Article

ECORFAN-Ecuador Journal
December 2017 Vol.4 No.7 1-7

Energy potential of some forest species in the northern zone of the Yucatan Peninsula, for their use as solid fuels

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Received July 18, 2017; Accepted November 5, 2017

Abstract

Campeche, Quinta Roo and Yucatan are states that have high forest activity, in tropical forest and wood industry, with a great waste disposal, which could be an alternative for profitable use. Promoting the management and use of this biomass, would generate energy benefits for the North of the Yucatan Peninsula. In this work, the energy potential of wood residues generated in the states of Campeche, Quintana Roo and Yucatán was determined by the calorific value and basic density. The wood preparation for density and calorific value studies was carried out in accordance with the Tappi T264 standard. The heat value was determined with a PARR 1266 calorimeter and the basic density according to the Tappi T258 standard. The statistical analysis was developed with the SAS program, version 9.3. The results show significant differences for basic density and heat value, being *Bucida buceras L*. the species with the highest values in both parameters, however, in this work was a negative correlation between the basic density and the calorific value.

Heat value, basic density, Yucatan peninsula, Wood waste

Citation: AGUILAR-SÁNCHEZ, Patricia, CARRILLO-ÁVILA, Noel, SUÁREZ-PATLÁN, Edna Elena, ORDÓÑEZ-PRADO, Casimiro. Energy potential of some forest species in the northern zone of the Yucatan Peninsula, for their use as solid fuels. ECORFAN Journal-Ecuador. 2017, 4-7:1-7

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1 Introduction

The energy system of a country is fundamental for its economic, environmental and social development, where a sustainable energy supply allows an adequate functioning of the productive system and, as a consequence, provides social benefits through the generation of jobs (Kautto N. and Peck P., 2012, Bondolich C. and Roccia H., 2013). In Mexico, there is potential for the generation of alternative energies from biomass, however, in 2010 the participation of this in the energy supply was only 4.3%, mainly due to the use of firewood and cane bagasse (García et al., 2015).

The northern zone of the Yucatan Peninsula is one of the areas with the greatest potential for the use of wood energy, with a great diversity of forest species, characteristic of the region. Much of the forest management practiced in the area focuses on the use of precious woods such as red cedar and mahogany, however, many of the species that coexist in the area are the main source of energy use, used as firewood for the rural populations of Campeche, Quinta Roo and Yucatán. Although there is a commercial use for their wood, the forestry activity and the wood industry generate a large amount of waste in the form of sawdust and some other pieces of wood of different shapes, which could represent greater income opportunities if they were used as energy options. (UNDP et al., 2014; German-Nava et al., 2014).

Therefore, within a sustainable scenario, biomass hopes to become one of the best renewable resources for the production of food, livestock feed, materials, chemicals, fuels, energy and heat (Aresta, 2012, García et al., 2015). In addition, studies prove that the chemical composition of natural biomass is simpler than that of solid fossil fuels, however, the characteristics of the biomass vary according to the source and need to be known in detail before any thermochemical process is developed. (Sauciuc et al., 2014; Vassilev et al., 2010).

It is said that the biomass potential represents a significant amount of energy and there are several transformation processes, which can be used to produce energy in the form of gas, liquid and solid, from virgin or residual biomass, and the potential characteristics of these Raw materials such as moisture and energy content are considered important effects for the selection of species and biomass residues (Klass et al., 1998, Ramírez, 2015). Thus, energy options such as solid fuels are seen as one of the best options, since this biomass does not need any prior chemical intervention for its use, besides having environmental and economic advantages, since it is cheap and is a renewable resource (Erol et al., 2010).

The calorific power of the biomass is an indicator of the energy that is chemically bound to it and that in the combustion process is transformed into thermal energy. The calorific value is considered the most important property of a fuel, since it determines its energetic value (Erol et al., 2010). Previous studies mention that the range of calorific power for wood is from 4000 to 5000 kcal · kg-1 in dry weight (Tancredi et al., 2005). On the other hand, density is a variable linked to physical properties, which has a positive correlation with calorific value (Kumar et al., 2010). Some of the values reported for densities range from 440 to 963 kg · m-3 (Manulala and Meincken, 2009, Telmo and Lousada, 2011).

However, due to the growing demand for energy, limitations for the creation of new technologies from biomass, have made fossil fuels with high calorific value widely used, making biomass lose importance despite the recent development of systems for the production of cleaner energy (Cutz et al., 2016, Bilgili et al., 2017).

So in this work the energy potential of wood residues generated in the states of Campeche, Quintana Roo and Yucatan was determined by determining the calorific value and basic density, to determine their viability as solid fuels.

