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ENEGETIC ANALYSIS OF TROPICAL BIOMASS

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Abstract. *The energy production from waste generates several environmental and financial benefits. Besides reducing the amount of residues in the environment generate a profit from these products, with the possibility of power generation in isolated regions or with low income population. In order to characterize the biomass and its power output potential, this study presents tests for several kinds of biomass for the evaluation of thermal parameters. The materials considered were cupuaçu (Theobroma grandiflorum), cacao (Theobroma cacao) and açai berry (Euterpe oleracea), growing cons materials in Brazil and high production of residues. The parameters considered for the evaluation process were the calorific power of the biomass, its elementary and immediate composition. For biomass on a dry basis, its high heating value in the range of 10-25 MJ / kg, with high content of volatiles, carbon, oxygen and sulfur levels considered close to zero. The analyzes were made based on data from the literature and in data obtained in the Laboratory of Analysis of Gases from Federal University of Itajubá (UNIFEI). Comparing the obtained results to biomasses widely used in power generation such as sugarcane bagasse and sawdust, the biomasses used in this study show its potential for thermochemical processes such as combustion, gasification and pyrolysis.*

Keywords: *biomass, characterization, thermochemical, heating value.*

1. INTRODUCTION

The growing demand for energy, the threat of the end of oil deposits and fluctuations in the market for fuel prices, has formed an ideal scenario for research aimed at exploring the potential of new sustainable sources of energy (GOLDEMBERG, 2009). Biomass is an alternative source of energy with great potential for replacement of fossil fuels, and can be found and converted into the solid, liquid and gaseous phases.

Using materials once considered waste can reduce the environmental degradation, generate profit and energy from different materials. Also, the utilization of different kinds of waste for energy generate a spread power generation, once the plant can be close to the source of the biomass.

Currently there are several types of biomass that are used for the production of energy, mainly, heat. The biomass used to generate heat is mainly used in boilers, through direct burning, this can reduce energy efficiency, when compared to other ways of energy conversion (MCKENDRY, 2002a). Other processes as gasification and pyrolisis presented as a way to transform biomass in a liquid, solid or gaseous fuel, in addition to the possibility of obtaining other compounds from the resulting gas, such as methanol and ammonia.

The main parameters for determining biomass potential for energy conversion are the heating value, defined as the amount of energy in the form of heat released by the combustion per unit of mass, in theory it is defined by the elemental composition of the material (JARA, 1989). This property is classified into two subdivisions: The High Heating Value (HHV), which combustion takes place at constant volume and in which the water formed during the combustion is condensed and the heat that is derived from this condensation is recovered and Low Heating Value (LHV) is the energy actually available per unit mass of fuel after deducting the losses with water evaporation (JARA, 1989).

At this paper the cupuaçu (seed and shell), cacao (seed and shell) and the açaí berry (seed). This are fruits of high productions in the north and northeasth of Brazil, in this regions is often find populations in isolated places without easy access to fuel and outside the region of energy transmission. A analysis of the power potention of this material was conduct in order to determine its potential for thermochemical processes.

2. BIOMASS

Biomass as a combustible material is varied and inexhaustible, ideal as a source of energy generation, attending to the current need for renewable and sustainable energy. Their study is necessary to know the characteristics of fuels and work on their properties so that they can be used in internal combustion engines, among other mechanical devices. It is a material of great importance in the substitution of fossil fuels, since the biomass can appear in the solid state and be converted to the liquid state e gaseous.

Gasification, pyrolisis and combustion are thermochemical alternatives for the energy generation with neutral carbon dioxide emissions and less impact on the environment. In the literature there are biomasses of typical use that have already been used in this processes, such as rice husk, sawdust, sugarcane bagasse, wood, and other materials with high energy potential that have not yet been widely studied as the açaí berry, cupuaçu, cocoa. These fruits are used in the food industry, generating residues materials, in this paper were selected açaí berry seed, cupuaçu shell and seed, cocoa husk and seed as possible biomass material for energy generation.

2.1 Cupuaçu (*Theobroma grandiflorum*)

Cupuaçu is a fruit original from the eastern Amazon, since the 90's the production and industrialization of the fruit increased considerably, allowing the expansion of the commercialization area (Souza *et al.*, 1998), producing 39,045 tons in the State of Pará (Brazil) in 2006 (Vieira *et al.*, 2013). The fruit has a yellowish-white acidic pope with a characteristic aroma, each fruit contains between 20 and 50 seeds that are inserted in the fruit, corresponding to 20% of the fruit weight (Cohen; Jackix, 2005), which present proximally 60% oil in its composition (Aguilar; Gasparotto, 1999).

