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PHYSICO-CHEMICAL PROPERTIES OF BAMBOO CHARCOALS FROM SPECIES *Bambusa vulgaris var vittatta, Dendrocalamus asper* AND *Phyllostachys pubescens*[1]

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Abstract

The search for sustainable fuels has become important for the development of energy generation in balance with the environment. Brazil has climatic conditions and a vast territory for the production of forest biomass. The research produced in the laboratory determines the gravimetric yield, upper calorific value, percentages of fixed carbon, volatile and ashes of the charcoals of bamboo species: *Bambusa vulgaris var vittatta, Dendrocalamus asper* and *Phyllostachys pubescens*. For the carbonization process, small pieces of bamboo were obtained, were dried in the stove at 100°C for 24 hours, the dried mass was weighed and added in a carbonizer heated to 150°C for 45 minutes, heated to 180°C for 45 minutes and heated to 210°C for 30 minutes, this charcoal was then cooled and weighed to calculate the gravimetric yield. The samples were pulverized in a pot mill, the upper calorific value in a calorimeter was determined. The volatile, fixed carbon and ash contents were determined according to the Brazilian MB-15 method. The results obtained for the species *B. vittatta, D.*

asper and *P. pubescens*, were respectively: gravimetric yield 44.08%, 42.77% and 47.09%; calorific value 28.806kJ/g, 29.075kJ/g and 28.489kJ/g; percentage of fixed carbon 62.1%, 66.09% and 57.8%; percentage of volatiles 35.89%, 30.92% and 40.4%; ash percentage 2.01%, 2.99% and 1.8%. It was observed that the *D. asper* specie presented better results in the general context of the analysis carried out because, despite presenting a slightly lower gravimetric yield, it presented the higher calorific value and higher fixed carbons content.

Keywords: Bamboo, Bioenergy, Sustainability.

PROPRIEDADES FÍSICO-QUÍMICAS DE CARVÕES DE BAMBU DAS ESPÉCIES *Bambusa vulgaris var vittatta, Dendrocalamus asper* E *Phyllostachys pubescens*

Resumo

A busca por combustíveis sustentáveis tornou-se importante para o desenvolvimento da geração de energia em equilíbrio com o meio ambiente. O Brasil possui condições climáticas e um vasto território para a produção de biomassa florestal. Esta pesquisa produziu em laboratório, para determinar o rendimento gravimétrico, poder calorífico superior, porcentagens de carbono fixo, voláteis e cinzas dos carvões de espécies de bambu: *Bambusa vulgaris var vittatta, Dendrocalamus asper* e *Phyllostachys pubescens.* Para o processo de carbonização, foram obtidas pequenas lascas de bambu, secas na estufa a 100°C por 24 horas, a massa seca foi pesada e adicionada em um carbonizador aquecido a 150°C por 45 minutos, aquecida a 180°C por 45 minutos e aquecido a 210°C durante 30 minutos, o carvão foi resfriado e depois pesado para o cálculo do rendimento gravimétrico. As amostras foram pulverizadas em um moinho de panelas, o poder calorífico superior foi determinado em um calorímetro. Os teores de carbono fixo, voláteis e cinzas foram determinados pelo método brasileiro MB-15. Os resultados obtidos para as espécies *B. vittatta, D. asper* e *P. pubescens* foram respectivamente: rendimento gravimétrico de 44,08%, 42,77% e 47,09%; valor calórico 28,806 kJ/g, 29,075 kJ/g e 28,489 kJ/g; percentual de carbono fixo 62,1%, 66,09% e 57,8%; percentual de voláteis 35,89%, 30,92% e 40,4%; percentual de cinzas 2,01%, 2,99% e 1,8%. Observou-se que a espécie *D. asper* apresentou melhores resultados no contexto geral das análises realizadas, pois apesar de apresentar um rendimento gravimétrico ligeiramente inferior, apresentou maior poder calorífico e maior teor de carbono fixo.

Palavras-chave: Bambu, Bioenergia, Sustentabilidade.

INTRODUCTION

In the city of Paris, France, December 2015, a new international treaty was drawn up to reduce global warming by up to 1.5°C, replacing the old Kyoto Protocol. The Paris agreement had the participation of the signatory countries of the Convention on Climate Change (COP 21). To achieve this objective, the treaty aims to reduce the emission of greenhouse gases, which is caused mainly by the use of fossil fuels (non-renewable). The treaty will come into force in 2020 and allow signatory countries to choose the best way to reduce the emission of gases, also considering the economic aspects (FREITAS; FAGUNDES; MIURA, 2017).