ISSN-On line: 1390-9959

2. Methodology

To achieve the stated objective, the following methodology was followed: Wood samples were collected from the main species harvested in the felling areas of the timber management programs of the states of Campeche, Quintana Roo and Yucatán. The samples taken were of residues that are generally abandoned in the field as branches of different diameters and pieces that are not sent to the transformation centers. Each sample collected was labeled with basic control information: name and coordinates of the site, date, species and sample number. These samples were sent to the laboratory of forest products and wood technology of the San Martinito Experimental Field (INIFAP), for the estimation of the basic density and calorific value.

Preparation of simple

The collected materials were transported to the laboratory where the samples were prepared in accordance with the TAPPI T257 standard. The milling of the study material was done using a Thomas Wiley mill. The milled material was sieved with No. 40 and 60 meshes, using only the material retained in No. 60 mesh. This material was placed in paper bags with their respective identification and stored for later calorimetry analysis.

Heating power (PC)

For the PC determination, a Parr 1266 Calorimeter was used, following the procedure of the operation manual. The calorimeter was calibrated with benzoic acid tablets of calorific grade. For its determination, a pellet was formed with the ground material with a weight between 0.5 to 0.9 g, with a sample moisture content between 5-10%. The pellet was placed in a combustion pod, in addition to the 10 cm ignition wire on the pellet, preventing the wire from rubbing against the walls of the capsule.

Then, the capsule with the pellet and the wire were placed inside the oxygen pump, closing to inject as oxygen the combustion medium. Finally, the pump was placed inside a bucket and connected to the electrodes. The determination of the CP was carried out in a time not greater than ten minutes, performing five repetitions per sample. The results were obtained directly from the calorimeter in units cal · g-1 and adjusted according to equation 1.

$$PCt = \frac{Ee\ (At) - 10 - Lai\ (k)}{Pm} \quad (1)$$

Where:
PCt total calorific value [cal · g-1]
The equivalent energy [cal · ° C-1]
At increase in temperature [° C]
The length of the burned ignition wire [cm]
Constant k (2.3 cal.cm-1)
Pm weight of the wood pellet [g]

Density

The density of the wood was determined by the volumetric displacement method, since precision and reliability were required in the results and the pieces collected from wood were irregularly shaped, for this purpose wax was used to cover the samples and avoid measurement errors. the weight of the sample before and after waxing. Afterwards, the sample was introduced in a container with water until it was completely covered. The container was placed on the digital balance so that during the operation the weight of the displaced liquid was recorded directly, which is proportional to the force of the water on the sample. The density of water is equal to 1 g · cm-3 and therefore the weight recorded by the balance is equal to the volume of the sample. The basic density was calculated by relating the anhydrous mass and volume of the saturated wood, as shown in equation 2.

$$Db = \frac{Po}{Vv} \quad (2)$$

ISSN-On line: 1390-9959

Where:
Db basic density of wood [kg · m-3]
Po anhydrous weight [kg]
Vv green volume [m3]

With the weight and volume data, the initial moisture content was calculated, expressed in the caution 3:

$$CH = \frac{(Ph - Po)}{Po} \cdot 100 \quad (3)$$

Where:
CH moisture content [%]
Ph initial weight of wet wood [kg]
Po anhydrous weight [kg]

For the estimation of the basic density and calorific power, five repetitions were made for each species and place of origin of the sample. An analysis of variance was performed represented in the statistical model of equation 4, as well as a multiple comparison of means by the Duncan method, using the SAS 9.3 program®.

$$y_{ij} = \mu + \tau_i + e_{ij} \quad (4)$$

Where:
Yij is the answer
µ is the general average of the experiment
Ţi is the effect of the treatment
eij is the treatment error associated with the response Yij

3. Results

According to the multiple means comparison, statistically there are significant differences in calorific power and basic density with $p < 0.05$ of the species studied. In relation to the calorific value (table 1) 11 groups were obtained, in a range of values ranging from 4000.3 to 4706.71 kcal · kg-1 being the species Coccoloba spicata (Bo'o) with lower PC and Bucida buceras L. (Pucte) the one with the highest PC value.

The basic density of the studied species was presented in values of 366.8 kg · m-3 and 846.2 kg · m^{-3} (table 2), being the species Bursera simaruba Sarg. (Chaká) the lightest wood and Bucida buceras L. (Pucte) the densest.

It can be observed that the calorific value and density results are in accordance with the data reported in the literature, noting that Bucida buceras L. and Psychotria pubescens Swartz were the species with the highest combustion values, having an energy content per unit volume of 3999.58 and 3914.72 Mcal · m-3 respectively.

