23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

# STUDY OF PHYSICOCHEMICAL FEASIBILITY FOR USE OF BIOMASS PENNISETUM PUPUREUM SCHUM

**Lucas Palmoni Medeiros Dantas**
**Álvaro Henrique Lisboa Alécio**
Universidade Federal de Alagoas, Av. Lourival Melo Mota, s/n; Tabuleiro dos Martins CEP:57072-900
lucaspmd@gmail.com; alvaroalecio@hotmail.com

**Christiano Santos Rolim Filho**
christianorolim8@gmail.com

**Karla Miranda Barcellos**
kmb.ufal@gmail.com

***Abstract.*** *Biomass is any renewable natural resource that comes from organic matter and, more recently, technologies are developing a better energy yield of biomass. The elephant grass, whose scientific name is Pennisetum pupureum, Schum, is a biomass worth mentioning, because it is a plant with high biomass production capacity, combined with others essentials qualities to be used as an alternative source of energy, such as fibers, lignin and high ration Carbon/Nitrogen (C/N).. This paper proposes an evaluation of the physical and chemical properties of biomass elephant grass, therefore, were made analysis in the laboratory to determine its characteristics through standard methods made by ASTM(American Society for test and materials), how moisture content, volatile content, ash content ,fixed carbon, higher and lower heating value. The results obtained from the analysis in specific laboratories showed satisfactory for the purpose of the study, besides being a natural raw material and easy to purchase regionally, elephant grass shown a great alternative energy in thermal processes, mainly in the form of briquette. The values obtained were very similar to the calorific value of the coal and reaches a value of 40% of the calorific power of the petroleum coke.*

***Keywords:*** *biomass, elephant grass, heating value*

## 1. Introduction

Biomass is any renewable natural resource that comes from organic matter, animal or vegetable origin, having as main goal energy production.

Since the energy rationing in 2001 the theme of use of biomass in power generation has been widely discussed in Brazil mainly because it is one of the major producers of biomass in the world. Goldemberg (2002) and Macedo (2002), for example, point the energy use of the advantages derived from biomass in reducing CO2 emissions, employment, among others, although also warn of the need to improve conversion technologies energy for appropriate use of this renewable resource.

Gasification is an alternative to the use of biomass, being defined as conversion of any solid fuel energy into a energetic gas by partial oxidation at high temperature (800-1000º C) (Sánchez, 2010). This conversion can be carried out in various types of reactors, fixed bed or fluidized bed. The gas produced has many practical applications since combustion engines or turbines for power generation and electric power, irrigation pumps, in direct heat generation, in boilers and furnaces to a source for production of raw material in chemical synthesis.

This study aims to find alternative and sustainable forms of fuel obtained from the gasification process. The biomass chosen to study is elephant-grass due to the abundance of this raw material of Alagoas's State ( Brazil).

The elephant-grass, whose scientific name is *Pennisetum pupureum, Schum,* was brought from Africa at least a century ago and it is used as feed for dairy cattle. This is a very well adapted grass in the brazilian territory. Elephant-grass is a plant with high biomass production capacity combined with other key features to be used as an alternative source for energy such as fibers, lignin and high ration Carbon/Nitrogen (C/N). The highest ration C/N is a qualitative desirable characteristic for energy production since the higher this ration is the most promising the plant is for the burning. (Pereira,2014).The three main elephant-grass advantages are: very rapid growth, tolerates poor soils in nutrients than sugar cane and eucalyptus which are species widely used as energy sources and generates a larger amount of biomass (Salgado, 2014). Each hectare planted of elephant-grass generates an average of 40 tons of dry biomass that become energy while for sugar cane that number drops to 20 tons and eucalyptus to 15 (Salgado, 2014). The elephant-grass is also ahead in the waiting time until the harvest. After six months of the planting it is ready to be harvested and the removal of the plant can be made up to twice a year. The sugar cane needs at least a year for the first harvest while the eucalyptus requires about seven years to reach a good size for cutting. However, the competition is drawn when it is about “who is greener”. The three plants are excellent sources of renewable energy the difference is in the fact that elephant-grass is the most productive.

In employment systems, projects of biomass for energy purposes require knowledge of the chemical and physical properties of the bioenergetics.

On following will be presented the elephant-grass characterization methodology for determination of moisture content, volatile content, ash content, fixed carbon, upper calorific value and lower.

## 2. Methodology

For immediate characterization of elephant-grass biomass was used the method ASTM (E-870-82). The tests were repeated four (4) times for each parsed property.