Energy is of vital importance to the world, since simple activities such as watching television and surfing the internet, as well industrial activities, transportation, food preservation and technological advances depend on energy (ELETROBRAS, 2017).

From the earliest times, civilization had been using biomass as source of energy, mainly in the form of firewood and charcoal. Biomass is considered a renewable energy source because while its combustion releases CO_2 into the atmosphere, the photosynthesis is responsible for the uptake of the carbon (CAMARGO et al., 2017).

The domestic energy supply in Brazil in 2016 (announced last year) registered 43.5% of renewable sources, which surpassed the percentage of 2015 by 2.2%. The proportion of renewable energy sources in Brazil is about three times higher than the average of the world (14.2%) and is about four times that of the Organization for Economic Cooperation and Development (9.5%) countries. These results are related to a 10% increase in the use of renewable sources in 2016, such as: biomass residues and wind energy sources (BRASIL, 2017).

Brazil has excellent climatic conditions and a vast territory for the production of forest biomass. Currently there is a great interest in research organizations and sustainable development in relation to some aspects of the species. Bamboo in relation to forestry stands out for having high rate of growth and easy handling, however the economic and energetic industrial potential of bamboo species is little explored when compared to other sources of forest raw material (SANTOS et al., 2016).

At its domain level, bamboo is defined as eukaryote (Eukaryota) and its subcategory is the plant kingdom (Plantae). The bamboo species are divided in woody and herbaceous: the woody ones have high bearing and resemblance to the trees in term of morphology, the herbaceous ones are of smaller size, similar to shrubs (SOUZA, 2014).

To obtain the charcoal of a ligno-cellulosic material such as bamboo, is necessary the carbonization process, defined as: a slow pyrolysis process, which has a main objective to eliminate most of the oxygen and the hydrogen by the action of the heat, making possible the concentration of carbon in the residual structure. The products generated in the carbonization, besides the main one, charcoal(C), are: CO, CO_2, CH_4, H_2 and pyrolysis oil (CARDOSO, 2015).

The objective of this study was to evaluate the energy potential and the physico-chemical properties of three bamboo species, *B. vulgaris* var vittatta, *D. asper* and *P. pubescens*.

MATERIALS AND METHODS

The materials and equipment used in this research were: bamboo samples from the species *B. vulgaris* var vittatta, *D. asper* and *P. pubescens*, longitudinal section saw, band saw, beakers, analytical and semi-analytical weighing-machine, stove, muffle furnace, carbonizer, cookware, calorimeter, porcelain crucibles.

The procedure begins by selecting the bamboo, then unfolding and obtaining small pieces (near 6x4cm), after, the samples were dried in a stove at 100°C (for 24 hours). The dried mass of the bamboo was weighed and then were added inside of the carbonizer and heated to the muffle furnace at 150°C for 45 minutes, raised to 180°C for 45 minutes, raised to 210°C for 30 minutes, the cooling was weighted down and the mass of the coal was weighed for the calculation of the gravimetric yield. The samples were pulverized in a pans mill (Figure 1).

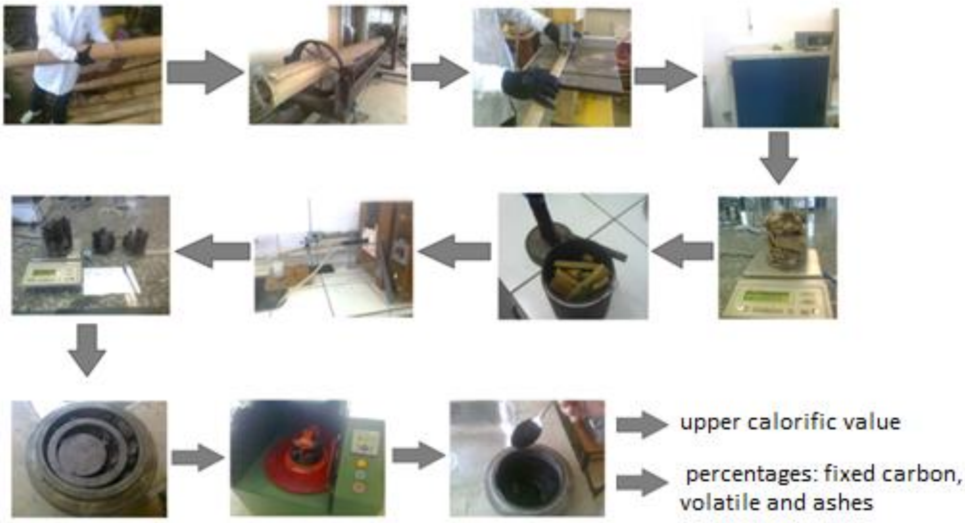


Figure 1 – Preparation of samples, production and pulverization of bamboo charcoal.

