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Use of a lignocellulosic residue as solid fuel: The effect of ash content in the energy potential

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ABSTRACT

Bark is a residue that can be used as fuel by the industry. One of the problems of its use is the impurity that it may contain. This study aimed to characterize physically and thermo-chemically the eucalyptus bark used as a fuel in a wood panel industry, relating the high heating value (HHV) with the ash content. Six treatments were provided according to particle size and washing process of the bark: T1 (850 μm to 425 μm/unwashed), T2 (retained on 250 μm/unwashed), T3 (< 150 μm/unwashed), T4 (850 μm to 425 μm/washed), T5 (retained on 250 μm/washed), T6 (< 150 μm/washed). The material was assessed regarding moisture content. The treatments were subjected to HHV and proximate analysis. The ashes were analyzed under SEM-EDS to identify the components/impurities. The data obtained in this study were statistically analyzed using the software R. The material presented moisture content of 70% on a dry basis, which is considered high for use in bioenergy. It was identified the presence of silica and calcium in the ash, which indicates the presence of soil in the material. The process of washing the bark was efficient for the reduction in ash content only in particle size < 150 μm. The separation of the bark in particle size was a better technique to reduce the impurities. The proximate analysis showed a significant difference among treatments. The ash content presented values from 2.63% (T1) to 13.86% (T3). The HHV was 18 828 J g^{-1} (T1) and 15 757 J g^{-1}(T3). The separation in particle size reduced 81.02% in the ash content, which represented an increase of 21.05% in the HHV. This result showed the effect of the ash content in the energy potential.

1. Introduction

Power generation is a topic that over the years has gained more importance due to its influence on economic stability and also political and environmental issues. Renewable resources are alternative energy sources, which may have advantages compared to fossil fuels, such as availability, easy workability, and lower cost. The renewable energy source is already seen as sustainable, and has presented a growing usage fee (Eia, 2015; Nematollahi et al., 2016).

Different sectors can provide biomass, such as lignocellulosic materials, agro-food and also waste from any organic source (Akbi et al., 2017). There is a high availability of biomass in Brazil. This biomass is mainly derived from plantations with energy purposes or from plantations' residue. The area of planted forests is of approximately 7.6 million hectares, of which almost 70% are eucalyptus forests (Ibá, 2015).

Biomass provided from vegetable resources represents a very important storage of energy. In order to use this energy, it is necessary to perform an appropriate process, such as burning/combustion (Madanavake et al., 2017). The combustion of the biomass is already a very common practice in several industrial sectors. It is usually inserted into a boiler, in which is provided heating and drying, followed by pyrolysis, combustion and post-combustion. This entire process can release hot air, and heat water and oil (Moraes, 2013).

This process may also offer some drawbacks. Biomasses frequently are presented in uneven characteristics, and can be classified energetically according to the moisture content (MC), impurities compounds (ash content), and high heating value (HHV) (Furtado et al., 2012). Modifications in any of these parameters will have an effect on the energy generation. It is recommended that energetic materials have a MC smaller than 10% (in dry basis) and up to 2% of ash content (Enplus, 2015).

The ash content is an inorganic residue that represents the percentage of the material that is not part of the burning process and its increase represents a reduction in the HHV. This component may also

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result in damage to the burning equipment by corrosive processes or by the material deposition on the structure which may reduce the thermal capacity (Garcia et al., 2014). Consequently, there is a concern about the reduction of ash content to prevent maintenance of equipment or to optimize the heat generation.

The ash content of a biomass may vary with the availability of minerals from the soil where it is developed. The minerals are absorbed by the plant and can be found in all organs and tissues. When the ash content is over the expected value, there is the possibility of the material having some type of external contamination (Fredo et al., 1999; Hansted et al., 2016).

The ashes are heterogeneous regarding their composition, varying according to the source of biomass and the burning process (Vassilev and Vassileva, 2007). The ashes present main components in their structure, such as silicates, cenospheres, and carbonaceous particles. Silicates are particles with spherical shape, composed by silica dioxide (SiO2); cenospheres are spherical particles composed by a mixture of metal oxides; and carbonaceous are particles with irregular shape, mainly the remaining parts of the incomplete burning, which may be present in the material when it is burned in commercial scales (Hwang et al., 2002; Cordeiro et al., 2008; Ahmaruzzaman, 2010).