Figure 1 represents the chart where is presented the obtained results by the analyzes through the method ASTM (E-870-82) that will be discussed on following. The results were consistent not discarding any obtained value. We assumed a weighted average of the four (4) values for each sample (material ‘fresh ’and briquetted materials).

| Date | 1 Mass crucible (g) | 2 Mass wet sample and crucible (g) | 3 Mass dry sample and crucible (g) | 4 Mass carbon and crucible (g) | 5 Mass ash and crucible (g) | 6 Mass wet sample (g) | 7 Mass dry sample (g) | 8 Mass carbon plus ash(g) | 9 Mass ash (g) | 10 Humidity (%) | 11 Carbon(%) | 12 Volatile (%) | 13 Ash (%) | 14 Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (2-1) | (3-1) | (4-1) | (5-1) | (6-7)/6 | (8-9)/7 | (7-8)/7 | (9/7) | |
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | |
| Average | | | | | | | | | | | | | | |

Figure 1. Chart insertion and calculation of data obtained

While the analyzes to obtain the Hhv were performed using C-200 calorimeter, analytical balance AUY-220 BALANCE ANALYTICAL CAP.220GR SHIMADZU, pure oxygen cylinder (99,95%). 5 analyzes were performed to obtain the elephant-grass HHV with triplicate “in nature” and duplicate in briquettes and then the LHV is obtained by calculation in a function of the water mass.

In Figure 2 is shown a flowchart of the entire immediate analysis obtained by the ASTM method in addition of the HHV and LHV obtaining.

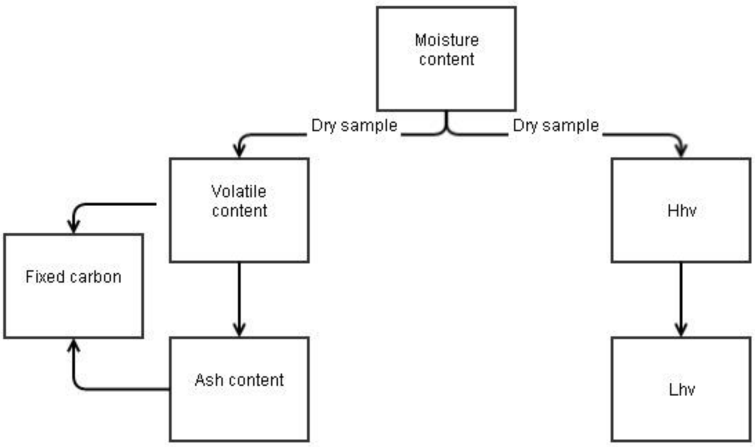


Figure 2- Flowchart of the immediate analysis, Hhv and Lhv for biomass

### 2.1. Moisture content

The determination of the moisture content consists in measuring the amount of water present in the sample. It was determined the moisture content on a wet basis following ASTM method (E-870-82) using a drying oven, porcelain crucibles all with lid, analytical balance AUY-220 BALANCE ANALYTICAL CAP.220GR SHIMADZU and desiccant. The results are shown in column 1 and 2 of Chart 1.

The crucibles and the covers were placed for one hour in an oven at 110°C (104°C to 110°C) and were then placed in a desiccator for thirty minutes until it reached ambient temperature so that they could be weighed; the crucibles were weighed with the covers and noted the value given by the balance in column 1, continuing, filled up three quarters of crucibles with a sample of elephant-grass, capped and weighed, noting the value obtained in column 2.

Having the crucibles with the sample weighed they were uncovered and both uncovered crucibles and their covers were placed in the oven for two hours at 110°C. After two hours the crucibles and covers were removed and now with the crucibles capped they were placed in the desiccator for thirty minutes until it reached ambient temperature. The capped crucibles were weighed and the obtained value noted. Repeating the procedure of placing uncovered crucibles and their covers in the oven however in a shorter period of time, for thirty minutes, and after in the desiccator for thirty minutes until it reached ambient temperature so that they could be weighed, the new obtained value was compared with the previous, if there was no important variation it was noted in column 3, in case there was an important variation the procedure was repeated until this variation became negligible. When the procedure of moisture content determination in wet basis was over the capped samples were placed in the desiccator.

### 2.2. Volatile content

It is the part of the fuel that separates itself into gas when the fuel is subjected to heating test pattern. It is composed of combustible gases (such as methane, carbon monoxide and hydrogen) and non-combustible gases. The dry samples obtained through the determination of moisture content, and kept in the desiccator were removed and placed in a muffle, one at a time for six minutes. This muffle is heated to 850°C and only when this value is reached than the samples are placed one at a time and it's waited until the muffle reaches 100°C, so it can be opened and the samples removed, avoiding damages to the equipment. This procedure was performed for all the samples with biomass, which lasted about 1 hour. They were taken to the desiccator and waited until was reached ambient temperature, lasted about 1 hour. After that, the samples weighed and the value noted in column 4, they were placed in the desiccator for another analyzes.