The pulverized samples were taken to the stove at 100°C for 24h, then the upper calorific value was determined on an IKA C 5000 calorimeter. The percentages of volatile, fixed carbon and ash contents were determined using a muffle furnace according to the method Brazilian MB-15, as follows: the crucibles were weighed and about 1.5g dry mass of the pulverized charcoal was added in the crucibles, the furnace was set at 950°C, the crucibles were capped and placed on the furnace door for 2 minutes, on the furnace inlet for 3 minutes and finally inside the furnace with the door closed for 6 minutes, the samples were withdrawn, the cooling was waited and weighed the mass of the pulverized charcoal after volatilization + crucible. The crucibles without the lid were taken to the oven at 750°C for 6 hours, the cooling was waited and the ash + crucible were weighed.

For the calculations, the following equations were used:

$$Gravimetric\ Yield = \frac{m2}{m1} \ .100\%$$

m1 = dried mass of the bamboo before carbonization.

m2 = dried mass of the charcoal after bamboo carbonization.

$$Volatile\ Percentage = \frac{[m4 - (m5 - m3)]}{m4} \ .100\%$$

$$Ash\ Percentage = \frac{(m6 - m3)}{m4} \ .100\%$$

$$Fixed\ Carbon\ Percentage\ = 100\% - Volatile\ Percentage - Ash\ Percentage$$

m3 = mass of the crucible.

m4 = mass of the pulverized charcoal.

m5 = mass of the pulverized charcoal after volatilization + crucible.

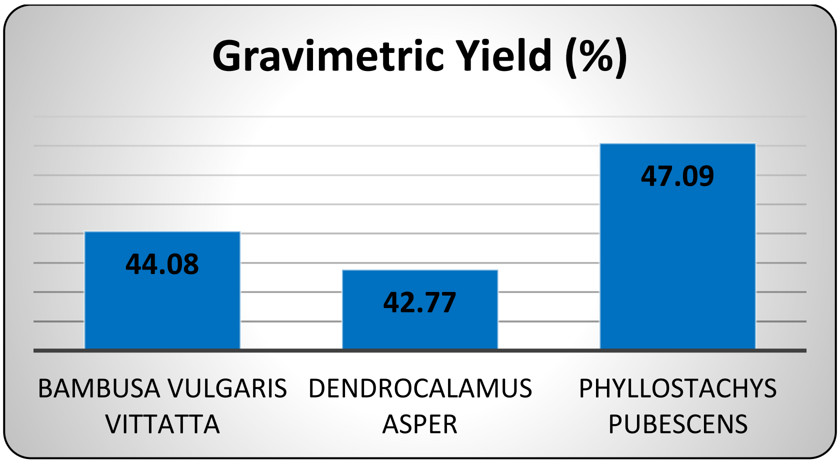
m6 = mass of the ash + crucible.

RESULTS AND DISCUSSION

The carbonization started at 150°C and the temperature was increased 30°C every 45 minutes under these circumstances, it was observed that the carbonization itself started (smoke started) at the end of the period with 180°C and quenched (smoke stoped) at 210°C with the time of 30 minutes. This final temperature (210°C) was lower than that used by Santos et al. (2016), which was 450°C, but the method used in this research was effective and good results were obtained (Table 1 and 2).

Table 1 - Gravimetric Yield Percentages:

Species	Gravimetric Yield (%)
Bambusa vulgaris vittatta	44.08
Dendrocalamus asper	42.77
Phyllostachys pubescens	47.09

