academicJournals

Vol. 11(41), pp. 4157-4161, 13 October, 2016
DOI: 10.5897/AJAR2016.11345
Article Number: 5BB381E61149
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of the gross and net calorific value of residues of wood pine and araucaria from reforestation

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Received 21 June, 2016; Accepted 26 September, 2016

The objective of this study was to assess the energy value of waste timber in the form of sawdust. Two types of wood: Araucaria (*Araucaria angustifolia*) and Pinus were evaluated with no defined species (*Pinus* sp). The sawdust was collected from a timber that receives wood from reforestation of these species in Southwestern Paraná, Brazil. The material collected was evaluated with a calorimeter bomb to determine the gross and net calorific value. The main results obtained led to the conclusion that the sawdust of *A. angustifolia* showed gross calorific value of 17.32 MJ.kg^{-1} and net of 17.00 MJ.Kg^{-1}, respectively, and *Pinus* sp. gross calorific value of 17.23 and net of 16.91 MJ.Kg^{-1}, respectively.

Key words: Wood energy, conifer of reforestation, gross calorific value.

INTRODUCTION

Forest biomass is a low cost and abundant energy source (Almeida, 2010). When compared with the other non-renewable sources, it has storage advantage, because it can be stored for later use during periods when it becomes necessary (Fowler, 2009).

Used for energy production, biomass can be classified into: Primary- from the forest or agriculture cultivated with energy purpose; Secondary- resulting from primary biomass, including agricultural, forestry and byproducts residues (Carneiro, 2012).

Forest residues are those tree parts such as stems, bark, stumps, leaves which are damaged and unmarketable in the timber manufacturing industry (Karaj et al., 2010). Residues from agriculture and silviculture (including timber processing) apart from being a sustainable source of alternative energy for rural development, can also serve as future supply of bioenergy which do not direct or indirectly have negative impacts on the environment (Scarlat, 2011). However, on the feasibility of projects involving biomass, one must consider the availability of these resources at regional and local levels, in addition to identification and

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evaluation of the energetic potential of different forest species, a fact that is already being regarded in developed regions around the world, with the aim of replacing fossil fuels (López-Rodriguez, 2009).

The term biomass refers to all organic material from plant species that capture and store solar energy, producing photosynthesis. Biomass energy, or bioenergy, is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels (Akpinar et al., 2008).

Forest biomass, mainly in the form of firewood, is currently regarded as essential, particularly in developing countries. In India, 70% of energy consumption for cooking food comes from this biomass, according to the Ministry of New and Renewable Energy of India - MNRE (2009) and Abbasi and Abbasi (2010). In rural areas of Turkey, firewood is the fifth largest energy source, and its fuel consumption average amounts to 0.75 m^3 man^{-1} $year^{-1}$ (Akpinar et al., 2008). According to the same author, there is a shortage of this input for domestic use as a result of indiscriminate deforestation, slow forest regeneration in the country and increasing population pressure. In Brazil, this source along with other traditional forms of energy, totals 12.5% of the total need, despite being among the countries with more advanced programs, especially when it comes to modern biomass (Lora et al., 2009).

The importance of the use of residual biomass is due to several factors, such as prevention of forest fire, due to the removal of this biomass from the plots, preventing damage to the local economy. It also contributes to the development of bioenergy crops and provides jobs and income in rural areas (López-Rodriguez, 2009).

Wood residues from sawmills can be used for power generation. Thus, the raw material from these locations, such as tree bark, slabs, sawdusts can be transformed into electricity through combustion (Demirbas et al., 2009).

Pérez et al. (2008) evaluated forest biomass residues from Spain, characterizing them from the energetic point of view. They found that the leaves were the part of the tree with biggest calorific inferior value and among the different species, *Eucalyptus* spp. residues showed higher values of about 65,000 MJ ha^{-1} $year^{-1}$.

Comparing the residues of *Eucalyptus globulus* with *Eucalyptus nitens* in young and adult phases of the species during a year, Pérez et al. (2006) found that *E. nitens* has a higher calorific value during adulthood for all residues except seeds, due to higher concentration of volatile components and essential oil. The author also analyzed that waste collected during the autumn season showed higher calorific value for both species, due to lower moisture samples at harvest. In comparing the residual samples, the bark is the part that has smallest calorific value.

The calorific value of a material is expressed by the content of energy that is released when the material is burned in air. Therefore, the heat generated during combustion of forest species or different timber residues may vary depending on their physical, chemical and anatomical possessions (Almeida, 2010). This phenomenon is divided into two: gross and net calorific value.

According to Kollmann et al. (1968), the net calorific value can be obtained indirectly by the following equation:

$$NCV = GCV - (600 \times 9.h)/100$$

Where: NCV (net calorific value) (Kcal/kg); GCV (gross calorific value (Kcal/Kg); H = hydrogen content (%).