The physicochemical characterization allows a better understanding of the material, enabling the implementation of treatments for the optimization of biomass use. The main purpose of this study was the physicochemical characterization of eucalyptus bark used as fuel in a wood panel industry. The specific objectives were to identify methods to reduce the biomass impurities.

2. Materials and methods

2.1. Material

The biomass was collected in a wood panel company in the city of Itapetininga/SP-Brazil (23°35′40″ S; 48°3′14″ W). The material is originated from plantations of hybrid eucalyptus (*Eucalyptus urophylla* x *Eucalyptus grandis*) with seven years old. The material used was the bark, obtained after the debarking of the logs. This process was held at the company's yard.

2.2. Preparation of the bark

The bark was fragmented into small pieces and it was milled in a crushing machine. Before the process of milling, it was provided the treatments that will be detailed on item 2.4.

The original moisture content of the material was calculated according to ASTM E871-13 standard. The moisture content was calculated in dry basis, using the Eq. (1):

$$MC = \frac{(ww - dw)*100}{dw} \quad (1)$$

The variables shown in the formula represent: '*MC*': moisture content in percentage; '*ww*': wet weight in g; and '*dw*': the dry weight in g.

In order to obtain the material dried, it was kept in the oven, at a temperature of 100 °C until it presented constant weight.

2.3. Treatments

In the laboratory, the material was subjected to three different particle sizes separation (between 850 and 425 µm sieve, retained on the 250 µm sieve and smaller than 150 µm sieve) and two processes regarding washing:

- washed (W) in running water for 10 min, with a total volume of 2L;
- unwashed (UW), the material was kept with the original characteristics.

Table 1
Treatments established regarding particle sizes and the process of washing the material.

Process	Treatments	Particle sizes (µm)
UW	T1	850–425
	T2	250
	T3	> 150
W	T4	850 – 425
	T5	250
	T6	> 150

Resulting in six treatments according to Table 1:

2.4. Particle size analysis

The biomass was placed in a stack of sieves arranged from the largest to the smallest opening. The sieves sizes selected were: 850 µm, 425 µm, 250 µm, 150 µm, and < 150 µm, according to the standard ASTM D293-93 (2010). The set of sieves was placed on the Ro-Tap sieve shaker. The duration of sieving was 3 min and after sieving, the mass retained on each sieve was weighed.

2.5. Proximate analysis

Prior to these analyses, the biomasses (all treatments) were dried in an oven at 100 °C.The determination of the ash content was held according to the standard ASTM D1102-84 (2007), and the volatile content, according to ASTM E872-82 (2013); both tests done in triplicates. Both standards were adapted, since all the material was used for the calculation. The fixed carbon content was calculated according to the Eq. (2):

$$FCC = 100 - (AC + VC) \quad (2)$$

The variables shown in the equation represent: *FCC* = fixed carbon content (%); *AC* = ashes content (%); and *VC* = volatile content (%).

2.6. High heating value

The high heating value of all treatments preformed was obtained in the calorimeter IKA C200 based on the standard ASTM D5865-13. For each treatment, three repetitions were carried out.

2.7. Morphological characterization

Morphological characterization of the ash was performed by scanning electron microscopy (SEM). The tests were performed at the Electron Microscopy Laboratory of the National Nanotechnology Laboratory using the microscope Inspect F50, by FEI.

In order to identify the components that were present in the SEM analysis, in other words, which mineral material constitutes the ashes, it was performed peripheral energy dispersive spectroscopy (EDS) analysis.

2.8. Statistical analyses

The effects of experimental treatments were analyzed using software R version 2.11.1,by analysis of variance (ANOVA) and Tukey's multiple range tests (5% of probability).

3. Results and discussion

The material was obtained in the same conditions in which it is used by the company, without any processing or cleaning. The initial moisture content was approximately 70% (dry basis). This high level may be explained by the storage in silos, without drying, keeping the moisture in the material. The high moisture content is a negative factor