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Description Of The Energy Content Of *Ateleia glazioviana* Baill In different Planting Spacings

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ABSTRACT

Background: The production of forest biomass for energy purposes is an activity which has been steadily increasing over the past decade. Numerous production strategies have been employed in order to improve the production of forest plots; they are considered to be one of the most important sources ofregional, renewable energy and therefore have great social and economic importance. This study aimed to profile the energy content of wood biomass and bark of the species *Ateleia glazioviana Baill* distributed in different spacings: 2.0 x 1.0 m and 3.0 x 1.5 m, three years after planting. This work was conducted with a randomized complete block design and three replications. The evaluations were performed with 36 trees in total, each was sample and cut into discs approximatelytwo centimeters thick, at the trunk positions: 0% (base), 1.30 m (diameter at breast height - DBH), 25%, 50% and 75% of the total height of the tree. Biomass (BIO), gross calorific value (GCV), specific gravity (ρ_b), ash content (AC), volatile material content (VMC) and fixed carbon (FC) and energy density (ED) of wood and bark were determined. The lower density spacing provided a greater production of biomass and wood bark per unit area. The higher values for GCV, ρb, VMC and AC was found to be higher in the bark when compared with the wood. The ED and FC of wood are superior to the bark in different spacings. The VMC and AC contents of the tree bark are superior to wood for both of the different spacings, unlike what was observed with FC, where the highest values are observed in the wood.

INTRODUCTION

The tree species *Ateleia glazioviana* Baill belongs to the Fabaceae family, and has deciduous tree characteristics. It is a medium size tree which generally grows from 5 to 15 m height, 20 to 30 cm in diameter at breast height (DBH), and can attain up to 25 m height and 70 cm DBH in adulthood (Carvalho, 2003). It is commonly found in the secondary vegetation of deciduous forests, especially in the Uruguay and Paraguay river basins (Reitz *et al.*, 1983). It is used in the recovery of degraded areas, and for lumber, energy, pulp and paper (Carvalho, 2003).

Over the past decades, anincreasing demand for energy based on non-renewable sources has lead to difficulties related to supply of energy, and the environmental and economic balance of said energy production. Some countries have employed alternative management practices in order to minimize these problems. In general, an increased focus has been placed on seeking alternative sources of energy, in particular through the increased usage of renewable resources.

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Data from the Food and Agriculture Organization of the United Nations (FAO, 2012a) noted the wood to be an important source of renewable energy. This same publication indicates that more two billion people depend on the energy contained in the wood for cooking food, and heating. In Brazil, the consumption of wood intended for energy is one of the most significant in the world, and is between 123 million to 150 million cubic meters according to the FAO (2012b) andSFB (2010), respectively.

The energy resources can be obtained directly and indirectly from wood, where the wood itself as well as waste materials can act as combustible material for energy purposes (Nogueira and Lora, 2003). In the case of combustible materials, such as wood, this should be determined by a tree's potential for the production of biomass and of its calorific value. The calorific value of the wood is the amount of energy in the form of heat released by complete combustion of a unit mass of combustible material (Eloy *et al*., 2016).

The spacing of trees is one of the main factors that affectthe formation of forests, and it has implications for silvicultural, technological, and economic fields as well. Interference in growth rates can affect wood quality, and production costs (Caron *et al*., 2015).For Trevisan *et al*. (2016) in the planning and implementation of forestry endeavors,all relevant species as well asall aspects that could potentially influence final costs, directly or indirectlyshould be considered. The end-use of wood is also often a relevant consideration for producers.

High density spacing is usually recommended in the production of wood production for energy purposes,considering that the objective is the production of higher volume of biomass per unit area in lowest time possible (Caron *et al*., 2015). This study aimed to conduct anenergy description of wood biomass and bark for the species *Ateleia glazioviana* Baill distributed in different spacings: 2.0 x 1.0 m and 3.0 x 1.5 m, three years after planting.

MATERIAL AND METHODS

Characterization of the study area:

The study was conducted in experimental area of the Federal University of Santa Maria, campus Frederico Westphalen - RS, Brazil, with geographic coordinates 27° 23' 26" S; 53° 25' 43" W, 461m. According to the Köppen climate classification (Alvares *et al*., 2013), the climate of region is Cfa, ie, humid subtropical with an average annual temperature of 19.1°C, varying with the maximum of 38ºC and minimum of 0°C.