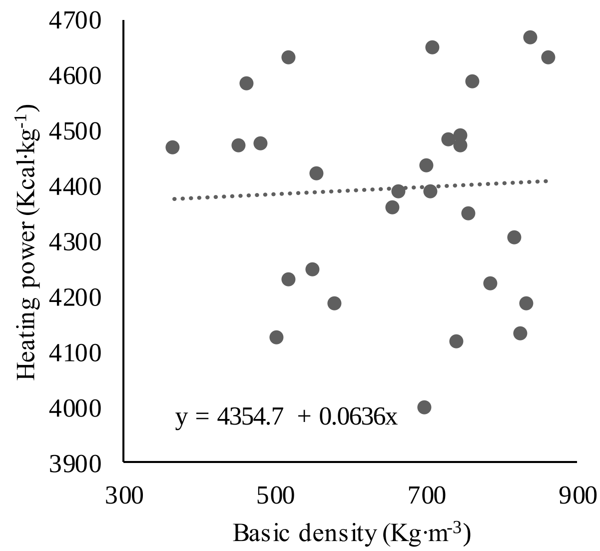
Species	**Calorific power ($kcal \cdot kg^{-1}$)**
Bucida buceras L.	4706.71 A
Psychotria pubescens Swartz	4667.61 AB
Lonchocarpus castilloi Standl.	4649.35 AB
Lysiloma latisiliquum (L.) Benth.	4631.77 AB
Thouinia pausidentata	4588.67 B
Swietenia macrophylla King.	4585.65 B
Swartzia cubensis (Britt & Wils.) Standl.	4490.52 C
Matayba oppositifolia Britton	4483.28 CD
Tectona grandis	4473.81 CD
Vitex gaumeri Greenm.	4470.84 CD
	4470.58 CD
Psidium sartorianum (Berg.) Ndzu.	4467.89 CD
Bursera simaruba Sarg.	4434.65 CDE
Exostema caribaeum (Jacq) Roem. & Schult.	4421.45 CDE
Piscidia piscipula (L) Sarg	4390.70 CDEF
Gymnopodium floribundum Roste	4388.82 DEF
Platymiscium yucatanum Standl	4360.13 EF
Diospyros cuneata Stanley	4350.90 EF
Caesalpinia violacea (Miller) Standl.	4304.48 FG
Mimosa bahamensis Benth	4247.24 GH
Thevetia gaumeri hemsl	4231.46 GH
Lysiloma latisiliquum (L.) Benth.	4222.46 GHI
Acacia gaumeri Blake	4187.20 HIJ
Guetta combsii Urban	4186.27 HIJ
Caesalpinia gaumeri Greenm.	4131.82 IJ
Acacia milleriana Standl.	4124.52 J
Guazuma ulmifolia Lam.	4118.19 J
Lonchocarpus Rugosa	4000.30 K

Table 1 Average calorific value of the forest residues of the Yucatan Peninsula (values with the same letter are not significantly different)

Species	Density ($kg \cdot m^{-3}$)	
Bucida buceras L.	846.2	A
Psychotria pubescens Swartz	838.7	B
Caesalpinia gaumeri Greenm.	834.6	C
Acacia milleriana Standl	825.6	D
Mimosa bahamensis Benth	817.9	E
Acacia gaumeri Blake	785.6	F
Thouinia pausidentata	763.2	G
Caesalpinia violacea (Miller) Standl.	756.4	H
Swartzia cubensis (Britt & Wils.) Standl.	747.1	I
Psidium sartorianum (Berg.) Ndzu.	746.8	J
Lonchocarpus Rugosa	742.1	K
Matayba oppositifolia Britton	730.9	L
Lonchocarpus castilloi Standl.	710.9	M
Platymiscium yucatanum Standl.	707.4	N
Exostema caribaeum (Jacq) Roem. & Schult.	700.9	O
Coccoloba spicata	698.3	P
Gymnopodium floribundum Roste	665.4	Q
Diospyros cuneata Stanley	657.1	R
Guetta combsii Urban	580.1	S
Piscidia piscipula (L) Sarg	555.7	T
Thevetia gaumeri hemsl	550.1	U
Lysiloma latisiliquum (L.) Benth.	520.4	V
Guazuma ulmifolia Lam.	503.0	W
Tectona grandis	483.0	X
Swietenia macrophylla King.	463.1	Y
Vitex gaumeri Greenm.	452.7	Z
	366.8	A

Table 2 Average basic density of the forest residues of the Yucatan Peninsula (values with the same letter are not significantly different)

The forest residues evaluated in this work show a coefficient of determination R2 of 0.002, which indicates that the values of basic density and calorific value are not directly related (figure 1), as was the species Lysiloma latisiliquum (L.) Benth, from which samples were obtained from the states of Campeche and Quintana Roo, these had an equal basic density, however, the calorific value was different, being higher the species from Quintana Roo.



