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Short Communication

Fuelwood characteristics and its relation with extractives and chemical properties of ten fast-growth species in Costa Rica

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ABSTRACT

The aim of this study was to investigate the fuel characteristics (calorific value and fuel value index) of 10 fast-growing species in plantations in Costa Rica. The effect of the chemical properties, extractives and moisture content were evaluated. The results revealed that the gross calorific value varied from 16.5 to 20.6 MJ kg^{-1} for sapwood, and from 16.3 to 20.1 MJ kg^{-1} for heartwood. No consistency was observed with regard to which type of wood (sapwood or heartwood) had the highest gross calorific value. Large variations among the species were observed in the case of the fuel value index. For heartwood, the slope gradient of linear correlation was affected by lignin and extractives in sodium hydroxide and dichloromethane solution, whereas in the case of sapwood, only ashes content affected significantly to calorific value. For chemical parameters or the amount of extractives, carbon, nitrogen and lignin contents, ashes and extracts in dichloromethane influenced significantly the calorific value of heartwood. The calorific value in sapwood was affected by the amount of extractives in ethanol–toluene and the amount of ashes. Finally, the fuel value index was affected by the quantity of carbon, the extractives in sodium hydroxide and dichloromethane.

1. Introduction

Costa Rica is a small country where a great variety of reforestation species, mainly for timber production, have been introduced [1]. On the other hand, only a few native and exotic species have gained commercial importance in various reforestation projects due mainly to lack of knowledge about genetic, reproductive and management processes [2].

Fast-growing species (with rotation periods of less than 20 years), such as *Terminalia amazonia*, *Terminalia oblonga*, *Vochysia guatemalensis*, *Bombacopsis quinata*, *Alnus acuminata*, and *Swietenia macrophylla* (native species) and *Tectona grandis*, *Cupressus lusitanica*, *Acacia mangium* and *Gmelina arborea* (exotic species), have produced excellent results as reforestation species in forest plantations [1–3]. These species are widely used in forest plantations not only because of the quality of their timber and their rapid growth, but also because of their capacity to adapt to abandoned areas. They can be used in agroforestry systems and mixed plantations and are also adequate for carbon sequestration [3,4].

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Due to the problems associated to environment and global warming of the planet, ample investigations have been carried out in recent years that aim at finding reliable and renewable sources of energy to substitute fossil fuels. Forest biomass is recognized as one of the most promising resources, as trees absorb carbon dioxide during their growth. The energy obtained from forest biomass would be carbon neutral [5].

During the sawlog processes, large amounts of residues are produced that may be used as sources of renewable energy [6,7]. Utilization of lignocellulosic material as energetic material offers many advantages, their components coming from renewable or natural sources being among the most important [8]. However, it must be pointed out that in the case of Costa Rica, one of the main obstacles is the lack of an industrial processing for this material [9]. Providing secondary use to these residues would be an innovative alternative to this kind of material for Costa Rica and for some developing countries.

However, in order to really give use to forest residues as sources of calorific energy, information about the fuel properties of the species used in reforestation is needed. For example, the gross calorific value of the wood varies from 17.6 to 18.7 MJ kg^{-1}. This value, nevertheless, depends on many factors [10], among which the moisture content (MC = mass fraction of water in the biomass) of the residue stands out. Other factors affect the calorific value, such as: the influence of the extractives, the amount of carbon, hydrogen and oxygen, celluloses, hemicelluloses, lignin and the proportion of other chemical components [8,11].

Tropical species, meanwhile, present different proportions of carbon, oxygen and hydrogen in general, and of course there are differences in the quantity of extractives [12]. Despite these differences, the calorific values, other important parameters in the energy values and the influence of other wood features have been taken from studies carried out with temperate species. This could lead to problems regarding energy estimations at the time of exploiting the species or when using the residues at sawmills.

In the case of Costa Rica with its tropical climate, although production of energy with wood-based lignocellulosic residues has begun, information on fuel characteristics of the most commercially used species is not available yet. Therefore, research is needed in order to determine those energetic parameters. Hence the objective of this study: to determine the main energetic/fuel parameters (calorific value and fuel value index) of the 10 most used species in forest plantations in the country. In addition, the study presents the relationship of these characteristics with chemical compositions (lignin, cellulose and extractives) and carbon fraction. This information will help industries, reforests and other entities use raw material from plantations integrally.

2. Methodology

2.1. *Material used and sampling*

Ten fast-growing plantation species in Costa Rica were used and they were localized in different part of this country (Fig. 1). The age of the plantations ranged between 6 and 21 years. Table 1 presents the density and dendrometrics conditions of the plantations. 3 trees with diameters close to the average diameter in each specie were selected (30 trees in total). Selected trees had good shape and were free of damage caused by insects or fungi. 1 m long logs were cut from the base of each tree and then painted at the ends to prevent loss of moisture.

2.2. *Sample collection*

2 Cross sections approximately 5 cm thickness were cut from each log. Each cross section was extracted 5 chips approximately 6 cm wide and 1 cm in long. The chips were used to determine maximum moisture content (MCg), specific gravity (oven-dried weight*green $volume^{-1}$) (SG) and green density (mass volume*green $volume^{-1}$) (GD). The total number of chips was 135. Determination of the calorific value (net and gross), ash percentage (weight*$weight^{-1}$), carbon fraction (C), nitrogen (N), carbon–nitrogen relationship (C/N) and the percentage of extractives (weight* $weight^{-1}$) was obtained through sawdust produced by the sawing process of the logs of each species. The sawdust was sieved through 0.25 mm and 0.42 mm meshes (40–60 meshes respectively), until approximately 8 g per test were obtained.

2.3. *Determination of the calorific value*

The calorific value was determined for green condition, named gross caloric value (GCV) and free-water condition (MC = 0%) and named net caloric value (NCV). Sieved sawdust from the 0.25 mm and 0.42 mm was used. Approximately 8 g of sieved material was obtained. 8 g of this material was dried at stove in 103 °C for 24 h. Both samples were divided in: 2 g for the determination of the moisture content (MC) and 3 samples of 2 g for the determination of the caloric value. In this case, it was determined using Parr calorimetric test through the D-5865 standard [13].

2.4. *Fuel characteristics*

Carbon fraction (C), Nitrogen content (N) and the C/N relation were determined by means of the Elementar Analysensysteme, Vario Macro Cube model. The fuel value index (FVI) was also determined, having the gross caloric value, green density and ash content (Equation (1)), as a reference, based on the methodology proposed by Purohit and Nautiyal [14].

$$\text{Fuel value index (FVI)} = \frac{(\text{Gross calorific value} * \text{Green Density})}{\text{Ash content} * 100} \quad (1)$$

2.5. *Determination of green moisture content, specific gravity and green density*

The calculation of the maximum moisture content (MCg) refers to the moisture content when sample is extracted from log, commonly referred to as green moisture content. The chips extracted from log were weighed and dried at 103 °C during 24 h, according to the D-4442 standard [15]. Afterward, the chips were weighed again, to obtain the dry weight. And equation (2) was applied to determine MCg. The chip volume was determined immersing the chip sample in water, then