The soil of the experimental area belongs to the region of Passo Fundo, Brazil, classified as Oxisol distrofic typical, clayey, deep and well drained.In preparation for the planting of seedlings, plowing and disking operations were performed; planting was done manually in September 2008.

The experiment was conducted using a randomized complete block design, where we evaluated the forest species *Ateleia glazioviana* Baill in two spacings (2.0 x 1.0 m and 3.0 x 1.5 m), with three repetitions.

Sampling:

The evaluations were performed at the three years after planting the seedlings, 36 trees were selected, which corresponded with 18 trees per spacing. Disks approximately two centimeters thick were cut from each sampled tree, in the following positions ofthe bole: 0 % (base), 1.30 m (diameter at breast height - DBH) 25%, 50% and 75% of total tree height. The discs were marked, separated from the bark of the wood, and subsequently, sectioned in two symmetrically opposed wedges of each disk.

Biomass (BIO):

A direct method which consists of cutting and weighing the different componentsof the trees was used to determine the biomass of wood and bark(Sanquetta, 2002). At each section along the bole, samples were taken and their fresh and dry matter was compared in a laboratory. The samples of the different compartments were weighed, identified, and taken for drying in an oven at 103°C with air circulation, until a constant weight was achieved.

The dry weight matter of the wood and bark, in tonnes per hectare, was calculated considering the population density of each spacing, and assuming a 100% survival rate according with experimental field conditions.

Specific gravity (ρ_b):

The procedures for this evaluation were carried out according to the technique norm NBR 11941 (ABNT, 2003). The ρb of wood and bark at every position on the bole was determined by averaging the values of the two sampled wedges. The mass was calculated (ρb pond) as a function of the total volume of each sample without tree bark, according to the method proposed by Eloy *et al*. (2014).

Gross calorific value (GCV):

In order to determine the GCV of the different tree components, the samples were ground up and passed through a 40 mesh sieve, in order to obtain a uniform material. Then a digital calorimeter, model C5000

CoolingSystem, IKA Werke was used, with adiabatic operations, according to the descriptions of the technical norm NBR 8633 (ABNT, 1984).

The GCV of wood and bark was determined by averaging the values of two wedges for each sample, this sampling occurred at every aforementioned position on the bole.

Next, gross calorific values were analyzed as a function of the total volume of each without tree bark, according to the proposed method Eloy *et al*. (2014).

Chemical analysis (CA):

To determine CA, we used the technique norm NBR 8112 (ABNT, 1983), which determined the volatile material content (VMC), ash content (AC), and fixed carbon (FC).

Energy density (ED):

The energetic density of the wood and the bark was calculated based on mass values, and superior calorific values according to the following expression:

$ED = \rho_b * GCV$

Where: ED = Energetic density (Kcal m^{-3}); ρ_b = Specific gravity (g cm^{-3}); GCV = Gross calorific value (kcal kg^{-1}).

Data analysis:

The data obtained were submitted to statistical analyses using the software "Statistical Analysis System" (SAS, 2003), which was used for various tests (analyses of variance, F tests and Tukey tests at the 5% level of probability).

RESULTS AND DISCUSSION

Analysis of variance showed a significant difference for wood biomass production and in the two spacings. On the other hand, significant differences were not observed for the other variables (GCV, ρb, VMC, AC, FC and ED) (Table 1).

Table 1: Analysisof variance forthe calorific power(PCS), specific gravity(ρb), volatile content (MV), ash content (CZ), fixed carbon (FC), biomass(BIO) and energy density(DE) of woodand bark of*Ateleiaglazioviana*distributedinand spaced 2.0x1.0 m and3.0 x1.5 m, three years after planting.

