Article

Gasification of Sugarcane Cutting Residues in the Capture of Carbon Dioxide by Simulation

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Abstract: The gasification of sugarcane cutting residues (RAC) is a process that occurs in a gasifier where the transformation of this raw material into a solid-state and a gasifying agent with a moderate calorific value occurs, thanks to the application of heat. And under restricted oxygen levels, we can say that there are several styles of gasifiers for air, steam, oxygen, and hydrogen, all of which have a performance that can be analyzed and categorized by their performance to avoid damage to the environment. (1) The objective of this article is based on the mathematical development using simulation of the gasification of cane cutting residues. (2) In the methodology, the simulation of the gasification and CO_2 capture process was developed from the biomass residues of the sugarcane cutting residues; it was carried out as a transformation of the primary fuel into a gas stream whose main components are CO_2 and H_2, which can be separated relatively easily by their concentrations, available pressures and in some cases, their temperatures; (3) According to the kinetic data obtained, the second-order reaction in the transformation and improvement of the process was identified; applying to the optimization of development in the capture of CO_2, contributing to the reduction of greenhouse gases. (4) The gasification simulation process results in a biomass conversion corresponding to 93% of its feed and the formation of volatiles whose molar fraction corresponds to 37% H_2, 12% CH_4, 37% CO and 12 % CO_2.

Keywords: Greenhouse, biomass, carbon dioxide, capture carbon dioxide, gasification

1. Introduction

Global warming and climate change do consider the main points of attention globally. Carbon dioxide is regarded as the primary contributor, and the end to t take interactivity to correct this burning afflicts the Inactivity and its inhabitants—the burning of fossil fuels. (1) Inactivity is their primary source of emission, being that in the daily life of their processes, they indiscriminately release large amounts of this greenhouse gas into the atmosphere. (2) Carbon Capture emissions in this age of technology are projected as an actual emission in this situation, given its capacity to contain emissions from its source CO_2 process.

This study aims to simulate determining the gasification process of sugarcane by using ware and its reaction kinetics. Several simulation models will be raised and compared by estimating their reaction kinetics, then the model with the. The tips will be reconfigured for their optimization in capturing carbon dioxide.

Gasification

Gasification stores solid waste at high temperatures (approximately 600°C) in equipment that does not contain oxygen. Oxygen is kept in low proportions, i.e., absent to prevent accelerated combustion; instead, the carbon-containing base of agricultural residues for the sugarcane industry is broken down into syngas and a well-known solid such as slag, ash, or coal residue. Note that operations in oxygen-free conditions (advertised by many suppliers) are challenging to carry out during operations on a commercial scale. The synthesis gas is formed mainly of CO, H_2, and CO_2 (3)(4), with some pollutants all having a sufficient heat capacity to be burned and reformed in energy. Still, it requires determining advanced systems that help pollution. Many of these operational facilities fail to produce the necessary power to be economically profitable. (5) Certain bioproducts and many of their derivatives are from these methods comprising emissions of gases into the atmosphere; much slag is considered a form of solid waste, and ash is the flywheels of air pollution control equipment (which requires exceptional management due to its toxicity), and liquid waste and wastewater.

Capture Systems CO_2

The Global Carbon Capture and Storage Institute (GCI) (2020) defines it as "an emission reduction technology critical to meeting global improve and storage of is a vital novel technology in the removal of emissions in there of this greenhouse gas, with the potential to drastic considerably and positively in the fight against global wintering CO_2 (6)(7)(SaqPost-combustion1). This technique applies significant points of gases with high content commonly coming from These, such as power generation plants that use fossil fuels and industrial processes in general CO_2 (8).

Figure 3 is a basic diagram of a capture and storage system. This system consists of the capture or separation of the gases generated in combustion and various processes for the production of a gas of deep concentration in CO_2, (9)(10), which is subjected to compression, at pressures aboaoveis transported, usually by pipeline lines or ships, depending on the specific requirements, to determine their subsequent use the production of dry ice in many food industries, they are stored correctly in many geological structures in several oil tanker wells, depleted gases, saline aquifers, with ca practical for dissolute ion in salt, have been found in the deep ocean200/bar (11).