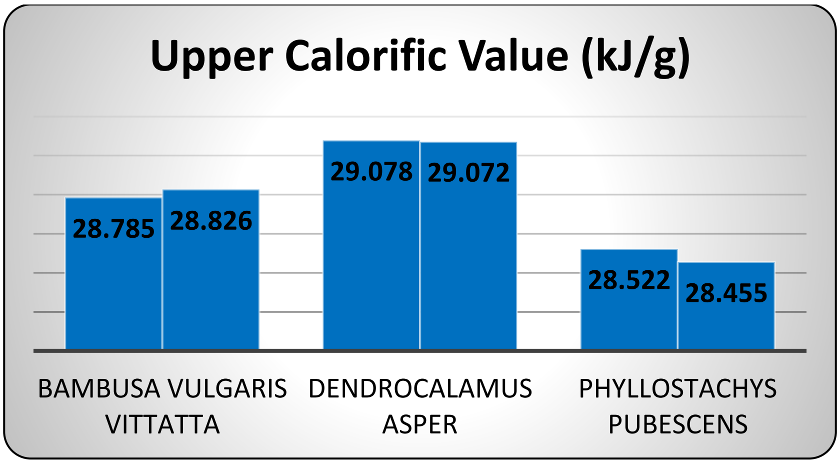


Graphic 1 – Gravimetric Yield.

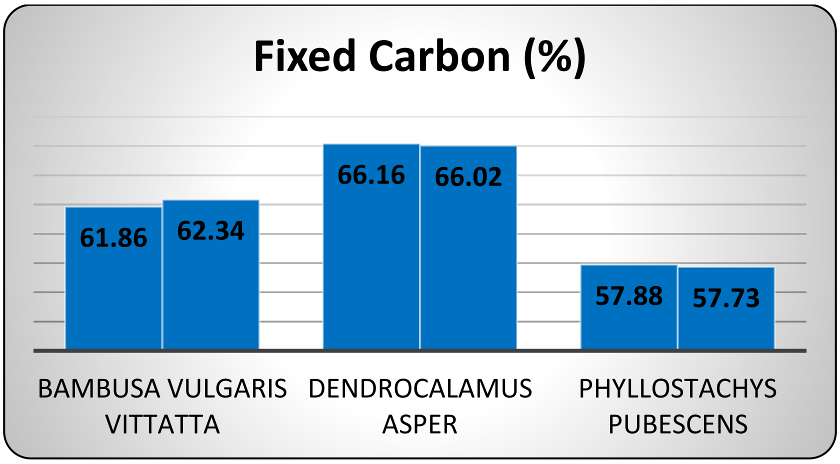
Table 2 – Results of percentages and upper calorifics values of bamboo charcoals:

Species	Upper Calorific Value (kJ/g)		Volatile (%)		Ash (%)		Fixed Carbon (%)	
B.vulgaris vittatta	28.785	28.826	36.02	35.76	2.12	1.9	61.86	62.34
D. asper	29.078	29.072	30.91	30.93	2.93	3.05	66.16	66.02
P. pubescens	28.522	28.455	40.5	40.3	1.62	1.97	57.88	57.73

* Two samples were used for each determined physical-mechanical property.



Graphic 2 – Upper Calorific Value.



Graphic 3 – Fixed Carbon.

In relation to the upper calorific value, the bamboo species *B. vulgaris vittatta* and *D. asper* presented values on average 28.806 and 29.075 kJ/g, respectively. These values were superior results than found by Santos et al. (2016), which were 28.373 and 27.802 kJ/g to *B. vulgaris* and *D. asper*, respectively. It was possible to observe high variation in the percentage of ashes among the bamboo species. In *B. vulgaris vittatta* the ash content was on average 2.01%, lower than found by Santos et al. (2016), which was 3% on average. To *D. asper*, it was observed that the value found in this research was higher than the value found by Santos et al. (2016), which was 1.9% on average. These differences occur because according to Vieira (2012) the same species cultivated in different regions, may have different chemical composition and consequently variation of ash percentage. In relation to the percentage of fixed carbon of the species *B. vulgaris vittatta and D. asper* it was observed that the values found by Santos et al. (2016), which were 73.4% and 71.5% on average respectively, were higher than those found in this research, but, is very important consider the gravimetric yield of Santos et al. (2016) was 34.7% and 36.9%, respectively, that were lower than of this research. For *P. pubescens*, there are no references, but it was observed in the results that in relation to the other species studied, presented higher gravimetric yield, lower percentage of fixed carbon and lower calorific value. It was observed in the results of the physicochemical analyzes indicated in this research that the D. asper specie presented the best values in the general context of the performed analyzes, because despite presenting a slightly lower gravimetric yield and a ash content little higher, it presented higher upper calorific value and higher fixed carbon content in relation to the other species analyzed.

CONCLUSION

The production methods used were efficient because the charcoals presented good results in relation to the physicochemical properties analyzed, which are relevant for their use as bioenergy. The results demonstrate that bamboo is an excellent alternative as a source of renewable energy, very important for sustainable development coupled with economic development.

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