Study factor	GL	Mean Square						
		PCS	ρ_b	VMC	AC	FC	BIO	ED
Wood								
Spacing	1	192.7	0.001	1.675	0.012	1.392	328.57*	0.001
Block	2	1524.7	0.002	6.865	0.102	5.291	2.174	0.039
Residue	12							
Coef. determination (R²)		0.66	0.40	0.97	0.82	0.98	0.97	0.69
Coef. variation (%)		66	8.60	0.51	9.9	1.82	11.72	8.61
Bark								
Spacing	1	36037	0.003	0.844	0.202	0.221	7.772*	0.024
Block	2	4513	0.001	29.330	0.407	23.140	0.015	0.013
Residue	12							
Coef. determination (R²)		0.86	0.54	0.77	0.96	0.74	0.94	0.67
Coef. variation (%)		1.29	9.70	3.69	4.12	18.99	14.92	9.44

* = Significant at 5% probability by the Fisher distribution; ns = not significant at 5% probability of error in the Fisher distribution.

By analyzing the GCV of *Ateleia glazioviana* trees, it was observed that the higher values were seen in the bark when compared to wood. This result supports those obtained by Vale *et al*. (2002) regarding the energetic characterization of wood and bark for 47 species, where in general the values for GCV bark proved superior to those obtained wood.

A decreasing variation in the system was noted in relation to the spacing; the less density spacing (2.0 x 1.0 m) saw the highest GCV values, for both wood (4.404 kcal kg^{-1}) and for the bark(4.658 kcal kg^{-1})(Table 2). These values are similar to those reported by Silva *et al*. (2012) in 4492 kcal kg^{-1} for species *Ateleia glazioviana*. However, inferior those reported by Howard (1973), who observed a GCV hardwoods species varying, in the rate 4600-4800 kcal kg^{-1}.

Table 2: Average test for the grosscalorific value(GCV), in kcalkg^{-1}, basic density(ρb), in g cm^{-3}, volatile content (MV), in %, ash content (CZ) in %, fixed carbon (FC), in %, biomass(BIO), in tonha^{-1} and energy density(ED) in Gcalm^{-3}, of wood andbark*Ateleiaglazioviana*distributedinspaced 2.0x1.0 m and3.0 x1.5 m, to three years after planting.

Spacing	PCS^{ns}	ρ_b^{ns}	MV^{ns}	CZ^{ns}	CF^{ns}	BIO^{1}	DE^{ns}
	kcal kg^{-1}	g cm^{-3}	%			ton ha^{-1}	Gcal m^{-3}
Wood							
2.0 x 1.0 m	4404(40)	0.465(0.05)	81.02(2.0)	1.52(0.3)	17.45(1.6)	12.66(1.2)a	2.047(0.23)

3.0 x 1.5 m	4394(27)	0.469(0.03)	79.97(2.4)	1.61(0.1)	18.42(1.6)	4.11(0.7)b	2.060(0.15)
Bark							
2.0 x 1.0 m	4658(53)	0.266(0.03)	81.72(4.8)	3.43(0.4)	14.85(4.4)	1.98(0.2)a	1.2359(0.14)
3.0 x 1.5 m	4504(72)	0.291(0.03)	80.97(3.8)	3.80(0.4)	15.23(3.4)	0.66(0.1)b	1.309(0.14)

[1] Means followed by the same letter in column do not differ among themselves, by Tukey test of probability at 5% of error; ^{ns} = not significant at 5% probability of error according Fisher distribution. Values in parentheses correspond to the standard deviation (±).

The energetic capacity of a species is determined by the amount of heat given off by a species sample during its combustion (Rocha, 2011). The GCV represents the quantity of calories released by complete combustion of a unit mass of fuel, where combustion occurred at a constant volume and in which water condenses during combustion, and the heat that is derived from this condensation is recovered (Brand, 2010 andNogueira and Lora, 2003).

According to Lima *et al.* (2011), ED can be used to quantify the energy contained in a given volume of wood. For Ateleia glazioviana, the ED of the wood (2,047 and 2,060 Gcal in m^{-3}) was higher than the bark(1,235 and 1,309 Gcal in m^{-3}) for the spacing 2.0 x 1.0 m 3.0 x 1, 5 m, respectively.

A direct relationship with the planting density andtheproduction of wood and bark biomass was observed; the treatment with higher density (2.0 x 1.0 m) demonstrated greater biomass production as when compared with the less dense spacing (3.0 x 1.5 m). For Caron *et al.* (2015) a greater production of biomass per unit area in reduced spacingswas influenced by the higher number of individuals. Studies carried out by Müller *et al.* (2005) and Eloy *et al.* (2016) demonstrated the influence of planting density on yield of forest stands. Ladeira (2001) found differences in the biomass distribution among different species and the same species, due to factors such as planting spacing, stand age and quality of a stand site.

