v. 2, n. 23, 2022

Journal of
Engineering
Research

GASIFICATION OF SUGARCANE BAAGASSE PELLETS TO OBTAIN CLEAN ENERGY AND HIGH HEAT POWER

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Abstract: The present work was developed with the objective of studying the gasification of pellets from sugarcane bagasse, made with binders to obtain a fuel of high calorific value and clean energy. Still within the sugarcane biomass pelletization process, characterizations of the main physical properties, such as moisture and specific mass of the final product, were made. In the production of pellets, bagasse was made with the addition of binder, a liquid also residual from the sugar and ethanol industry, used to increase the binding potential between the particles, stability and calorific value. A comparative study of the calorific value of the pellets was carried out, through a thermal analysis, using differential scanning calorimetry (DSC) and thermogravimetric (TGA) analysis. In this study, it was observed that with the pelleting process there was a 10-fold increase in mass per unit volume of sugarcane bagasse, directly implying an increase in the PCI of the biomass pellet in an increase of 3.6 times the PCI of bagasse in natura.
Keywords: Pellets, gasification, calorific value, sugarcane bagasse, characterization, biomass.

INTRODUCTION

The production of electric energy, worldwide, is mostly derived from fossil and non-renewable sources, such as petroleum derivatives. The scarcity of oil is an increasingly concrete fact, and while the price of this fuel rises, the search for alternative energies is even more present, in addition to the need to reduce toxic gas emissions. The continuous search for economic improvements and sustainable solutions has received attention from a broad research community around the world (VIEIRA JÚNIOR, 2021).

Natural and renewable resources have been the focus of numerous researches, driven by the increasing consequences for the environment generated by the use of fossil fuels. The correct use of renewable sources is an excellent way to replace "dirty energy" and avoid damage to the planet (Azevedo, 2013).

According to Freitas et al (2020) in 2018, renewable sources represented 83.3% of the domestic supply of electricity in Brazil, which is the result of the sum of the amounts referring to national production plus imports, which are essentially from renewable.

Renewable energies are imposing themselves, gaining more and more market. Among these new clean energy alternatives, biomass. The effort to use biomass for energy production has grown considerably in recent decades. In addition to recycling agricultural and food waste, such as sugarcane bagasse, biomass energy prevents the increase of carbon dioxide in the atmosphere. (BARROS et al. 2022).

In 2021, energy from biomass in Brazil appears in a prominent place, as it contributes to an amount of approximately 13% of the Brazilian energy matrix. Therefore, the world trend is for this potential to be further explored in the near future, with a view to meeting targets for reducing fossil carbon emissions into the atmosphere to reduce the effects of global warming (HANSSEN et al., 2020).

Sugarcane bagasse biomass has been used in Brazil on a large scale for steam generation, electricity and heat generation among its main applications, being a by-product of juice extraction in alcohol and sugar production plants. Thus, the sugarcane biomass becomes the main agricultural residue in the country, especially when referring to the use of biomass for energy generation and of the produced amount of sugarcane, approximately 30% of the weight turns into residues called residues. bagasse (SILVA, GOMES AND ALSINA, 2007).

Due to its large amount available in Brazil, being one of the largest sugarcane producers in the world, the pelletization process appears as an alternative for the proper destination of this by-product, having the ability to compact the residual sugarcane biomass. with more attractive properties and advantages in the requirement of increased calorific value, storage and transport (STAHL and BERGHEL, 2011).

Sugarcane bagasse, in natura, resulting from the milling process, has approximately 50% moisture and a specific mass of 120 kg/ m^3. The bagasse PCI under these conditions is around 3,100 to 4,400 Kcal/Kg (Petrobrás, 1982).

The projections of the National Energy Plan 2050 point to a growth in the production of biomass for energy purposes in Brazil from a total of 205 Mtoe in 2015 to a total of 530 Mtoe in 2050, with biomass from agricultural residues rising from 48 Mtoe (in 2015) to 165 Mtoe (in 2050) and sugarcane bagasse from 38 Mtoe (in 2015) to 68 Mtoe (in 2050). This increase is partly explained by the increase in cultivated area, but also by the increase in productivity. With the adoption of energy cane, it is expected that the productivity of sugarcane in ton per hectare will grow from around 77 t/ha in 2015 to 99 t/ha in 2050, increasing the density per area of sugarcane residue biomass. sugar available (Ministry of Mines and Energy, 2018).

