the main justification for the development of this research is the need to improve the processes of obtaining clean energy from renewable sources and to investigate the thermodynamic performance of charcoal production from the slow pyrolysis process of babassu coconut, testing its use as a biosorbent.

## 2. EXPERIMENTAL PROCEDURE

The research was conducted at the Federal Institute of Education, Science and Technology of Ceará (IFCE) - Campus Juazeiro do Norte. The were performed using as biomass the endocarp of babassu coconut.

Pyrolysis tests were carried out in a muffle, which apparatus is basically composed of a metal chamber, with an inner coating made of refractory material. Its internal control panel allows access to heating rate programming and the internal resistances are capable of raising the internal ambient temperature up to 1200 ° C (figure 1a). If it was necessary to use a greenhouse, before going to the muffle, in order to guarantee a desired moisture content of the raw material (figure 1b). In order to store the biomass and facilitate its removal from the interior of the muffle, the sample holder was constructed and used, which was developed with iron tubes, with one of its ends closed, and with the following dimensions: 80 mm diameter, height of 100 mm and mass of 488.7 grams (figure 1c). Finally, to accurately measure the values of the masses presented by the samples, a semi-analytical balance was used, in which it presents an error of 0.1 grams (Figure 1d).

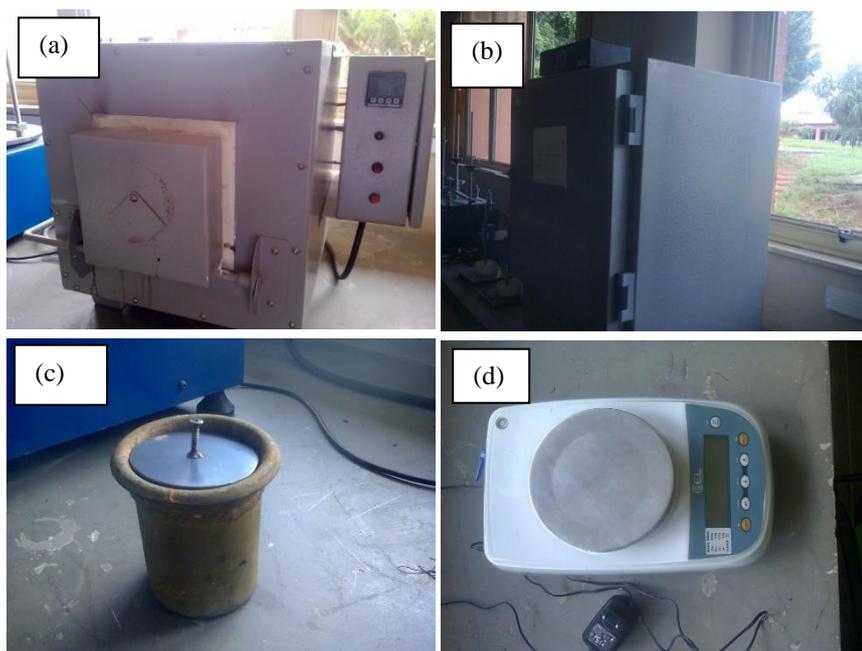


Figure 1: Equipment used during research. (a) Muffle Furnace; (b) Kiln; (c) Sample holder; (d) Semi-analytical

The pyrolysis tests were executed using 80 grams of babassu coconut's endocarp. The samples were initially taken to the kiln for 30 minutes at 100 °C to remove humidity. Then, the material was weighed and pyrolyzed. For each of the pyrolysis tests the following parameters were used: a heating rate of 7.5 °C/min, residence time of 1.0 minute and final temperatures of 100, 150, 200, 250, 300, 350, 400, 450, 500 and 550 °C. After reaching the desired temperature in each experiment, the capsule containing the material was removed from the inside of the muffle furnace and placed on the semi-analytical balance.

The yield of the coal production was found using Eq. (1), based on the biomass weights before starting the process and after the pyrolysis:

$$Efficiency[\%] = \frac{Charcoal\_mass \cdot 100}{Biomass\_mass} \quad (1)$$

Being:

Charcoal\_mass - Mass of the Charcoal produced.

Biomass\_mass - Mass of the biomass used on the tests.

The activation process was initiated when the carbonization reached a temperature of 250 °C with a gradual increase of 7.5 °C/min and remaining at the maximum temperature for 20 minutes, thereby obtaining the activated charcoal. For the accomplishment of the analysis, the digestion of the samples was performed. When it occurs, all metal content becomes soluble, making its detection easier, and the obtained value will be of the metal in its total concentration.