According to the chemical composition of the elementary, wood can assume hydrogen content of 6% (Silva, 2001).

The objective of this study was to compare the energy values of sawdust of *Araucaria angustifolia* and *Pinus* sp., by determining the gross and net calorific power, for use as an environment friendly energy source.

MATERIALS AND METHODS

Localization of the experiment

The experiment was conducted in the soil laboratories of the State University of Paraná West, in Cascavel City, Paraná. The sawdust samples were acquired from Biasin Timber in Realeza City, Paraná, located at approximately 528 km from the capital Curitiba. The timber is used to manufacture doors and windows. The company possesses productivity ranging between 54 and 55 m^3 of sawn timber per day. The main forest species used in this process are *Eucalyptus* sp. *Pinus* sp. and *Araucaria angustifolia* from reforestation.

For this work, the wood residues used were the *Pinus* sp. and *A. angustifolia* from commercial plantations. The samples were available without mixtures, under the same conditions they were in after processing, and in this condition, can be used as fuel. They remained stored in the laboratory until the day of the tests.

Collection of residues of biomass

The residue samples were collected randomly from the timber industry, the total amount of waste was produced in the processing of woods, collecting approximately 1 kg of each material. The waste used in the experiments were characterized as that of sawdust of *Araucaria angustifolia* and sawdust of *Pinus* sp. (Figure 1), resulting from the processing of the planer molding.

Characterization of materials

The residues obtained in the timber were sent to the Soil Labs of the State University of Paraná West, where they were given the calorific value of the residues by bomb calorimetry. Four replications were made for each sample biomass.

Determination of the calorific value

The determination of gross calorific value was done according to

Figure 1. Shavings of wood used in the experiment: *A. angustifolia* (a) and *Pinus* sp. (b).

Figure 2. Isothermal bomb calorimetry used.

ABNT/NBR 8633 (1984) (charcoal/determination of calorific value).

In this procedure, the samples which were previously dried *in natura* were placed in a calorimeter bomb isothermal E2K model (Figure 2), for analysis of the gross calorific value (GCV) to be released by the sample. For each sample, four repetitions were made. The transformation of the values for the GCV to net calorific value (NCV) was performed using the equation Kollmann et al. (1968), already mentioned, with the percentage of hydrogen present in the material as 6%.

Data analysis

To understand the range of values obtained in the experiment, spreadsheets and graphs were used with Broffice calc for the purpose of evaluating the contrast and comparison of mean values for the energy aspects and analysis of immediate shavings of *A. angustifolia* and *Pinus* sp.

RESULTS AND DISCUSSION

Gross calorific value (GCV)

The average values for the higher calorific value of 17.32 were MJ.Kg^{-1} for *A. angustifolia* and 17.23 MJ.Kg^{-1} for *Pinus* sp. mean values from conifers, but which nevertheless exhibit discrepancy observed in the ranges of values between one species and another (Figure 3).

Net calorific value (NCV)

The net calorific value found by indirect method was 17.00 MJ.Kg^{-1} for *A. angustifolia* and 16.91 MJ.Kg^{-1} for *Pinus* sp. (Figure 4).

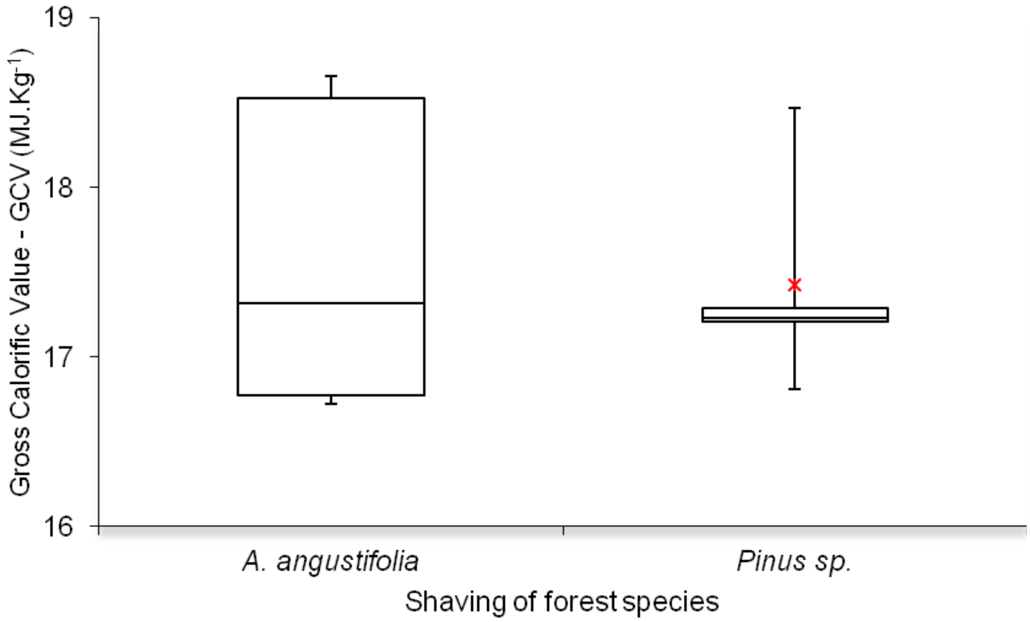

Figure 3. Gross calorific value (GCV) shavings of *A. angustifolia* and *Pinus* sp.