Biomass gasification is based on the possibility of commercially developing the technology that makes it possible to reduce the cost of kW/h and that would make the energy obtained from biomass competitive in relation to energy obtained from conventional fuels, and its use contributes to improving the balance of CO2, NOx and SOx in the atmosphere, when compared to fossil fuels.

Gasification is a thermochemical conversion process that occurs between oxygen and substances that contain carbon in their constitution, in general residual biomass (coal, wood, bagasse, etc.), to obtain a mixture of gases called synthesis gas. or syngas (acronym for synthesis gas). In this process, the carbon undergoes thermal oxidation with the oxygen used in amounts lower than stoichiometrically necessary for its complete combustion. For this reason, the generated synthesis gas consists of gaseous components that are still liable to combustion, mainly hydrogen (H2) and carbon monoxide (CO). (REZAIYAN et al., 2005).

Progress in gasification technologies and the diverse uses of the synthesis gas it produces have made it possible to integrate gasification with various industrial processes to produce chemical raw materials and generate energy, making gasification one of the precursor technology options for biorefineries. (SIKARWARA, ZHAOA, et al., 2017).

GOAL

The objective of this work was the production of sugarcane bagasse pellets and the study of its gasification to obtain clean energy with a high calorific value.

MATERIALS AND METHODS

PREPARATION OF BIOMASS

The initial stage of the methodology of this project consists of the preparation of the biomass of sugarcane bagasse, where after being collected it was weighed and sent to an oven for a period of 24 hours, to reduce its moisture content. After calculating the moisture content, the biomass was milled using a knife mill. In order to obtain a standardization of the particles, with 200g of ground biomass, the granulometric separation was then carried out, through a vibrating sieve, selecting the granulometry of the biomass for the process. After preparing the biomass, the specific mass was calculated.

PELLETS PRODUCTION

For the production of pellets, the biomass was added with a binder, also residual liquid from the sugar and alcohol Industry, to increase the binding potential between the particles, their stability, and calorific value. After the additivation of the biomass, the process of manufacturing the pellets began through a hydraulic press with the aid of a cylindrical matrix. Moderate pressure was applied for 30 min. Heating during the production process took place through a heat gun with a working range of 300 to 500°C. After carrying out the procedures described above, the pellets (briquettes) of added bagasse were cooled for 5 min. at room temperature, in order to be removed from the hydraulic press.

CHARACTERIZATION OF PELLETS

To calculate the moisture, the pellets with binder were ground and 3 samples of 5g were placed in petri dishes and taken to an oven for 2 hours at 105°C. At the end of this time, the samples were taken to the desiccator for 10 min for later weighing. This process was repeated three times, interspersed for 30 min in an oven. At the end, the samples were taken to the desiccator for 10min and the weighing was performed until the weight was stabilized, thus reducing the moisture contained in the samples.

The specific mass of each pellet was calculated by measuring the mass over the volume that he occupies. The pellet was weighed and its volume calculated (Equation 1) and then replaced in the specific mass formula (Equation 2).

$$V = \pi \times (R)^2 \times h \qquad \text{(Equation 1)}$$

Where:
V = pellet volume
R = pellet radius
h = pellet height

$$p = m/V \qquad \text{(Equation 2)}$$

Where:
p = specific mass
m = pellet weight

GASIFICATION SYSTEM

The gasifier used in this work was a 4 kW/t gasifier imported from India, of the competitor type (downdraft), with an open top air gasification agent, coupled with a generator set, containing an Otto Cycle engine, was fed with biomass residues (Pellets), of 1 kW of nominal electric generation. Because of its small size, its application is for domestic use with the purpose of generating thermal energy or generating electric energy.

COMPOSITION OF GASES DURING OPERATION OF THE GENERATOR SET GASIFIER

The identification of the gas composition for the power obtained was performed through the gas analyzer. The volumetric percentage of: CO, CO2 and O2 at the gasifier outlet (%CO, %CO2 and %O2) and at the engine exhaust outlet (%COesc, %CO2esc and %O2esc) was also found. of lambda at the gasifier and exhaust outlet.

LOWER CALORIFIC VALUE OF THE GAS, DETERMINED FROM ITS COMPOSITION

The calorific value of the fuel gas produced in the gasifier, PCIgáscomp., in Kcal/Nm3, was calculated using the empirical formula of Dulong (Equation 3), as a function of the percentage of each compound present in the gas.