The shell of the cupuaçu is rigid and woody, its weight depends on the size and weight of the fruit, which on average has 1.5 kg, one hectare of production can result in 22 ton of shell (Santos *et al.*, 2004).

The cupuaçu seed, as well as the pope, has been used in the food industry. From the pope one can obtain many products such as juices, ice cream, sweets, yogurts, jellies, liqueurs, among others. The seeds, when fermented, dried and toasted, can pass through the same production process of chocolate, obtaining the so-called "cupulate", its butter can also be used in the pharmaceutical industry in a similar way to cacao butter (Souza *et al*., 1998).

The popularization of the fruit with the food industry encouraged the cultivation and, consequently, increases the production of residues. Some growers use the shell for the as organic fertilizer, but since it is a woody material its has a low decomposition. Thus mostly of the shell is discarded near the processing and sale area, resulting in proliferation of diseases and pests due to the accumulation of organic matter.

Cruz Junior (2010) analyzes the possibility of producing activated carbon from the shell of the fruit and Gonzalez *et al.* (2008) analyzes and compares the oil extracted from cupuaçu seeds with other fruits for biodiesel production and extraction of plasticizing additives for paints and soap.

2.2 Cacao (*Theobroma cacao*)

Cacao is a tropical fruit, in Brasil it is cultivated mostly in the northeast. The cacao production in Brazil in 2017 was almost 215 thousands ton (IBGE, 2018). The main product of cacao comes from the processing of the seeds, becoming cocoa or chocolate in many ways. However there is a large variety of products as the cocoa butter, use in the cosmetics industry, and the products derivate by the pope, such as jam, licor, ice cream, yogurts and juice.

The husk also can be used as animals food, fertilizer production, biogas production. One ton of dry cacao generates 8 tons of fresh husk (CEPLAC,2018).

2.3 Acai berry (*Euterpe oleracea*)

The acai berry production represents a major socioeconomic production in the Amazon region in Brasil due the consumption of the pope and the natural coloring that is used in the pharmaceutical, cosmetic and food industry. In 2012 the total production in Brasil was 817 thousand ton (Embrapa, 2016). The acai berry composition is 85% seed and 15% pope, that means a large amount of seeds to be disposal after the pope processing.

The use of the seeds has been analyse for the production of fertilizer production, furniture, animal food, activated carbon and power generation (Luczynski, 2008; Oliveira *et al.*, 2016).

3. METODOLOGY

The biomasses used for characterization were analyzed in the Laboratory of Analysis of Gases (LAG), at the campus of Itajubá of Federal University of Itajubá (UNIFEI).

First, the samples underwent a pre-drying process, the acai berry seeds and the cacao material were exposed to the action of the san, the cupuaçu shell and seeds were oven-dried at 70°C for 24 hours. All the materials were grounded, in order to produce a powder for analyses, with a Willey-type knife mill (MSSL-031 Multicience) at a fixed rotation of 5000 rpm with a 10 mesh.

Once the material was grounded and dry the analyses could be performed. For the proximate analyses was determined with a Thermogravimetric Analyzer (TGA) (LECO model 701), three samples were used for each material.

In order to obtain the calorific value, the ABNT NBR 8633/84 standard was followed, the calorimeter (IKA WORKS model C-2000) was used in the same laboratory. The tests were also done in triplicate and the measured PCS was obtained, described in Table 3.

The ultimate analysis was permormed using a CHNS Elemental Analyzer PerkinElmer 2400 series. Since biomass presents low percentage of sulphur the analysis were performed using a cilinder for carbon, hidrogen and nitrogen only, the oxigen was calculated by diference.

Using the elementary composition of the biomasses the calculation of the lower calorific value (LHV) of each was made from the Mendeley Equation (Equation 1). From the calculation of the LHV it is possible to obtain the superior calorific value (PCS) calculated from Equation 2. The results of this equations were compared with the experimental value from the calorimeter.

$$PCI = 339C^t + 1030H^t - 109\left(O^t - S^t\right) - 24W^t \quad (1)$$

$$PCS^t = PCI^t + h_{vap\_H_2O}\left(9H^t + W^t\right) \quad (2)$$

Where:

$$h_{vap\_H_2O} = 2442\frac{kJ}{kg}$$

4. RESULTS AND DISCUTION

The magnitudes studied throughout the work are: moisture, ashes, volatiles, elemental composition, calorific value. The composition of the materials (Table 1) can be used to predict their behavior in thermochemical transformation processes.