### 2.3. Ash content

It is determined by the complete burn of the combustible and includes all the fuel mineral constituents. These constituents appear in the solids combustible and embrace compounds of: Aluminum oxide (Al2O3), Ferric oxide ($Fe_2O_3$) and Silicon oxide ($SiO_2$). With the muffle cold the samples that were kept in the desiccator are placed with the crucibles uncovered in the muffle which begins to be heated slowly until 750°C and is maintained at this temperature for two hours. The interval is given by the following procedure, while the muffle heats from 0°C to 500°C, having a heating time of sixty minutes, with a programmed heating speed of 8°C/min, after reaching the value of 500°C its heating time remains the same of sixty minutes and its speed is amended to 4°C/min. With the wanted 750ºC temperature reached it is expected until the muffle reaches 100°C so it can be opened and the sample removed, avoiding damages to the equipment, after they are weighed by the balance and the obtained values noted in column 5.

### 2.4. Fixed carbon

It is the fuel residue left after the volatile matter liberation and consists mainly in carbon although contains some volatile elements that were not released (O2, H2, N2, S). The following Equation 1 determines it:

*(Carbon with ash mass (g) - Ash mass (g)) / (Dry sample mass (g))* (1)

Chart 1: Results obtained through the quoted methodology

| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mass crucible (g) | Mass wet sample and crucible (g) | Mass dry sample and crucible (g) | Mass carbon and crucible (g) | Mass ash and crucible (g) | Mass wet sample (g) | Mass dry sample (g) | Mass carbon plus ash(g) | Mass ash (g) | Humidity (°/°) | Carbon(°/°) | Volatile (°/°) | Ash (°/°) | Total (°/°) |
| | | | | | | (2-1) | (3-1) | (4-1) | (5-1) | (6-7)/6 | (8-9)/7 | (7-8)/7 | (9/7) | |
| 1 | 61,57 | 76,18 | 65,17 | 62,69 | 61,90 | 14,61 | 3,59 | 1,12 | 0,33 | 75,36 | 21,85 | 68,81 | 9,33 | 100 |
| 2 | 61,24 | 77,55 | 65,23 | 62,47 | 61,61 | 16,31 | 3,99 | 1,23 | 0,37 | 75,54 | 21,62 | 68,94 | 9,42 | 100 |
| 3 | 60,47 | 77,45 | 64,64 | 61,76 | 60,85 | 16,98 | 4,17 | 1,29 | 0,38 | 75,42 | 21,63 | 69,07 | 9,28 | 100 |
| 4 | 60,34 | 75,78 | 64,06 | 61,51 | 60,69 | 15,44 | 3,72 | 1,17 | 0,35 | 75,91 | 21,96 | 68,43 | 9,60 | 100 |
| Average | 60,90 | 76,74 | 64,77 | 62,11 | 61,27 | 15,84 | 3,87 | 1,20 | 0,36 | 75,56 | 21,77 | 68,81 | 9,41 | 100 |

## 2.5. Calorific power

Calorific power is the amount of heat released by the complete burn of the fuel mass (or volume) unit having the reaction products being cooled to the fuel temperature (18 or 25°C). The calorific power of a fuel gives its “energetic content”, independently of the fact if it is or not a complete burn.

The fuel’s calorific power is defined as the amount of internal energy contained in the fuel being that the bigger it is the calorific power, the more energy will it contain. ( De Souza, 2014).

There are two types of calorific power: Higher Heating Value (HHV), Lower Heating Value (LHV).

Higher heating value: It’s the amount of heat produced by 1 kg of fuel when it is combusted with excess air and the exhaust gases are cooled in a way that the water vapor in them is condensed.

Lower heating value: It’s the amount of heat produced by 1 kg of fuel when it is combusted with excess air and the exhaust gases air cooled to the water boiling point, avoiding that the water contained in the combustion is condensed.

### 2.5.1. Higher Heating Value (HHV)

The analyzes for HHV obtaining were performed through a C-200 calorimeter, analytical balance AUY-220 BALANCE ANALYTICAL CAP.220GR SHIMADZU, pure oxygen cylinder (99,95%). Five analyzes were performed to obtain elephant-grass HHV, with triplicate “in nature” and duplicate in briquettes.

“In nature”: At first, an amount of elephant-grass about 0,9 to 1,1 g was put in a crucible and taken to the analytical balance, where it was weighed, after, it began the preparation to determinate the Higher Heating Value with the required adjustments in the metallic vase contained in the calorimeter bomb, it opened the threaded vase with help of an appropriate tool after it is opened and the equipment side found inside the vase inverted connects up a cotton thread in the conducting wire, five (5) ml of distilled water are placed inside of the vase, with that the crucible with elephant-grass was embedded in the handle, where occurs the combustion reaction always putting in contact the elephant-grass with the cotton thread. The vase is capped, pressurized in approximately 30 bar for thirty seconds and after pressurization another white cover is embedded on top of the vase. With the vase properly capped it is placed inside of the calorimeter bomb. 2 (two) l of water are used to fill the tank. The calorimeter bomb is closed and the readout happens in approximately seventeen minutes. With the ending of this seventeen minutes the value is found on the equipment display and its unit is in (J/g), with that the calorimeter is opened, the vase removed from inside the calorimeter bomb and on following uncovered. To open the vase depressurized it for approximately fifteen seconds and the crucible removed where was possible to confirm the burn. The presented results are in Chart 2.

