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GASIFICATION OF WASTE FROM FURNITURE INDUSTRIES FOR GENERATION OF SUSTAINABLE ENERGY

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ABSTRACT With the inevitable decline in availability of fossil fuel sources, there has been a worldwide increase of interest in renewable energy, aiming at sustainability in all aspects: technical, economical, social and environmental. The renewable energy has advantages over fossil fuels, such as generating employment opportunities in remote areas, contributing to poverty alleviation, diversifying the energy matrix, and diminishing impacts on the emission of pollutants into the atmosphere. The generation of waste in the forest-based industry is a natural consequence of the transformation of wood, so new techniques for the use of biomass for energy have been developed in order to meet the growing energy demand. The use of wood wastes as an energy source contributes positively to the environment by reducing environmental problems related to contamination of soil, air and water through improper disposal of waste. Thus, the process of biomass gasification becomes an interesting alternative, since among the techniques of energy conversion has been enacted, this process has many advantages due to the conversion of biomass into a combustible gas that can be used for heat generation, electricity and synthesis of chemicals. The syngas produced from gasification of eucalyptus residues showed large potential with an average High Heating Value of 6.60 MJ/m³, and regular composition during the process, with predominance of carbon monoxide (19,02% v/v), followed by hydrogen (11,58% v/v), carbon dioxide (10,18% v/v) and methane (8,20% v/v). There was no interference of climatic conditions in the results.

Keywords: bioenergy, gasification, waste.

INTRODUCTION With the declining availability of energy from the eighties, it became necessary to preserve energy drastically. Since then, Brazil has been investing in improving the systems of power generation through the use of biomass, because among other advantages the use of biomass provides better balance in emissions of greenhouse gases than fossil fuels, essential for propagation of this energy source, once environmental concerns are one of the pillars of sustainability so desired worldwide.

The generation of waste in forest-based industries is a natural consequence of the transformation of wood, and its inadequate disposal causes environmental problems related to contamination of soil, air and water. In the furniture sector, the greatest loss occurs in the processing of wood, reaching in some cases, up to 80% of a tree missed between the harvest and the manufacture of furniture. In 1991, Brazil was responsible for 4% of world production of wood for furniture manufacturing, with a total of 37,968,000 m^3. From this material, 49.29% was converted into product, and the remainder (50.71%) is waste generated by industrialization, in other words, a volume of 19,255,000 m^3. (Feitosa, 2008)

Forest residues can be exploited in a sustainable manner through gasification. The gasification of solid fuel, such as waste from the furniture industry, can be defined as the thermodynamic convertion into a combustible gas comprising a mixture of carbon monoxide (CO), hydrogen (H_2), methane (CH_4), small amounts other light hydrocarbons, carbon dioxide (CO_2), water vapor (H_2O), and nitrogen (N_2), which is present in the air supplied to the reaction. This gas, called synthesis gas, can be used to generate heat, electricity and chemicals, bringing benefits such as: sustainability, regional economic development, social and agricultural development, regular supply of power, and reducing in the balance of emission of greenhouse gases (Dermibas and Dermibas, 2007).

This study aims to investigate the syngas from gasification of eucalyptus wood (chips) for determining the energy potential from the analysis of its composition and heating value.

METHODOLOGY This study was conducted at the Laboratory of Renewable Energy in the Department of Agricultural Engineering, Federal University of Viçosa, Brazil. The process of gasification of eucalyptus wood chips occurred in three tests, in three consecutive days, with an average of 4 hours each test. The feedstock can be observed in Figure 1.

Figure 1 – Chips of Eucalyptus wood

Reactor design and configuration The gasification system consists of a downdraft gasifier, model GEK-Allpowerlabs, and ancillary equipments: cyclone, filter, burner, venturi ejector, condenser and peristaltic pump. The reactor temperature was monitored by thermocouples type K, in the combustion, zone, reduction zone, air inlet and gas outlet, at intervals of 15 minutes. Reactor pressure was monitored constantly by water column, air and gas flow was measured by anemometers, and air temperature and humidity was measured by thermo-hygrometer.