Table 1. Elementary composition of the biomass

	Carbon (C)	Hydrogen (H)	Nytrogen (N)	Oxygen (O)*	O/C ratio	H/C ratio
Casca de cupuaçu	50.61 ± 1.1	6.9 ± 0.2	1.0 ± 0.1	41.4 ± 1.4	0.81	1.36
Semente de cupuaçu	58.72 ± 1.8	9.4 ± 0.3	1.6 ± 0.1	30.3 ± 2.2	0.51	1.59
Casca de cacau	43.1 ± 2.6	5.8 ± 0.4	2.2 ± 0.1	48.8 ± 3.1	1.13	1.35
Semente de cacau	52.4 ± 3.3	8.0 ± 0.6	2.8 ± 0.2	36.7 ± 4.1	0.70	1.52
Semente de açaí	44.5 ± 0.8	6.1 ± 0.2	1.1 ± 0.1	48.2 ± 1.0	1.1	1.35
Sugarcane Bagasse[1]	45.4	5.5	0.5	40.1	-	-
Wood[2]	46.3	6.0	0.3	31.4	-	-

*Calculated by difference;1.Garca-pèrez (2002);2.Feldmann (1998).

Table 1 shows similar aspects in the studied biomasses, such as the high content of C and O in the studied materials, and low content of N and sulphur, which can be better observed in Fig. 1. The low content of nitrogen and sulfur indicates a lower emissions of pollutants (SOx, NOx), reducing the formation of slag and scale in combustion (Jenkins *et al.*, 1998). According to the diagram proposed by Van Krevlen the lower O/C ratio and the higher H/C ratio represents the higher calorific value (Mckendry, 2002b).

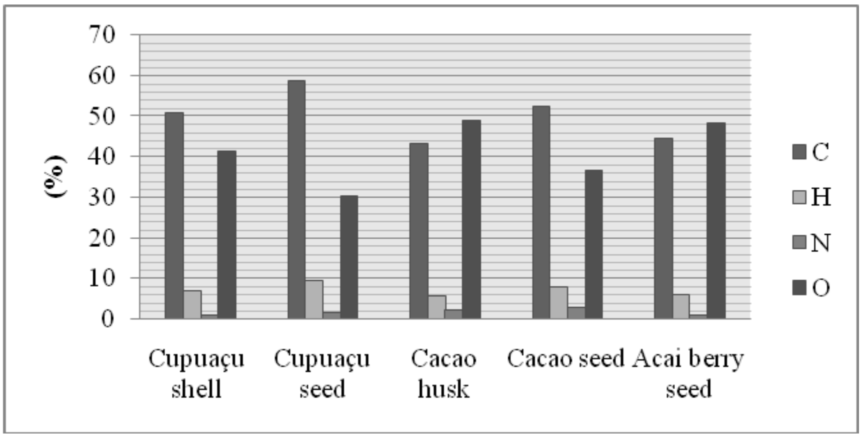

Figure 1. Elementary composition of biomass

Table 2 show the proximate analysis of the biomass, in Fig. 2 it can be also observed. The results show a high moisture level, mostly for the materials that were treated just with sun heat, aside for the cacao seed that has the moisture values close to the ones that were oven-dried.

Table 2. Proximate Analysis of biomass

	Moisture	Volatile	Volatile dry	Ash	Ash dry	Fixed carbon
Cupuaçu shell	5.40 ± 0.08	71.61 ± 0.11	75.69 + 0.08	1.71 ± 0.01	1.81 ± 0.01	21.27 ± 0.29
Cupuaçu seed	3.27 ± 0.05	82.85 ± 0.48	85.65 ± 0.49	2.84 ± 0.10	2.93 ± 0.11	11.03 ± 0.37
Cacao husk	28.26 ± 0.80	50.47 ± 0.46	70.36 ± 0.35	6.48 ± 0.03	9.03 ± 0.13	14.78 ± 0.45
Cacao seed	6.92 ± 0.11	77.95 ± 0.08	83.75 ± 0.01	3.27 ± 0.01	3.52 ± 0.08	11.84 ± 0.08
Acai berry seed	23.68 ± 0.71	58.30 ± 0.69	76.39 ± 0.24	1.15 ± 0.05	1.51 ± 0.07	16.86 ± 0.09
Sugarcane Bagasse[1]	7.00	76.35	82.10	1.49	1.60	15.16
Wood[2]	10.30	74.27	82.80	5.74	6.40	9.69

1.Garca-pèrez (2002);2.Feldmann (1998).