Technologies for the capture of CO_2

The question of the many countries before the reports of different climates are a product of the effect of CO_2 emissions provoked great interest in the research of technologies and optimization of capture, developing the most convenient processes immediately to implement in the energy industries, which are primarily responsible for almost half of the pollution of emissions of this gas in the European Union (12) (13)

The technical capacity to regroup CO_2 from the primary sources of emission was established; somehow, there are currently very few large-scale protests of this technology, first of all, because of the costs involved and, in most cases, the technologies are individual have not been accurate at the level they were intended. In this way, we can theoretically exceed the standard of emission capture; the current focus of research is on economically controlling the processes used today (12).

The technical side of this process goal is to produce a CO_2-focused current that can be safely moved into storage. The technology is applied in 1st place in coal, lignite, mineral coal, and natural gas power plants; in addition, its continuous values give an advance to these sciences can expand its uses to all those areas where CO_2 is released as a way to obtain energy (14)(15).

At present, various capture technologies are being improved at a practical and commercial level, which can be classified depending on at what point in the process the degradation of the process itself is intervened and carried out. If the system acts by capturing the available fuel before the combustion process is completed, the process is known to be captured in pre-combustion; on the other hand, if it is captured in the chimney gases, that is, after the burning of the fuel, it is called post-combustion capture; and, when the technique focuses on the same combustion process, we speak of oxy-combustion capture CO_2 (15).

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2. Materials and Methods

Equipment

The equipment used in the simulations was as follows:

RAC Gasification

- Reactor RCTR Restoic
- Dry Flash2 Separator
- Reactor Yield
- Reactor Gibbs
- Split separator

CO_2 uptake

- Mixer
- Rad Frac Reactor (Absorb)
- Bomb
- Heat Exchanger
- Rad Frac reactor (stripper)
- Bomb
- Heat Exchanger
- Monoethanolamide Reagent (MEA)

The methodology developed for this project is based on bibliographic research with the application of the aspen plus simulator because a wide variety of references were spectated and reviewed in pacts such as chemical kinetics, gasification processes, and capture of CO_2, as well as the consultation of different studies carried out in the application of these technologies. On the other hand, this research is also pigmented as experimental, corresponding to this the simulation of the different scenarios and models proposed to determine the most relevant reaction kinetics.

This research work is based on the simulation of the experimental data obtained from the study carried out by Chatrattanawet and collaborators (2019); through its application in the Aspen Plus process modeling programs, in this way it is possible to perform treatment and analysis, as describing gasification simulation of the gasification process and CO_2 capture, from the biomass residues of the agricultural waster cane, base research an of next and last analysis exposed in (16) (17). We also calculate the kinetic result set simulation model results of the simulation model. The Reconfiguration of the model was determined to optimize the gasification process and capture of CO_2.

Calculation of the Kinetic Model

The overall reaction of the RAC gasification process can be represented by cellulose, (18)a constituent of a more significant proportion, according to Equation 1. The cellulose decomposition equation is considered with second-degree kinetics, taking into account its direct transformation into the products of interest in gasification without degradation of these or the formation of intermediate products.

Equation 2 corresponds to the variation of the cellulose concentration over time, referred to as the kinetic constant, and the concentration of cellulose raised to its reaction order. This Equation 2 can be manipulated and integrated between their respective initial and final limits of attention and time, as equation 3.

Equation 3 can be rearranged to agree with the shape of equation 4, where it represents the time variable and corresponds to the value of the slope Equation 5. The reaction kinetics for the previously proposed simulation models were determined using this expression.

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The technique used to develop this research is the determination of the mathematical model with the help of the simulation of RAC gasification and CO_2 capture using the Aspen Plus VERSION 12.1 program.

When starting the simulation, the definition of the components of the reactants and products is given in

Table ***1***; the biomass of sugarcane harvest residues was named in the program as cellulose (represents the majority fraction within its composition) with a calculation base of 100 kmol/h of this with its corresponding current 1, the values were entered pressure and temperature, as well as its flow rate. In-stream 2, the water used in the simulation was defined as the gasifying medium, with a temperature of 25°C and 1 atmosphere, and a molar flow of 50 kmol/h. The gasifier equipment was simulated using an RCstr block, labeled R1, where streams 1 and 2 enter for their conversion, with a residence time of 1hr at 700°C. Stream 3, Figure 1, resulting from the gasification process, enters a heat exchanger (H1) to lower its temperature and facilitate the separation process through S1 (Flash2 block) of the volatile phase in stream 6. Finally, a compressor (C1) was used to increase the pressure of the stream to 1.5 bar.