Fuel properties It was used eucalyptus waste in the form of chips, from the Department of Forestry at the Federal University of Viçosa, Brazil. The process of biomass gasification was started with ignition of charcoal. Table 1 shows the results of proximate analysis and density of the wood chips, performed at the Laboratory of Wood Energy according to ABNT Methods - NBR 8112/83.

Table 1 - Proximate analysis and density of the eucalyptus wood chips

	Humidity (%)	Volatiles (%)	Ash (%)	Fixed Carbon (%)	Density (kg/m³)
Eucalyptus Chips	9,74	90,55	0,44	9,02	179,80

Table 2 presents the elemental composition and heating value of eucalyptus wood according to the methodology proposed by Parikh et al. 2005 and Parikh et al. 2007.

Table 2 – Ultimate analysis and High Heating Value of eucalyptus wood chips

	C (%)	H (%)	O (%)	HHV (MJ/kg)
Eucalyptus Chips	46,94	6,08	45,84	17,30

Operation and performance The reactor was filled with charcoal (maximum size of 2 cm) until reach the height of the air inlets in the combustion zone. The reactor and fuel hopper was supplemented with eucalyptus chips, sealed, closed and weighed to begin the process of ignition. Before starting the ignition process it was opened the valve of the pressurized air in the Venturi injector, keeping a vacuum of about 6 cm of water column in the reactor to facilitate the ignition in the combustion. It was added 3 ml of ethanol inside reactor to facilitate the ignition, and the gasifier was started using a pilot flame of LPG.

Particulate matter was separated from the syngas by a cyclone attached to the gasifier. The gas followed to a filter filled with small pieces of charcoal and steel wool on the top, to reduce the concentration of tar. After filtering, the gas is cooled in a coil immersed in a tank with water at 20 °C for condensation of remained tar. The gas is pumped through a peristaltic pump each 15 minutes, during 5 minutes, and analyzed as the concentration of H_2, CO, CH_4, CO_2, and heating value via gas analyzer Wuhan Cubic Optoeletronics, model Gasboard 3300. After readings all syngas produced is burned to avoid contamination in labor environment.

RESULTS The gasification agent was the environmental air, with average temperature of 23.6 ± 1.7 °C and average humidity of 75.4 ± 4.1 %. The reactor operated satisfactorily throughout the test period, with average negative pressure of 6.6 ± 0.23 cm of water column, providing enough air to keep the zones of combustion and gasification active.

The average temperature of the gasification zone was 857.2 ± 9.1 ºC, while the average temperature of the combustion zone was 1184.5 ºC ± 63.9.

The composition of the syngas during gasification process can be seen in Figures 2, 3 and 4. Statistical analysis were performed considering only the region of stability (stead state), since the begining of the test sets the time of heating system, and the end of the test load has little biomass, these two regions are not representative for the characterization of gas .