### 3. RESULTS AND DISCUSSION

From the results obtained in each test, the thermogravimetric curve (TG) (figure 2a) was constructed, in agreement with all the phenomena that occur throughout the temperature range during the pyrolysis process. However, it was verified that the results obtained are in agreement with the literature (Rocha, 2003), in which, through pyrolysis experiments with the bagasse of sugar cane, a graph was obtained that presents like Thermalgravimétricas curves for reasons of heating at 5, 10 and 15 ° C / min, as shown in Figure 2b.

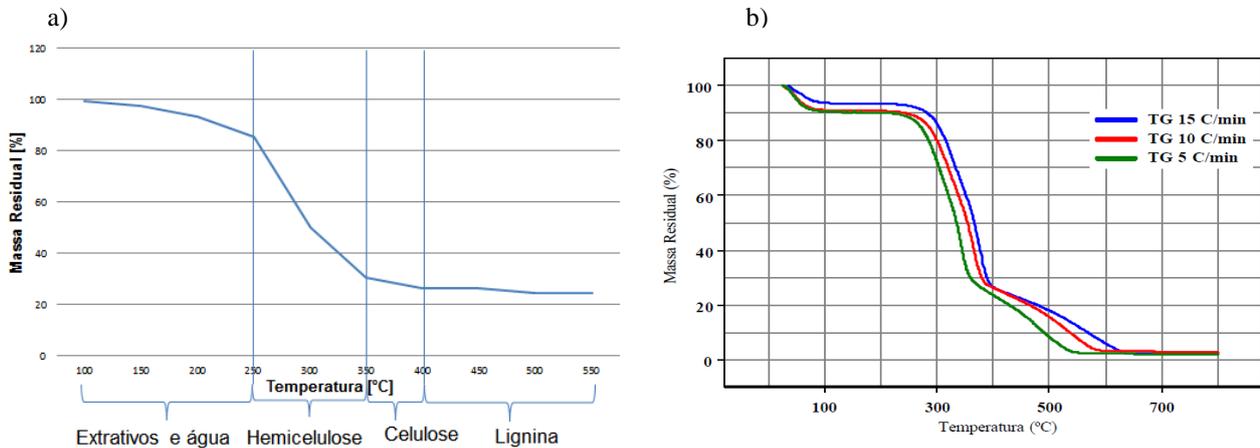


Figure 2: Thermogravimetric curve. (a) Obtained in the research; (b) Literature (Rocha, 2003)

It was observed that between 100 and 200 ° C the mass loss is very small, about 6.3%. This loss corresponds to the humidity present in the biomass, even after the kiln. At 200 ° C, the break of chemical bonds begins, and it starts the thermal cracking of hemicellulose, being more intense between 250 and 350 ° C. In this range, it was observed the greatest reduction in mass, 54.66% of degradation, with the loss of methoxy groups. Hemicellulose decomposes more easily because it basically consists of pentoses and hexoses (Santos, 2013).

The product obtained from the pyrolysis was a compact and high-quality charcoal (Figure 3). In addition, its efficiency was determined as approximately 24.54%.



Figure 3: Charcoal produced from babassu coconut at 550 ° C

The tests using activated carbon showed that the concentrations of the heavy metals analyzed by atomic absorption spectrometry were influenced by the adsorption and desorption process of the Ni, Cu, Cr, Cd and Ag metals, due to the treatment with the addition of 5 g of activated charcoal to 50 ml of digested crude slurry. For Copper, Cadmium and Nickel all the tests revealed that the samples containing active carbon were influenced by the desorption process. For Silver, the activated charcoal was influenced by the adsorption process. For Chromium and the samples treated with the biosorbent, there were no significant changes in the concentration of the crude slurry, indicating that the samples were not influenced by the adsorption or desorption processes.

#### 4. CONCLUSIONS

It can be concluded from the results obtained that the charcoal, produced from the slow pyrolysis of the endocarp of the babassu coconut presents a satisfactory yield, with a mass loss of 75.46%, where the thermodegradation of the babassu coconut endocarp occurs, with greater intensity, near 300 °C and from 500 °C the mass losses are minimal, indicating the end of the thermo-degradation of the biomass. However, it is necessary to carry out calorific value tests to evaluate its efficiency as biofuel. In general, pyrolysis products have the following advantages: cheap energy product; causes less environmental impact; and has great application in the chemical and steel industries. However, among the components of biomass, hemicellulose contributes most to the emission of gases. The adsorption and desorption process of the Ni, Cu, Cr, Cd and Ag metals were influenced by the adsorption and desorption process of the heavy metals analyzed by atomic absorption spectrometry. Nickel, all the tests revealed that the active charcoal was influenced by the desorption process. However, the only metal that had its concentration reduced when treated with this biosorbent was Silver, showing that active coal is more suitable for treating industrial effluents from electroplating, which are rich in silver.

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