PCIgáscomp. = 3050. (%CO) + 2580. (%H2) + 8500. (%CH4) + 13500. (%C2H2) + 14050 (%C2H4) (Equation 3)

Where:

%CO is the percentage content of carbon monoxide in the gas;

%H2 is the percentage of hydrogen content in the gas;

%CH4 is the percentage content of methane in the gas;

%C2H2 is the percentage content of ethyne in the gas;

%C2H4 is the percentage content of ethylene in the gas;

THERMOGRAVIMETRIC ANALYSIS (TG/DTA AND DSC)

The equipment used to perform the thermogravimetric analysis was a thermobalance TGA/SDTA-EQ-028 (Shimadzu) with aluminum crucibles, and the results were obtained in the form of a thermogram. To study the calcination temperature of the hydrated precursors, the flow rate of the treatment gas (N2) was maintained at 50 ml/min. The temperature range of the analysis was found between room temperature and 900°C. The integrated areas of the bands were obtained using the FIAK FIT software, with the aid of Gaussians.

BIOMASS CONSUMPTION

The calculation of the consumption of biomass in the gasifier was done by filling the reactor with an amount of biomass, and immediately activating the stopwatch. The values of mass consumed and time were recorded and the consumption of biomass was calculated using Equation 4.

$$Cbio = Mad/t \quad \text{(Equation 4)}$$

Where:

Cbio = biomass consumption

Mad = added mass

t = time the mass was consumed in the gasifier (h).

RESULTS AND DISCUSSION

BIOMASS CHARACTERIZATION

After the tests carried out, a humidity of 83.63% and a value of 0.063g/cm³ (63kg/m³) of specific mass of the biomass was verified.

CHARACTERIZATION OF PELLETS

A moisture content of 15.13% was obtained, slightly above normal, due to improperly storing the pellets, as the moisture must be between 10 and 12% (RASGA, 2013). For the specific mass, a value of 0.63g/cm³ (630kg/m³) was found.

COMPOSITION OF GASES DURING OPERATION OF THE GENERATOR SET GASIFIER

Table 1 presents the gas composition obtained during the gasifier operation.

The lean gas produced at the inlet is the gas obtained at the gasifier outlet, where it was used as fuel by the electric generator, which transformed into electrical energy, obtaining 280w of power, being able to light lamps from the lamp bank coupled to the gasifier.

The gases that leave the electric generator are the so-called exhaust gases, where there was a 7.9% increase in CO2 release compared to the intake, as one of the components present in greenhouse gas (GHG) emissions, CO2 is absorbed, in equal proportion to its emission, by the plants that generate the fuel, the balance of CO2 emissions resulting from the combustion of biomass is practically nil. One can also analyze the decrease in carbon monoxide (CO) and hydrocarbons (HC) as shown in Table 2.

LOWER CALORIFIC VALUE OF THE GAS, DETERMINED FROM ITS COMPOSITION

The compressed gas PCI considering per kg of pellets was equal to 15,767.658 Kcal/kg.

Power (kWe)	%CO	%COesc.	$\%CO_2$	$\%CO_2esc$	$\%O_2$	$\%O_2esc$	Lambda	Lambda esc.
0,28	19,59	0,86	10,10	18,00	0,59	3,76	0,67	1,12

Table 1 - Compositions of gases related to the power obtained.

Gas Analysis		
Gases	Admission (%)	Exhaust (%)
CO	19,59%	0,86%
CO2	10,10%	18,00%
HC	69,72%	2,10%
O2	0,59%	3,76%
CO Corr.	19,59%	0,86%

Table 2 - Intake and exhaust gases in the gasifier.

Comparing with the calorific value of in natura sugarcane bagasse, which is 2,130.51Kcal/kg, and that of commercial firewood, which is 3,100.22Kcal/kg (EPE, 2013), it is observed that there was a significant increase.

THERMOGRAVIMETRIC ANALYSIS (TG/DTA AND DSC)

The decomposition of the sugarcane bagasse pellet was stable until around 110°C as shown in figure 1, after that point, there was a slow degradation (21%), of lost mass between 100 and 200°C, corresponding to the loss of moisture. Then, from 270°C, a more significant loss of mass (57%) is observed, referring to the loss of organic matter present in the sample, which is accentuated, mainly between 400 and 500°C. The loss of mass that occurs at higher temperatures may be associated with the elimination of cellulose and hemicellulose. From 450°C, the lost mass is already around 90%. According to Santos et al (2019), it presents for this temperature region the elimination of aromatic compounds, which may be related to the elimination of lignin and the formation of fixed carbon. At the end of the analysis, the remaining mass was 3.35% of the original.