In the aspen program, we place the compounds resulting from gasification to improve the process and their assimilation; all of this helps capture CO2 in optimal conditions, applying the Electrolyte NRTL model for electrolyte systems in water other solvents. (Including mixed solvents, together with LK-Plog and Peng-Rob; simulation of CO_2 uptake (absorption) starts with the amine at 30% of its weight, its name is monoethanolamine (MEA) it enters the mixer where it is at 40 °C 1.5 bar the process occurs with vapor-liquid.

In the CO_2 capture simulation procedure (Separation), Figure 2, absorption occurs. The amine is pumped to the heat exchanger; its temperature increases to 80°C, and it enters the Rad Frac Reactor (STRIPPER), where the separation is carried out. Of the amine and CO2. Here we have another process: reboiler, also known as a boiler.

For the optimization of the CO_2 capture system, Figure 3, recirculation is applied from the amine that has been separated from the CO_2; this amine re-enters the process at the beginning and undergoes purge (Current that is used to eliminate an accumulation of inert or undesirable substances) where the 70% of this amine re-enters the system and is coupled to the amine solution that is added to it.

3. Results

The results were obtained from the simulation of the RAC gasification processes and the capture of CO_2. The simulation was carried out in Aspen Plus V12.1, through which the gasification of the RAC could be determined, and each of the proposed processes is detailed. In addition, a comparative analysis was carried out between the two simulated methods to show the efficiency of the drying and incineration stage. In the case of gasification in the capture of CO_2, we have a recirculation that optimizes the capture of CO_2. Finally, the process graphs with the highest performance were analyzed to verify that each optimization occurred best.

The question that many ask is how much profitability has the gasification of RAC in countries like ours. We can say that it is a way to obtain energy in rural places where we find that firewood and pellets are still used in some instances. If you think about pollution, because we have a CO_2 capture system that guarantees the minimum risk of decay analysis, we demonstrate a considerable reduction of the It ensures that the environment will not be affected. The gasification process is optimized to the point where we have a meager percentage of ash.

It should be noted that (8) developed the following research where it indicated that the data of the agricultural residues of the sugarcane harvest (RAC), fundamentally we can compare the data of the leaves, can be a very efficient biofuel and of economic importance for the sugar mills, dedicated to the sustainable generation of electrical energy from cleaner and renewable biofuels.

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The Gasification and Roasting of RAC can occur within the industrial facilities of many sugar mills, as long as they initially go through three basic processes: Drying, filtering, and chopping. Table 2

