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The Energy Properties Variation Along The Wood Stem Of Four Species

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ABSTRACT

It is important to invest in forests plantations with fast-growing species, which represent suitable alternatives for production of raw material used for generation of energy. This study aimed to evaluate the energy properties of four fast-growing species and the variation of their properties along the stem using sampling spots. Five trees were harvested by specie and from each tree it was removed one disc at the base and other discs from different heights. A small part of each disc was transformed in sawdust to be used to determination of fixed carbon, volatiles matter, ash content and higher heating value. The results were statistically analyzed considering the specie and sampling spots as factors and the means were compared using the Tukey´s test. It was observed that interaction between specie and sampling spot was significant for all properties studied. Regarding only the specie factor, all properties were significant too, but for the sampling spot factor only the volatiles matter and fixed carbon were significant. The higher heating value mean found was (20.12 MJ / kg) for specie Toona ciliata, and the lowest value mean found was (17.90 MJ / kg) for Melia azedarach. All species studied have a high potential as energy resource, based on the energy properties.

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INTRODUCTION

Wood energy is the oldest renewable energy source. It is a kind of biofuel derived from biomass. This energy can be produced in a liquid, gaseous or solid form and be used for electricity production. Also, this energy is used for heating and cooking, especially in poor countries. When comparing this source to other, the wood energy has many advantages including increase the energy security by promoting alternatives to fossil fuels and help to mitigate the climate change by reducing GHG emission (FAO 2015a).

In Europe, the governments are working to promote wood energy and reach the target of 20% of energy consumption from renewable sources by 2020 (FAO, 2015b). In Brazil, 9,5% of the primary energy production was derived from wood in 2013. The industrial sector is the main consumer in Brazil and 33% of this energy is used in charcoal form, especially in pig-iron and steel industry. Firewood and wood residues are consumed for energy purposes mainly in the pulp and paper industry and food and beverage sector (Ministry of Mines and Energy 2014).

To support this scenario is important to invest in forests plantations with fast-growing species, which represent suitable alternatives for production of raw material used for generation of energy. The *Acrocarpus franixifolius* Wight & Arn, also known as mundani, australian ash, ash indian, pink cedar, shingle tree (Onyango *et al*. 2010), belongs to the Caesalpiniaceae family and it is native from the tropical regions of Asia with high rainfall. It is a big tree, with its height between 30 and 40 meters (Whitmore and Otarola 1976). It is a species with fast growth that can reach up to 8,5m high in the first 12 months (Martinez *et al* 2006).

The *Melia azedarach* L., also known as cinnamon or chinaberry, is a medium-sized specie and belongs to the Meliaceae family (Cabel 2006). It is widely cultivated in Asia and South of Latin America being quite adapted to the cold weather (Martinez 2002, Bobadilla 2004). Their tree can reach more than 40 meters high (Cabel 2006).

The *Grevillea robusta* A. Cunn, also known as grevílea, is a native species from Australia and

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belongs to the Proteaceae family. It can be found in the tropical and subtropical regions of the Southern Hemisphere and it is considered a species of fast growth that reaches heights between 30 and 35m and the diameter of 80cm (Hardwood and Gatahun 1990).

Another alternative is the Australian red cedar (*Toona ciliata* M. Roem) a native species from Australia that belongs to the family Meliaceae Botany (Dordel *et al*. 2010). It is considered a big tree reaching up to 55 m high and 2 meters in diameter, it is a fast-growing species very similar to Eucalyptus (Tsukamoto Filho *et al*. 2002, CIFLORESTAS 2015).

This study aimed to evaluate the energy properties of four species and the variation of their properties along the stem using sampling spots.

MATERIAL AND METHODS

The *A. fraxinifolius* Wight & Arn, *M. azedarach* L., *G. robusta* A. Cunn and *T. ciliata* M. Roem species were collected from forest plantations located in Corupá, in the state of Santa Catarina, Brazil (26º25'45"S 49º15'48"W).

The sampling and preparation of the material were performed according to NBR 14660 (ABNT 2004). Five trees of each species were used in this study. From each one, a disk was obtained at the base, 25%, 50%, 75% and 100% from the commercial height of the stem. After, a small part of each disk was processed in sawdust and homogenized according to the species and sampling spot, in order to form a representative composite sample of the factors evaluated.

Fixed carbon, volatiles matter and ash content were performed according to the procedures of NBR 8112 (ABNT 1983) in quadruplicate. The higher heating value was determined using a bomb calorimeter IKA WERKE C5000 following the procedures of NBR 8633 (ABNT 1984).

For statistical analysis, it was used a randomized design in a double factorial, with species and sampling spot as factors. The analysis of variance was used to compare the means and where the result found was significant, the means also were compared by Tukey´s test. All tests considered the level of significance at 5%.

RESULTS AND DISCUSSION

It was observed that interaction between specie and sampling spot was significant for all properties studied. Regarding only the specie factor, all properties were significant too, but for the sampling spot factor only the volatiles matter and fixed carbon were significant (Table 1).

Table 1: Analysis of variance summary for proximate analysis and higher heating value.

Factor	DF	MS			DF	MS
		VM	FC	Ash		HHV
Specie (A)	3	35,105*	37,334*	0,060911*	3	15,5368*
Sampling spot (B)	4	1,992*	0,866*	$0,009398^{NS}$	4	$0,1048^{NS}$
Interaction AB	12	0,735*	0,497*	0,01142*	12	2,9699*
Residuals	60	0,372	0,143	0,004925	40	0,7967
Total	79				59	
ECV (%)		0,75	2,13	13,57		4,76

Note: *Significant; NSnot significant. DF= Degree of freedom, MS= Mean Square, VM= Volatile matter, FC= Fixed carbon, HHV= Higher heating value, ECV= Experimental Coeficient Variation.