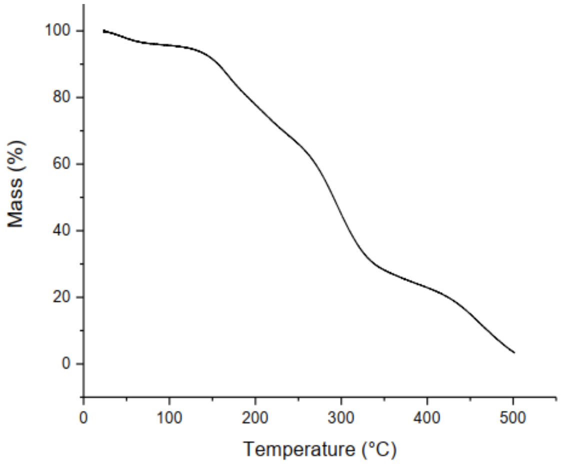

Figure 1 - Sugarcane Biomass Pellet TG Curve.

The DSC technique was used to measure the PCI, in Kcal/Kg, of the sugarcane bagasse pellet fuel, in order to compare it with that

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172232207106

obtained through gasification. The PCI of a fuel is an effective measure of the energy released or absorbed by the process, therefore, more easily applied in practice.

Figure 2 shows the DSC graph where you can verify the presence of two exothermic peaks. The PCI calculation was performed, integrating the area over the peaks, with the help of the PIAK FIT software. The area equivalent to energy in mW was divided by the heating ratio and sample mass in (mg) to obtain the PCI in mW/mg.

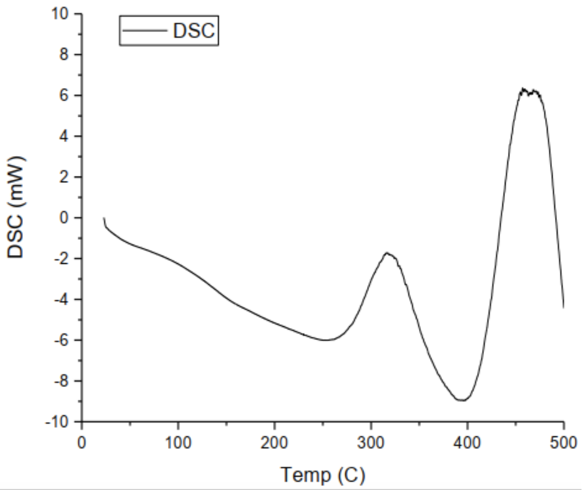

Figure 2 - Pellet DSC Curve.

Subsequently, the values were converted to Kcal/Kg to compare the energy released by the biomass, in the form of lean gas. Table 3 displays the temperature values, with their respective PCI.

Note that the energy value equivalent to the second peak is very similar to that obtained through gasification, 15,000 Kcal/Kg, differing by 6.24%.

BIOMASS CONSUMPTION

The value of the biomass consumed by the gasifier at the end of the recorded time (0.37h) was 4.72 kg/h.

Table 4 presents energy analyses, showing the power, voltage, amperage and hertz generated by the gases from the consumption of biomass pellets in the gasifier.

CONCLUSION

Considering that the specific mass is a parameter of great influence on the Biomass PCI, the first part of this work was dedicated to the adequacy of the production of sugarcane bagasse pellets. In fact, with compaction, there was a 10-fold increase in specific mass,

Peak	Temperature (°C)	PCI (Kcal/Kg)
1	326,88 °C	4.930,69 Kcal/Kg
2	464,66 °C	14.777,72 Kcal/Kg

Table 3 Temperature values with respective PCI.

Power (w)	Voltage (Voltz)	Amperage (A)	Hertz (Hz)
280W	232.5 V	1.2 A	61.14 Hz

Table 4 - Analysis of energy generated by gases from the pellets in the gasifier.

which directly implied an increase in the PCI of that biomass.