3.1. Figures, Tables, and Schemes

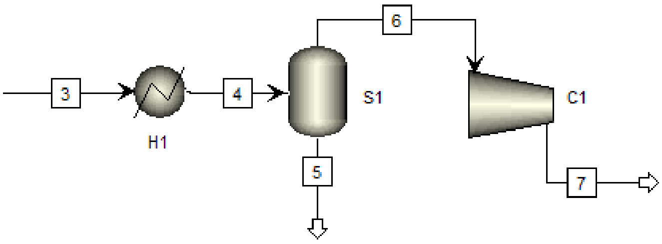

Figure 1. Stream 3, resulting from the gasification process

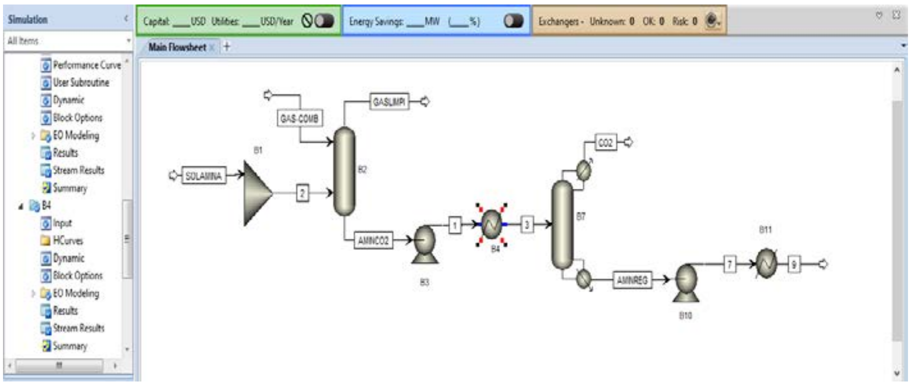

Figure 2. CO2 capture simulation procedure (absorption)

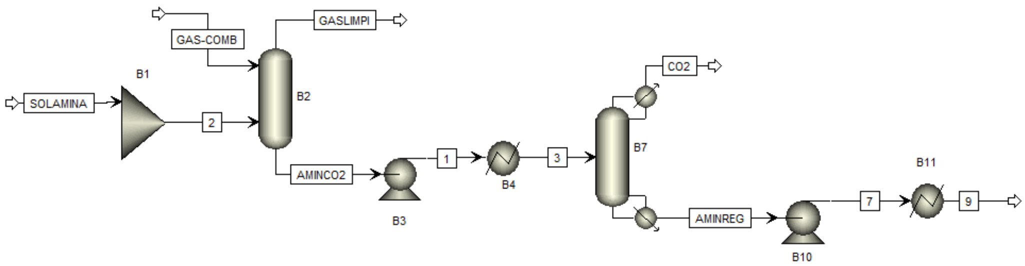

Figure 3. Basic Diagram of a capture and storage system CO_2

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Table 1. Operating Conditions.

OPERATING CONDITIONS	
Flue gas temperature	40oC
Flue gas pressure	1.5 bar
Total inflow	602874.4 kg/h
Co2 input flow	48319.4 kg/h
The temperature of the amine solution is 30% of its weight	40oC
Inlet pressure amine solution	1.1bar
Inlet flow of the mine solution 30% of its weight	554555.5kg/h
Number of stages in the absorber	18
Pressure in the absorber (upper stage)	1.1bar
Flow ratio	13
Number of stages in the stripper	40
Reboiler energy	5x107 cal/s
Stripper pressure (upper stage)	2 bar
Discharge pressure	2 bar

Table 2. Gasification data the average of the three simulations d.

Gasification simulation		
Compound	**Molar Fraction**	**Mass Flow**
CELLULOSE	1.94E-22	3.56E-17
CO	0,373672851	11836,00044
CO_2	0,124282313	6185,187033
H_2O	0,003786774	77,14441267
H_2	0,373731517	851,9586477
CH_4	0,124526546	2259,098378
C	3.37E-66	4.58E-62

Table 3. CO_2 capture data

SEPARATION DATA ($_{CO2}$)		
Compounds	**Mass flows (kg/h)**	**Molar fraction**
C_2H_7NO	43,375698	0,01063652
CO_2	1024,34624	0,25118858
CO	58,3290986	0,01430337
H_2	5.92E-06	1.45E-09
H_2O	2877,01792	0,70549782
N_2	0	0
CH_4	0	0
H_2S	70,4086294	0,01726549
COS	3,24480173	0,00079569
H_3N	0,25488063	6.25E-05
CHN	1,01832761	0,00024971

Table 4. CO_2 optimization data

RECIRCULATING DATA (CO2 SEPARATION)		
Compounds	**Mass flows (kg/h)**	**Molar fraction**
C_2H_7NO	155,816840	0,013358
CO_2	2798,521650	0,239925
CO	165,795452	0,014214
H_2	1.695754E-05	1.453818E-09
H_2O	8332,250643	0,714347
N_2	0	0
CH_4	0	0
H_2S	200,625294	0,017200
COS	9,385330	0,000804
H_3N	0,724457	6.210978E-05
CHN	1,019191	8.737819E-05