Graphic 1 Linear regression analysis, calorific value & basic density

4. Conclusions

Forest residues from forest management programs in the northern Yucatan Peninsula represent an opportunity for the generation of alternative energies. Given that, the values of calorific power and basic density obtained in this study showed high values such as the species Bucida buceras L. (Pucte).

On the other hand, the viability of forest biomass as fuel depends on the correlations and associations between its chemical composition, so it is important to have other analyzes such as chemical composition and elemental and proximal analysis that can strengthen this study.

Aknowledgement

The authors thank the Sector Fund CONACYT / CONAFOR 116375 for supporting the development of this research.

5. References

Alemán-Nava, G. S., Casiano-Flores, V. H., Cárdenas-Chávez, D. L., Díaz-Chavez, R; Scarlat, N., Mahlknecht, J., Dallemand, J. F., Parra, R. (2014). Renewable energy research progress in Mexico: A review. Renewable and Sustainable Energy Reviews, 32, pp.140–153.

Aresta, M., Dibenedetto, A., Dumeignil, F. (2012). Biorefinery from biomass to chemicals and fuels. De Gruyter, Alemania.

Bilgili, F., Koçak, E., Bulut, Ü., Kuşkaya, S. (2017). Can biomass energy be an efficient policy tool for sustainable development? Renewable and Sustainable Energy Reviews, 71, pp. 830–845.

Bondolich, C., Roccia, H. (2013). Desarrollo regional con energía de la biomasa Fundación Agropecuaría para el Desarrollo de Argentina, p.14.

Cutz, L., Haroc, P., Santana, D., Johnsson, F. (2016). Assessment of biomass energy sources and technologies: The case of Central America. Renewable and Sustainable Energy Reviews, 58, pp. 1411–1431.

Disponible en: www.ccmss.org.mx/wp-content/uploads/2014/10/CATALOGO-MADERA.pdf

Erol, M., Haykiri-Acma, H., Küçükbayrak, S. (2010). Calorific value estimation of biomass from their proximate analyses data. Renewable energy, 35, pp. 170-173.

García, C. A., Riegelhaupt, E., Ghilardi, A., Skutsch, M., Islas, J., Manzini, F., Masera, O. (2015). Sustainable bioenergy options for Mexico: GHG mitigation and costs. Renewable ans Sustainable Energy Reviews, 43, pp. 545-552.

Kautto, N., Peck, P. (2012). Regional biomass planning- Helping to realice national renewable energy goals? Renewable Energy, 46, pp. 23-30.

Klass-Donald, L. (1998). Biomass for renewable energy, fuels and chemicals. Academic Press, San Diego California EUA.

Kumar, R., Pandey, K.K., Chandrashekar, N., Mohan, S. (2010). Effect or tree-age on calorific value and other fuel properties of Eucalyptus hybrid. Journal of Forest Research, short communication, 21:4, pp. 514-516.

Munalula, F., Meincken, M. (2009). An evaluation of South African fuel wood with regards to calorific value and environmental impact. Journal Biomass and Bioenergy, 33, pp. 415-420.

Parr. (1999). 1266 Isoperibol Bomb Calorimeter. Operating Instruction Manual. Technical Note No. 367M. Parr Instrument Company. Illinois, USA.

PNUD, GEF, CONAFOR, RAINFOREST. (2014). Biodiversidad en Bosques de Producción y Mercados Certificados Catálogo de maderas tropicales de México. 10/10/2017, de Programa de las naciones unidas para el desarrollo.

Ramírez-Guardado, M. A. 2015. Estimación del carbono retenido en la biomasa áerea, en una selva tropical de Yucatán, México. Tesis de maestria en Energía Renovable. Centro de Investigación Científica de Yucatán, AC, México, p.111.

Tancredi, N., Amaya, A., Medero, N. (2005). Residuos de Madera de Bosque Tropical: Obtención de Carbón Activado y Determinación de Poder Calorífico, Montevideo Uruguay), Congreso Interamericano de Residuos. Mérida.

Technical Association of the Pulp and Paper Industry (TAPPI). (2006). Preparation of wood for chemical analysis. T 257 cm-85. TAPPI Test Methods. Fibrous Materials and Pulp Testing. Atlanta, GA., U.S.A.

ISSN-On line: 1390-9959

December 2017 Vol.4 No.7 1-7

Telmo, C., Lousada, J. (2011). Heating values of wood pellets from different species, Journal Biomass and Bioenergy, 35, pp. 2634-2639.

Vassilev, S. V., Baxter, D., Andersen, L. K., Vassileva, C. G. (2010). An overview of the chemical composition of biomass. Fuel, 89:5, pp. 913-933.

ISSN-On line: 1390-9959