Another important parameter studied was the pellet moisture, despite all the pre-test dehumidification work, at the time of the experiment the pellets contained 15.13% moisture, which negatively interfered in the gasification test, even so, a PCI of 15,767 Kcal/Kg was obtained, that is, equivalent to about 3.6 to 5.1 times greater than the PCI of bagasse in natura.

The DSC technique was also used to evaluate the PCI of the biomass used, with the result obtained being 14,777.72 Kcal/Kg, a result very similar to that of gasification, differing only by 6.24%.

It was possible to reach at least 280W of power from the gasifier gases, once one of the lamps coupled to the generator system was lit. In view of the above, it was possible to show that it is possible to obtain electrical energy, in a small gasifier, and using sugarcane bagasse pellets as fuel.

REFERENCES

AZEVEDO, P.J.S. Uma análise dos efeitos da crise econômica-financeira sobre as políticas de incentivo às energias renováveis. [Dissertação] Universidade do Porto, 2013.

BARROS, TV.; LOPEZ, G. de S.; SANTOS, RJ dos.; PARIZI, MPS.; CARDOZO-FILHO, L.; FERREIRA-PINTO, L. Gasificação de biomassa em água supercrítica como tecnologia de produção de hidrogênio. Pesquisa, Sociedade e Desenvolvimento, [S.l.], v. 11, n. 9, pág. e32511931296, 2022. DOI: 10.33448/rsd-v11i9.31296.Disponível em: https://rsdjournal.org/index.php/rsd/article/view/31296. Acesso em: 21 jul. 2022.

FREITAS L, S., MENEZES, D., SERRA D, SILVEIRA., POLICARPO N, A. DE OLIVEIRA, M. L. M. Gaseificação e pirólise da casca da castanha de caju (ccc) em estudos de avaliação do ciclo de vida (acv) para fins energéticos. Ambiente: Gestão e Desenvolvimento, 2020.

HANSSEN S, V., DAIOGLOU V., STEINMANN, Z. J. N., FRANK S., POPP A., BRUNELLE T., LAURI P., HASEGAWA T., HUIJBREGTS, M. A. J. VAN VUUREN D. P. Biomass residues as twenty-first century bioenergy feedstock— a comparison of eight integrated assessment models, Climatic Change (2020) 163:1569–1586.

MME. Potencial dos Recursos Energéticos no Horizonte 2050. Ministério de Minas e Energia. Rio de Janeiro - RJ. 2018.

PETROBRÁS. Dados técnicos da biomassa. Rio de Janeiro, Petrobrás Depto. Industrial. Divisão de Fontes Energéticas Alternativas, N.29, p. 65, 1982.

RASGA, R. O. S.; Pellets de madeira e sua viabilidade econômico-financeira na substituição do óleo BPF-A1 em pequenos e médios consumidores no Estado de São Paulo 2013. 2013, 165 f. Dissertação (Mestre em Agroenergia) - Escola de Economia de São Paulo da Fundação Getúlio Vargas, 2013.

REZAIYAN, J.; CHEREMISINOFF, N.P.; Gasification technology: a primer for engineers and scientists, CRC Press, 2005.

SANTOS, O. R.; CORRÊA, N. C.; FRANÇA, L. F.;Processo de transformação termoquímica da torta do mesocarpo do dendê para obtenção de biocombustíveis. Amazonian Journal of Agricutural and Enviromental Sciences, v. 62, p. 1-7, 2019.

SILVA, V. L. M. M.; GOMES, W. C.; ALSINA, O. L. S.; Utilização do bagaço de cana-deaçúcar como biomassa adsorvente na adsorção de poluentes orgânicos. Revista Eletrônica de Materiais e Processos, v.2, p. 27-32, 2007.

STAHL, M.; BERGHEL, J.; Energy efficient pilot-scale production of wood fuel pellets made from a raw material mix including sawdust and rapeseed cake. Biomass and bioenergy, v. 35, p. 4849-4854, 2011.

SIKARWARA, V. S. ZHAO, M.; FENNELL, P.S.; SHAH, N.; ANTHONY, E.J. Progress in biofuel production from gasification. Progress in Energy and Combustion Science, n. 61, 2017. 189-248

VIEIRA JÚNIOR C. M.; SANTOS H, S., DOS SANTOS, S. T. O.; DA SILVA, S, P. R. Aproveitamento energético a partir da gaseificação de resíduos do cultivo de milho (Zea mays) após três anos em estoque. Research, Society and Development, v. 10, n. 15. 2021.