The mean values of volatiles matter in different longitudinal positions by species are shown in Table 2.

Table 2: Effect of sampling spots and species on the volatile matter content (%).

Sampling spot	*A. fraxinifolius Wight & Arn*		*M. azedarach L*		*Grevillea robusta* A. Cunn		*Toona ciliata* M. Roem	
Base	82,39	aA	82,43	aA	82,30	aAB	79,12	bA
25%	82,44	aA	82,43	aA	82,48	aA	79,60	bA
50%	82,81	aA	82,42	aA	82,96	aA	80,01	bA
75%	82,56	aA	82,07	aAB	82,71	aA	79,74	bA
100%	82,38	aA	81,00	bcB	81,11	bB	79,90	cA

Note: Means followed by the same letter do not differ statistically (Tukey´s test).

The *A. fraxinifolius Wight & Arn* volatile matter did not show difference between the spots along the height of the stem and the mean content was 82,51%. The *M. azedarach* L. and *Grevillea robusta* A. Cunn showed difference at 100%, decreasing the value in the highest part of the stem. The *Toona ciliata* M. Roem had the lower volatile matter content between the species, differing statistically from all other sampling spots. This occurred, possibly, due to anatomic differences among the species.

The mean values of fixed carbon in different longitudinal positions by species are shown in Table 3.

Table 3: Effect of sampling spots and species on the fixed carbon content (%).

Sampling spot	*A. fraxinifolius* Wight & Arn		*M. azedarach* L		*Grevillea robusta* A. Cunn		*Toona ciliata* M. Roem	
Base	16,58	C	17,06	bcB	17,29	bA	20,49	aA
25%	17,00	B	17,08	bB	17,22	bA	19,74	aAB
50%	16,68	B	17,14	bB	16,45	bAB	19,30	aB
75%	16,74	B	17,26	bB	16,91	bB	19,79	aAB
100%	17,12	C	18,12	bA	17,31	cA	19,51	aB

Note: Means followed by the same letter do not differ statistically (Tukey´s test).

The *A. fraxinifolius* Wight & Arn fixed carbon content did not show difference between the sampling spots and the mean value for this species was 16,82%. The *M. azedarach* L. was the only with the significant difference between sampling spots within the species, at position 100%, where it was found the highest value (18,12%). The *Toona ciliata* M. Roem showed the highest values of fixed carbon in all the sampling spots when compared to other species. This behavior was expected once the fixed carbon content is inversely proportional to the volatile matter content.

The mean values of ash content in different longitudinal positions by species are shown in Table 4.

Table 4: Effect of sampling spots and species in the ash content (%).

Sampling spot	*A. fraxinifolius* Wight & Arn		*M. azedarach* L		*Grevillea robusta* A. Cunn		*Toona ciliata* M. Roem	
Base	0,43	bB	0,48	ab	0,52	ab	0,59	a
25%	0,56	aAB	0,41	B	0,54	a	0,61	a
50%	0,48	abAB	0,46	ab	0,42	b	0,57	a
75%	0,61	aA	0,49	ab	0,43	b	0,58	a
100%	0,50	bAB	0,55	ab	0,49	b	0,64	a

Note: Means followed by the same letter do not differ statistically (Tukey´s test)

The species *A. fraxinifolius* Wight & Arn was the only one that showed a significant difference by sampling spot. The other species did not differ statistically. The lowest ash content was observed for the *M. azedarach* L species, at position 25%. It is usual to find differences between species because the ash content is quite variable in the wood. In the Brazilian Cerrado it was found values between 0,14% and 2,73% of ash content for 47 different species (Vale *et al* 2002).

The mean values of ash content higher heating value in different longitudinal positions by species are shown in Table 5.

Table 5: Effect of sampling spots and species on the higher heating value (MJ/Kg).

Sampling spot	*A. fraxinifolius Wight & Arn*			*M. azedarach* L			*Grevillea robusta* A. Cunn			*Toona ciliata* M. Roem		
Base	18,08	Ab	A	19,13	ab	A	17,95	b	B	19,97	a	A
25%	18,02	B	A	17,78	b	AB	18,73	b	B	21,02	a	A
50%	17,81	Bc	A	16,82	c	B	20,89	a	A	19,01	ab	A
75%	18,11	B	A	18,56	ab	AB	17,88	b	B	20,50	a	A
100%	18,24	Ab	A	17,22	b	AB	19,32	a	AB	20,08	a	A

Note: Means followed by the same letter do not differ statistically (Tukey´s test)

The higher heating value of *A. fraxinifolius* Wight & Arn and Toona ciliata did not show significant difference along the stem. The species *M. azedarach* L. and *Grevillea robusta* A. Cunn differed statistically with this factor.

The *M. azedarach* L. showed the HHV at the base (19.13 MJ / kg) and the lowest in the sampling spot 50% (16.82 MJ / kg). *Grevillea robusta* A. Cunn showed the HHV in the position 50% (20.89 MJ / kg) and the lowest in the base (17,95MJ / kg). The *Toona ciliata* M. Roem stood out between the other species showing the highest value in all positions.

It was found no significant difference for the higher heating value along the stem for the species *Acacia mearnsii* De Wild, *Eucalyptus grandis* W. Hill, *Mimosa scabrella* Benth and *Ateleia glazioveana* Baill. (Silva *et al*. 2013). The same result was found for *Schizolobium amazonicum* Huber ex Ducke. (Vidaurre 2012) .

Conclusion:

All species studied have a high potential as energy resource. Based on the energy properties, the *Toona ciliata* is the most promising resource because it had the highest heating value between the species evaluated.

In general, it was found no significant influence of the longitudinal position along the stem in relation to the energy properties from the species evaluated.

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