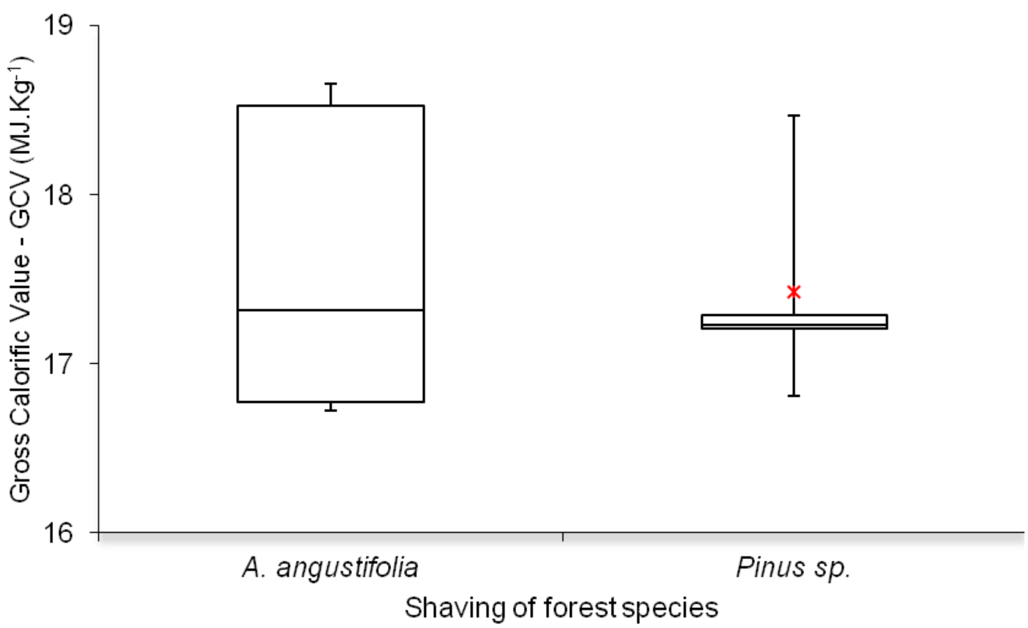

Figure 4. Net calorific value shavings of *A. angustifolia* and *Pinus* sp.

The GCV indicates the amount of energy released during the transfer of heat related process, that is, the higher the GCV, the more the efficiency (Vieira, 2012).

When comparing the results with residues from other species, such as shavings of *Cedrelinga catenaeformis*, which has a gross calorific value of 20.63 MJ.Kg^{-1} (Vale et al, 2007), values similar to those found by Quirino et al. (2004) 20.63 MJ.Kg^{-1} and below those found by Gabardo et al. (2011) for the same conifers, GCV of 27.99 MJ.Kg^{-1} in Araucaria and 32.05 MJ.Kg^{-1} to Pinus was obtained.

Mattos et al. (2006) featured another timber residue, sawdust *A. angustifolia* from commercial plantations with 38 years of age. The residue showed a calorific value of 46.70 MJ.Kg^{-1}, also higher than that found by other authors.

The values found for the NCV from the resulting value of the gross calorific value, discount the energy used to evaporate the hydrogen in fuel formation, in the form of water (Nascimento, 2006). Thus, Cordeiro (2011) evaluated the potential of bagasse energy malt from breweries in Pernambuco and obtained NCV ranging from 23.32 to 47.01 $MJ.Kg^{-1}$, an amount that increased with decrease in moisture content. Smaller values were described by Brand et al. (2004), analyzing residues of *Eucalyptus* spp. newly produced ranging from 15 to 25 $MJ.Kg^{-1}$.

Conclusion

From the results obtained in the experiment performed with the shavings of *A*. *angustiflolia* and shavings of *Pinus* sp., it can be concluded that the energy potential of shavings of *A. angustifolia* was higher than that of *Pinus* sp, while the values shown for GCV and NVC from wood shavings of *A. angustifolia* were 17.32 and 17, 00 $MJ.kg^{-1}$, respectively, while for the residue of shavings of *Pinus* sp., the GCV and NVC were 17.23 and 16.91 $MJ.kg^{-1}$, respectively. The residues of both species are given for energy purposes.

Conflict of Interests

The authors have not declared any conflict of interests.

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