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ANALYSIS OF THE GASIFICATION OF BIOMASS PELLETS AND INFLUENCES OF DIFFERENT COMPOSITION

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Abstract.

The objective of this work is to evaluate the composition of syngas mixtures obtained from biomass gasification, considering different concentration for the reagents of the combustion. Furthermore, the effect of moisture on pellet composition was analyzed. The syngas mixture obtained will be determined by applying a simplified chemical equilibrium model. The results obtained will allow to evaluate simultaneously two effects: the effect of the composition of the biomass in the products of combustion and the effect of the moisture in the formation of the synthesis gas.

Keywords: biomass pellets, specific emissions, gasification, syngas mixtures.

1. INTRODUCTION

Actually, the greatest challenge in the energy field is to combine efficiency and sustainability, so that an equilibrium is achieved. Increasingly, the search for accessible and renewable sources of energy has made biomass a major target for studies. The synthesis gas resulting from the gasification of the fuel, known as syngas, in addition to its moisture content, has its properties altered according to the biomass used and the conditions under which they were subjected during the preparation and firing processes.

In the gasification mechanism, incomplete combustion of the solid fuel is responsible for the final composition of the process, in which the final product presents higher concentrations of CO, H₂ and CH₄, in various proportions (NASCIMENTO, 2014). This composition makes possible a considerable application of syngas in the activation of internal combustion engines and in the production of methanol, which reflects on the importance of this energy source nowadays.

Based on this context, the main objective of this work is to evaluate the composition of syngas mixtures obtained from biomass gasification and the characteristics of its composition in the combustion of the biomass fuel.

2. METODOLOGY

Initially, for the present work the simplified chemical equilibrium model presented by Costa *et al.* (2017) was adapted, for the determination of the syngas mixture obtained after biomass gasification. The calculations were performed using the software's EES (Engineering Equation Solver) e Gaseq.

The global reaction of the biomass with the standard air result as the products of the combustion the formation of CO, CO₂, N₂, H₂O and CH₄, according to Equation (1):



The values of x , y and z depend on the type of biomass that will be analyzed, wherein the composition was obtained from the literature. The term w represents the moisture present in the biomass and may vary from 10 to 20%, as indicated by Williams *et al.* (2012), wherein the percentage of moisture calculated for biomass from sugarcane bagasse was of 10.4. In Eq. (1), m represents the number of moles of air present in the reactants. Thus, the six unknowns terms of the reaction are η_{H_2} , η_{CO} , η_{CO_2} , η_{CH_4} , $\eta_{\text{H}_2\text{O}}$ and η_{N_2} . The determination of these variables was carried out by applying a balance to the carbon, hydrogen, oxygen and nitrogen, according to Equations (2) to (5):

$$\eta_{\text{CO}} + \eta_{\text{CO}_2} + \eta_{\text{CH}_4} - 1 = 0 \quad (2)$$

$$\eta_{H_2} + 4\eta_{CH_4} + 2\eta_{H_2O} - x - 2w = 0 \quad (3)$$

$$\eta_{CO} + 2\eta_{CO_2} + \eta_{H_2O} - y - w - 2m = 0 \quad (4)$$

$$2\eta_{N_2} - g - (3,76 * 2 * m) = 0 \quad (5)$$

The solution of the global reaction is completed considering more two reaction equations for the water-gas shift homogeneous reaction and for the methane formation reaction, respectively,

$$K1 = \exp\left[\frac{-\Delta G^{\circ T}}{RT}\right] = \frac{\eta_{CO_2} \eta_{H_2}}{\eta_{CO} \eta_{H_2O}} \quad (6)$$

$$K2 = \exp\left[\frac{-\Delta G^{\circ T}}{RT}\right] = \frac{\eta_{CH_4}}{\eta_{H_2}^2} * \left(\frac{P}{\eta_{TOTAL} P_0}\right)^{-1} \quad (7)$$

In this model, the reaction temperature was defined for values available in the literature for the combustion reaction of each biomass.

2.1 Results

Table 1 indicate the values found in the published data for different biomasses. These compositions were used in the mathematical model mentioned above, considering a moisture of 16%.

Table 1: Composition of biomass on dry basis.

Ultimate analysis (% w/w d.b.)	C	H	N	O
Rubber wood ¹	51,3	6.5	0.2	42
Cotton stalk ²	46,5	6.2	1.8	45.5
Sugarcane bagasse ³	50,5	7.1	1.9	40.5
Miscanthus ⁴	46,1	6.7	0.4	46.8

(1) Costa *et al.* (2017); (2) Yang *et al.* (2018); (3) Ren *et al.* (2017); (4) Sher *et al.* (2018).

Table 2 shows the concentration of the syngas obtained from the simplified model to biomass reaction with air. The concentrations of H₂, CO, CO₂, N₂ and CH₄ were calculated according to the temperatures reported for each biomass, as indicated in the Table 2 and the Fig. 1.