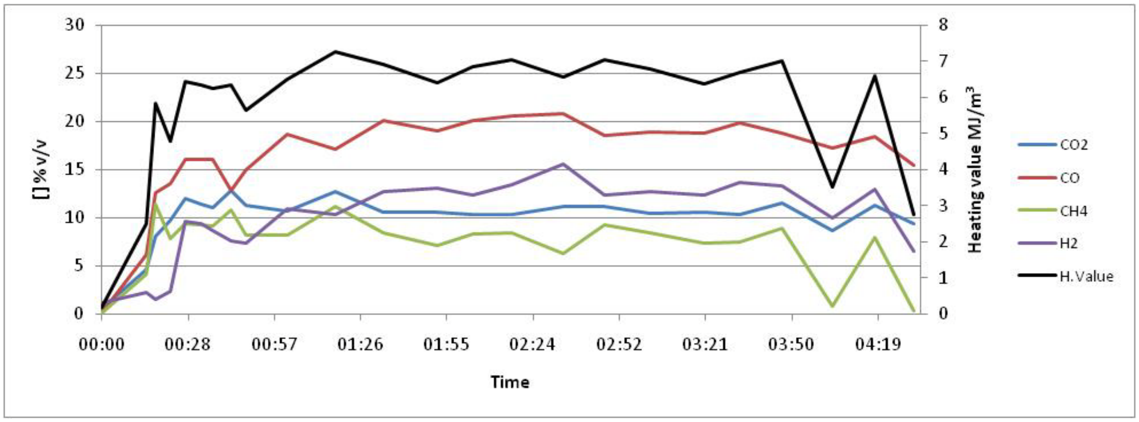

Figure 2 - Gas composition and calorific value as a function of time during the gasification of Eucalyptus chips, Test1.

In test 1, the syngas had regular composition 1 hour and 30 minutes after the beginning of the experiment. However, it took 2 minutes after ignition of the reactor to have a burnable gas. The statistical analysis of Test 1 can be seen in Table 3.

Table 3 - Statistical analysis of the composition and heating value of syngas during the gasification of eucalyptus chip, Test 1.

	CO_2	CO	CH_4	H_2	HHV
Median	10,61	19,01	8,35	12,69	6,83
Average	10,87	19,28	8,29	12,72	6,79
Maximum	12,69	20,76	11,13	15,56	7,27
Standard Deviation	0,69	1,02	1,22	1,33	0,29
Coefficient of Variation	6,35	5,25	14,70	10,45	1,18

The gas produced had higher carbon monoxide content, with an average of 19.28% v/v, followed by the concentration of hydrogen (12.72%), carbon dioxide (10.87%) and methane (8.29%). The average heating value of syngas was 6.79 MJ/m3.

In test 2, the syngas had regular composition, but the concentration of carbon dioxide and methane is unstable during the experiment (Figure 3).

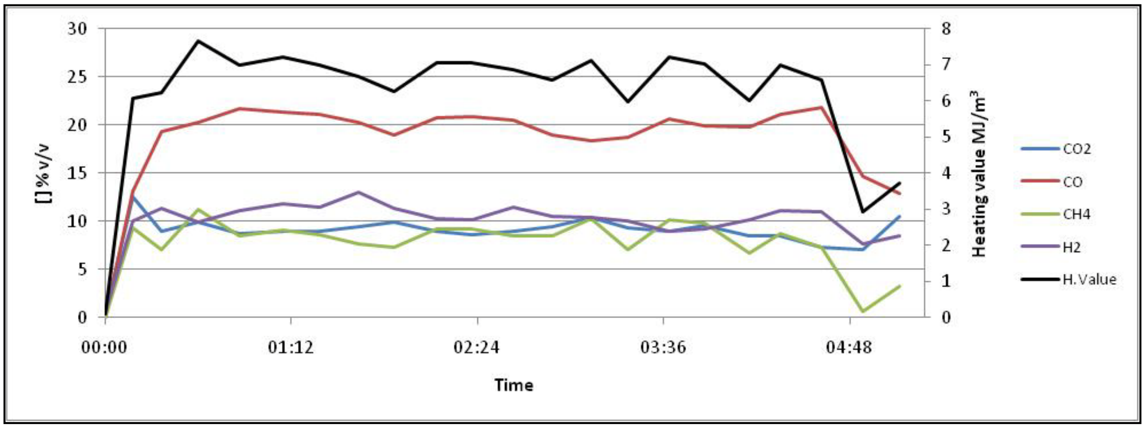

Figure 3 - Gas composition and calorific value as a function of time during the gasification test with Eucalyptus chips, Test2.

In test 2, the syngas had regular composition 22 minutes after the beginning of the experiment. It took 5 minutes after ignition of the reactor remained to have a burnable gas. The statistical analysis can be seen in Table 4.

Table 4 - Statistical analysis of the composition and heating value of syngas during the gasification of eucalyptus chip, Test 2.