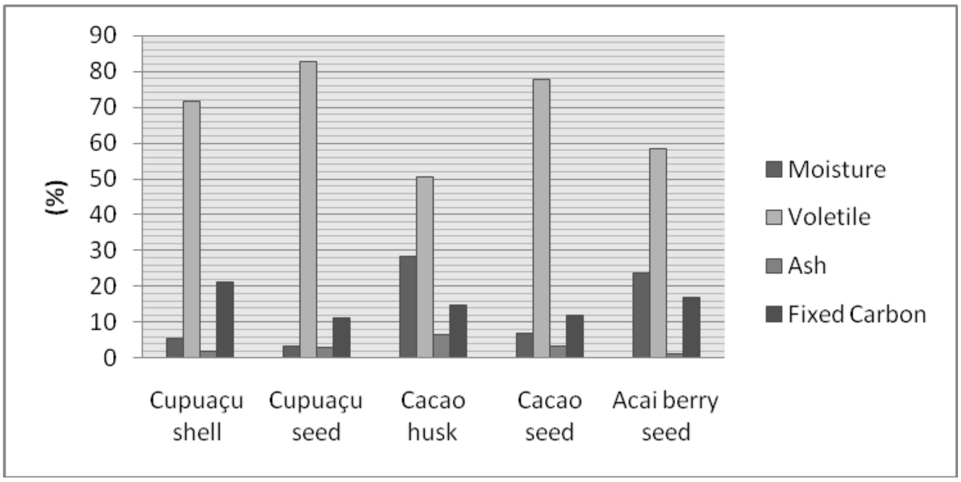

Figure 2. Proximate Analysis of biomass

The moisture in an attention factor, for combusting purposes it aims at the lowest humidity of the material, since this makes it difficult to burn, requiring more energy for its evaporation, causing efficiency loss in the process. Fuels with humidity above 30% have the ignition process compromised (Mckendry, 2002). The cacao husk and the acai berry seed shows higher content of moisture, indicating that these materials will need a dry treatment for its utilization in thermochemical processes.

The volatile materials are the biomass portion released when it is heated from 400 to 550°C. During the heating process the material decomposes into volatile solids and gases. Typically, the biomass has high content of volatiles (up to 80%), especially when compared to coal, which has less than 20% (Quaak *et al*, 1998). A high volatiles value indicates a high disposal to ignite, because the higher the volatiles content, the greater the reactivity, accelerating the combustion process for energy conversion.

The fixed carbon represents the remaining mass after drying and volatilization, excluding the ashes content. The higher fixed carbon content indicates a high heat generation in the material combustion.

At the end the ash content is low, what is a god characteristic for combustion and termochemical processes. A high content of ashes can lead to problems like the formation of partly-fused agglomerates and slag deposits at high temperatures, bounded ash deposities and accumulation on surfaces at lower temperatures, acceleration of metal wastage of furnace due gas-side corrosion, formation and emission of sub-micron aerosols and fumes (Livingston, 2006).

These factors are confirmated by the heating value of the biomass (Table 3), with a range of 10 to 25 MJ/kg it shows the higher values for the materials with low moisture content

Table 3. High and Low Heating Value of biomass

	HHV* [MJ/kg]	LHV [MJ/kg]	HHV** [MJ/kg]
Cupuaçu shell	17.9 ± 1.4	18.6 ± 0.8	20.1 ± 0.8
Cupuaçu seed	25.4 ± 0.3	25.3 ± 1.1	27.4 ± 1.2
Cacao husk	10.91 ± 0.3	10.3 ± 1.0	11.7 ± 1.1
Cacao seed	21.44 ± 0.3	20.3 ± 2.2	22.1 ± 2.3
Acai berry seed	12.60 ± 0.3	11.8 ± 0.6	13.3 ± 0.6
Sugarcane Bagasse[1]	17.85	17.85	35.89
Wood[2]	19.20	19.2	37.39

1.Garca-pèrez (2002);2.Feldmann (1998);*experimental;**teorical

5. CONCLUSIONS

All the materials study in this paper showed very significant potential for their energy utilization, considering the elementary and immediate composition and the heating value analyzes. The results for açaí berry seed and cacao husk show the two lowest heating value, most likely because the high moisture content, leading to a need for a dry process for these materials.

Due to the high heating values, superior to sugarcane bagasse and wood, it is possible to conclude that the biomasses analyzed in this paper are a alternative energy supply for heat generation and power generation. Nevertheless, deep studies are necessary to determine the main applications and the economic viability of cogeneration systems using these biomass.

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