Onecan observe decreasing variations of biomass production for the different components of the tree, due to the increase of useful area, or plant spacing. Over time, the amount of accumulated wood in a particular place tends to equalize at different spacings.In denser planting, growth stagnation occurs at younger ages than in plantations with wider spacings (Caron *et al*., 2015).

The TMV and TCZ content of the bark at spacings 2.0 x 1.0 x 1.5 m and 3.0 m were superior to VMC values and AC of the timber. Different variations were observed with the variable FC, in which a larger amount was observed in the wood, compared to bark (Table 2). Similar results were reported by Brito and Barrichello (1978) in a study of five species of eucalyptus and, similarly, by Vale *et al.* (2002) working with 47 species of the cerrado. The VMC and FC content ofthe wood in this study was lower than the results observed by Brito and Barrichello (1982), who reported contents of 85% and 25%, respectively.

According to Vieira *et al.* (2013), FC is related to the amount of AC and VMC, because it represents the mass remaining, after volatile compounds have been extracted, excluding the AC and moisture contents. FC depends mainly on VMC, since the AC, especially for wood, is low. For the same author, wood with higher FC had higher ρb;thus, ρb and FC can be used as indicator variables of the wood quality for direct combustion. The FC is directly related to the GCV, regardless of the material that is used. It can be except then that a high FC content implies a higher GCV.

Fuels which have high levels of FC and low VMC contents tend to burn slower, resulting in a longertime required for complete combustion, as compared to fuels that have lower levels of FC (Nogueira and Lora, 2003 and Brand, 2010). The knowledgeof chemical composition is important for the projection of furnace capacity, because such a metric depends on the percentage of volatiles present in a given sample (Brand, 2010).

The evaluation of the amount of AC is of interested when consider the energy of a product. When this variable is present in high concentration, it can result in a decrease in GCV and result in a loss of energy efficiency, and maintain high concentrations of inorganic residues (Vieira *et al*., 2013). The same applies to substances that do not burn and remain in solid form and are undesirable for energy use. This is also related to the presence of minerals that may originate, in part, from chemical fertilization (Vale *et al*., 2011).

Inanalyzing the ρb of trees, it was observed that the highest values were present in the bark, when compared to wood. Although no significant difference occurred between the plant spacing, it was observed that there was a positive systematic variation from the useful area provided by the spacing. Higher values for both the wood ρb (0.469 g cm^{-3}) and ρb for bark (0.291 g cm^{-3})were observed in greater spacing (3.0 x 1.5 m) (Table 2).

The ρb results presented in Table 2 are in the range that Quirino *et al.* (2005) reported in 108 forest species, ranging from 0.200 to 1.080 g cm^{-3}. Our results also agree withthose observed by Eloy *et al.* (2013), who found no significant effect of spacing on ρb wood. However, the results are different from those found by Garcia *et al.* (1991), who reported a decrease of wood ρb with increasing spacing of *Eucalyptus grandis* and *Eucalyptussaligna* trees. According to Eloy *et al.* (2013), these differences could be due to several factors, such as genetic variability of forest stands, and various different environmental conditions that may differ according to the different ages of trees.

With respect to an energy product, Brito and Barrichello (1982) reported that wood with a higher ρb, is known to produce denser vegetal charcoal, while on the other hand, less dense wood results in lighter and porous vegetal charcoal. According to Vale *et al.* (2002), the wood burns rapidly but produces less energy per unit of volume; this wood is also noted to resist ignition. The same authors suggest the intermediate range between medium and hard ρb woods, varying from 0.650 to 0.800 g cm^{-3} for use in form of firewood, in order to facilitate the ignition of wood materials.

Conclusion:

The least denseplant spacing (2.0 x 1.0 m) provided a higher production of wood biomass and bark per unit area.

Higher GCV values and ρb for trees may be found in the bark when compared with wood. The ED of wood is higher than the bark, in differentspacings.

The VMC and AC contents of the bark are superior to wood for the different spacings, unlike with FC, where the highest values wereobserved in the wood.

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