The analyzes of elephant-grass HHV obtaining, now in a briquette, were performed using the same procedure that was used for elephant-grass “in nature” and its results are presented in Chart 2.

### 2.5.2. Lower Heating Value (LHV)

The results for LHV in “in nature” and in briquette were obtained through the already know values of elephant-glass Hhv and latent heat of water condensation, from the Equation 2 obtained the values presented in Chart 2.

$$LHV = HHV - m_{H2O} \, x \, h_{lv} \qquad (2)$$

$h_{lv}$- Latent heat of water condensation : 2,257.2 J/g
$m_{H2O}$- Mass of water (g)

#### 2.5.2.1. Mass of water- $m_{h2o}$

The mass of the water is the amount of water in percentage of the total mass present in the studied biomass (humidity), being the same found in the vapor state for HHV calculation.

For the process of briquetting some parameters of the raw material require attention. In order to be successful the moisture of the material must be between 8 and 15%. Thus, a mass of water was stipulated for 15%, which was obtained through a balance from the knowledge of the total moisture present in the biomass determined by immediate analysis of moisture content. The data present in Chart 2 show the difference of calorific potential when biomass is used "in natura" and in briquette.

Chart 2: Results obtained for calorific power

| | Mass crucible (g) | Mass sample (g) | $m_{H2O}$ (g) | HHV (J/g) | LHV (J/g) |
|---|---|---|---|---|---|
| "In Natura" | 10.51 | 1.08 | 0.162 | 13,884.00 | 13,518.33 |
| | 10.52 | 1.02 | 0.153 | 13,685.00 | 13,339.65 |
| Briquette | 10.18 | 1.00 | 0.150 | 14,143.00 | 13,804,42 |
| | 10.09 | 1.05 | 0.158 | 14,879.00 | 14,522,36 |
| | 10.19 | 1.04 | 0.156 | 14,927.00 | 14,574,88 |

These data show a significant amount of calorific value. The petroleum coke, which is used in ceramics and steel mills, has a calorific value of up to 36,000J/g (BR, 2012), i.e., the elephant-grass reaches 41% of this value. When it is in form of briquette its HHV is a more than 'in nature' So, it is clear that this biomass can be used as a auxiliary fuel, with the advantage of being a natural raw material, with low cost and less polluting source of energy.

## 3. Conclusion

The obtained results from the immediate analysis presented satisfying values for the objective of the study. Some characteristics presented in the test demand a study more careful logistic due to the fact that the elephant-grass presents a high moisture content which requires its drying for burn and storage and a considerable ash content generated through its burn, and even tough presents such value has good properties for the burn since it presented a high volatile content, low ash content and high fixed carbon content. Beyond that, for been a natural raw material and of easy acquisition, the elephant-grass has shown to be a great energetic alternative for a process of small-medium size gasification once it presents a calorific power very close to the mineral coal and reaches a value of 41% the calorific power of the petroleum coke, for example.

## 4. References

De Souza, L.A. 2014. Fuel calorific power. 25 Nov. 2014 <http://www.mundoeducacao.com/quimica/poder-calorifico-combustiveis. htm/>.

Goldemberg, J. 2002.Energy and Sustainable Development, Conference: Sustainability in Generation and Use of Energy in Brazil for the next 20 years- Unicamp February 18 to 20 of 2002.

Macedo, I.C. 2002. Energy and Sustainable Development, *Conference: Sustainability in Generation and Use of Energy in Brazil for the next 20 years*- February 18 to 20 of 2002.

Pereira, G.E.2014. Capim elefante a new source of alternative energy, Biomass Journal BR. 25 Nov.2014 http://www.biomassabr.com/bio/resultadonoticias.asp?id=1907

Petrobras, 2012. "Coque verde de Petróleo". 17 May. 2012 < http://www.br.com.br/wps/portal/portalconteudo/produtos/paraindustriasetermeletricas/coqueverededepetroleo/>.

Salgado,R. 2014.The grass that generates energy. 25 Nov. 2014 <http://epocanegocios.globo.com/Revista/Common/0,,EMI131148-16368,00-O+CAPIM+QUE+GERA+ENERGIA.html/>.

Sánchez, C.G.2010. Biomass gasification technology. Campinas, SP: Átomo Publisher.

## 5. Responsibility notice

The authors are the only responsible for the printed material included in this paper.