	CO_2	CO	CH_4	H_2	HHV
Median	8,98	20,37	8,56	10,75	6,99
Average	9,08	20,24	8,60	10,74	6,81
Maximum	10,34	21,83	11,24	12,95	7,66
Standard Deviation	0,67	1,04	1,26	0,96	0,46
Coefficient of Variation	7,38	5,14	14,65	8,94	6,75

The gas produced had higher carbon monoxide content, with an average of 20.24% v/v, followed by the concentration of hydrogen (10.74%), carbon dioxide (9.08%) and methane (8.60%). The average heating value of syngas was 6.81 MJ/m3.

In test 3, the syngas had regular composition 55 minutes after ignition of the reactor, and as well as in test 2, the concentration of carbon dioxide and methane was unstable during the experiment (Figure 4).

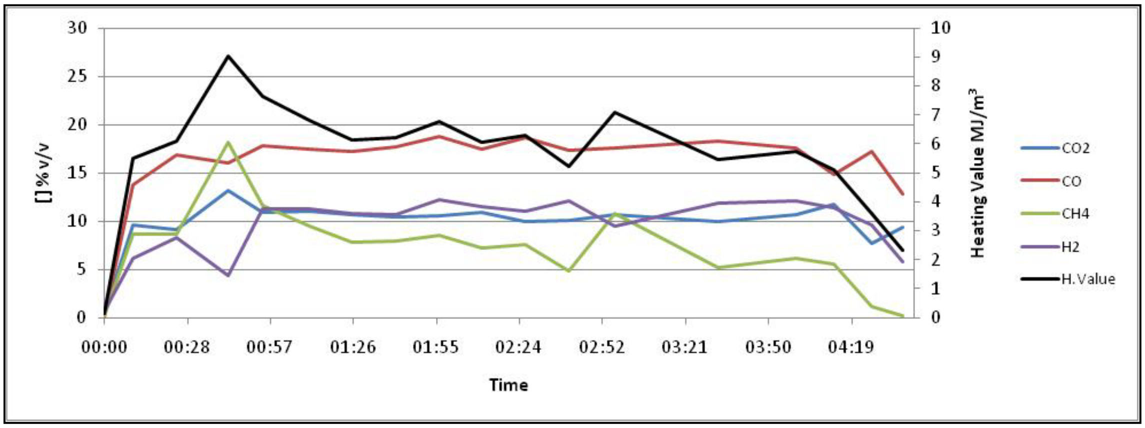

Figure 4 - Gas composition and calorific value as a function of time during the gasification test with Eucalyptus chips, Test3.

The gas was burned 3 minutes after ignition of the reactor. The statistical analysis can be seen in Table 5.

Table 5 - Statistical analysis of the composition and heating value of syngas during the gasification of eucalyptus chip, Test 3.

	CO_2	CO	CH_4	H_2	HHV
Median	10,62	17,55	7,69	11,31	6,17
Average	10,59	17,55	7,72	11,28	6,21
Maximum	11,69	18,81	11,59	12,17	7,62
Standard Deviation	0,50	0,99	2,12	0,76	0,77
Coefficient of Variation	4,72	5,64	27,46	6,74	12,40

The gas produced had higher carbon monoxide content, with an average of 17.55% v/v, followed by the concentration of hydrogen (11.28%), carbon dioxide (10.59%) and methane (7.72%) . The average heating value of syngas was 6.21 MJ/m3.

It can be observed that although weather and operating conditions, the three tests produced synthesis gas with composition very similar. There is a high variation of concentration of methane as indicated by the coefficient of variation in all tests.

CONCLUSION The process of gasification of eucalyptus chips obtained satisfactory performance. Climatic conditions and operating conditions of the gasifier did not affect the final quality of the syngas. The syngas produced from gasification of eucalyptus residues showed large potential with average High Heating Value of 6.60 MJ/m³, and regular composition during the process, with predominance of Carbon Monoxide (19,02%v/v), followed by Hidrogen (11,58% v/v), Carbon Dioxide (10,18% v/v) and Methane (8,20% v/v). The temperature of the combustion zone and gasification zone was in accordance with the theory, maintaining the temperature of the combustion zone upper than the gasification zone, essential condition to the endothermic reactions of gasification and pyrolysis happen.

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