Table 2: Results of biomass gasification.

Syngas Composition (% v/v d.b.)	T [K]	XPH ₂	XPCO	XPCO ₂	XPCH ₄	XP _{N2}
Rubber wood ¹	1126	6,02	19,51	23,38	0,01	52,07
Cotton stalk ²	1123	4,65	13,39	28,79	0,06	53,16
Sugarcane bagasse ³	1400	4,57	21,12	21,11	0,001	53,2
Miscanthus ⁴	1073	4,79	12,02	30,38	0,01	52,8

Note: measured for m = 0,33 (molO₂)

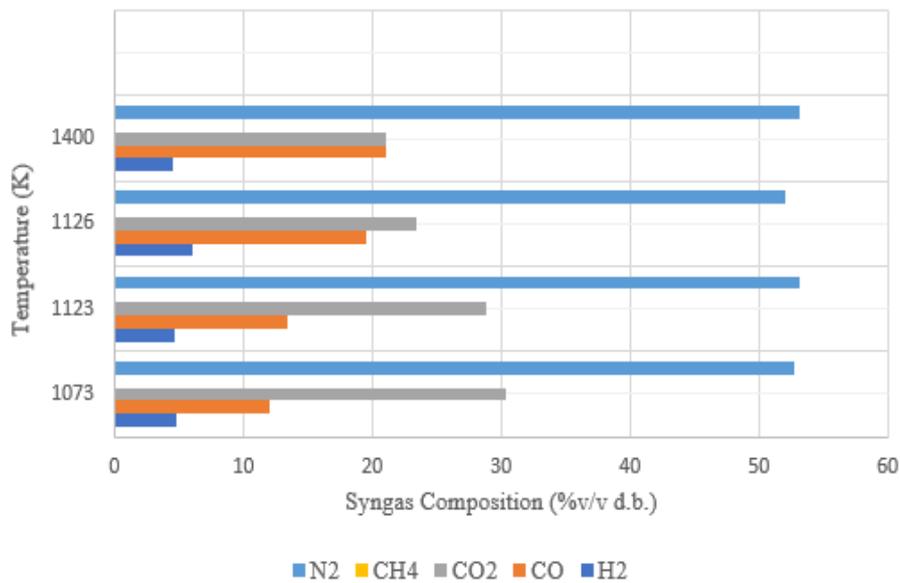


Figure 1: Composition of the syngas obtained for each biomass analyzed.

The concentration of H₂ varied between 5 and 8% for each biomass analyzed, and the N₂ concentration varied between 51 and 53%. These values will be compared with the literature and with other models of the chemical equilibrium for the biomass.

Figure 2 shows the influence of moisture on the syngas concentrations, for the sugarcane bagasse combustion at 1400K, for moistures of 10, 16 and 20%. The CH₄ concentrations were almost uninfluenced, as was expected from the literature data. However, the H₂ and CO₂ concentrations increased significantly with increasing moisture.

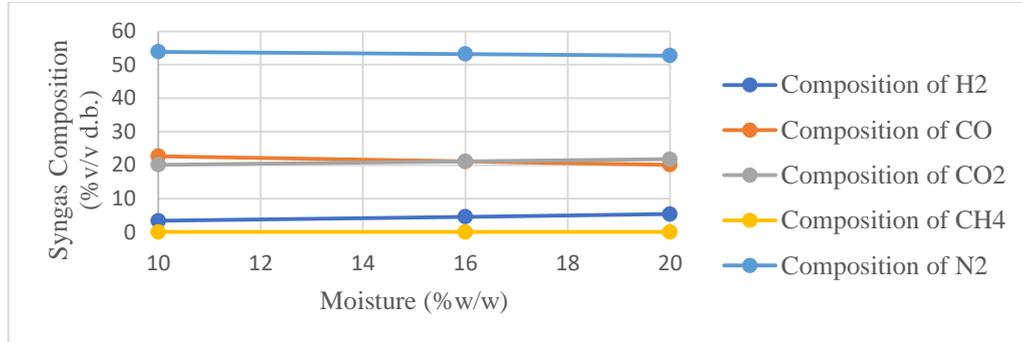


Figure 2: Influence of moisture in the composition of sugarcane bagasse syngas.

The behavior of the curves of the syngas compositions was comparing with the results showed by Costa *et al.* (2017), for different concentrations of moisture.

3. CONCLUSION

The preliminary results presented in this study showed that the composition of syngas after gasification depends on several factors, in which the main analyzed were the moisture presents in the solid fuel and the reaction temperature. The simplified model for the chemical equilibrium is being analyzed for other equations reactions for the carbon and tar.

The results indicated that H₂ concentrations resulting from biomass combustion were lower than those found in many published works. To improve this, new reaction equations are being implemented in the chemical model. In addition, the concentrations of syngas depend on the composition of each biomass analyzed, and it is difficult to compare with data obtained in the literature for different biomass pellets.

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