3.2. Formatting of Mathematical Components

$$1\ (C_6H_{10}O_5)_n \rightarrow 1\ CH_4 + 1\ CO_2 + 3\ CO + 3$$ Gasification process (1)

$$\frac{dC_x}{dt} = -k \cdot {C_x}^2$$ Kinetic calculus (2)

$$\int_{C_{xo}}^{C_x} \frac{dC_x}{{dC_x}^2} = -\int_{t_o}^{t} k \cdot t$$ (3)

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$$\frac{1}{C_{xo}} - \frac{1}{C_x} = -k \cdot t \quad (4)$$

$$\frac{1}{C_x} = k \cdot t + \frac{1}{C_{xo}} \quad (5)$$

4. Discussion

Another of the questions that we find a lot is whether the energy produced by the RAC will have the same performance and that if the energy produced is clean because we are a country that its energy base is fossil biofuels we highlight that the data we find in our gasification shows that it has the same performance it can be used in the same way however in (19) we highlight that in this work shows us the different renewable sources for the generation of electricity is constantly increasing in recent years biomass can be considered a renewable source for obtaining bio products and "clean" electrical energy for this, depending on the type of biomass, an adequate technology is necessary to convert biomass efficiently, and a promising alternative is gasification in this work, using the Simulation software Cycle Tempo 5.0 to solve balances of matter and energy, the potential for electricity generation in internal combustion engines from poor gas obtained by gasification of the main biomasses without substantial current use was evaluated: cane harvest waste and pruning and citrus renewal residues with these wastes, altogether, 1,229,208 tons on a dry basis per year, 774 GWh of electricity could be generated annually, 27% of the total electricity consumed in the province. Table 3

It is also questioned because we do not use a fixed bed reactor in our gasification. We can also highlight that it was tried to do more simply and at the same time also practice demonstrating that if the conditions and the system are adapted, gasification can be carried out with optimal results; we find that in the research of (OECD/FAO, 2009) the basic theory of the operation of the gasification process today is highlighted, gasification is considered an economically competitive, thermally efficient and environmentally friendly technology later, the following factors are analyzed and selected with criteria, comparing the raw material residues of the sugarcane harvest (RAC).

Energy recovery system internal combustion engine Gasifying agent air Plant production capacity 0.8-ton RAC/h plant design capacity 1-ton RAC/h Estimated synthesis gas production 2408 Nm3/h Type of gasifier Fixed bed- Downdraft synthesis gas obtained from biomass gasification is used for electric power generation by an internal combustion engine, in search of supplying the energy necessary for the operation of the plant and selling the remaining surplus for $ 150 per MWh (Renovo Program) finally, the reasons why it is considered convenient to install a plant for the production of syngas within them are listed the low costs of the raw material, the development of local industry and the use of agricultural waste. Table 4

5. Conclusions

After running the model of the modeled gasification process, a conversion of the biomass corresponding to 93% of its feed is obtained, and the formation of volatiles whose molar fraction of 37%H, 21% CH_4, 37% CO, 12% CO_2 corresponds to an of and once waste and water have been eliminated.

On the other hand, in the carbon dioxide capture process, a yield of up to one of sequestration concerning the processed gas stream was obtained, and obtaining a final molar composition of the process output gases with 45% CO, 23% H, 21% CH_4, 38% CO y 7% CO_2, concerning its molar composition, for the best run.

In comparison to the reaction kinetics of simulations 1, 2, and 3, a significant difference was obtained due to the influence of the feed flow and process temperature that affected the calculated kinetic coefficient, these being 0.0562; 0.0377, and 0.036, in units of $M^{-1} s^{-1}$, respectively.

The process's optimization gave a notable change in the mass flow of CO_2 in the gases resulting from the absorption process, going from 3380 to 4.51e–5 (kg/hr) and obtaining, for this optimized model, a final gas molar composition corresponding to 45% H_2, 10% CH_4 and 43% CO.

6. Patents

There is no patent in this research.

Author Contributions: The Conceptualization and methodology, software José Barreiro and Marconis, Castillo; to the validation Eduardo Arango; investigation, resources, Sandra Peña and Carmen Forero; writing—original draft preparation, Sandra Peña; review Francisco Velasco and editing, Sandra Peña; visualization, supervision, project administration, Carmen Forero.

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Data Availability Statement: The data can be found at the link: http://repositorio.ug.edu.ec/bitstream/redug/57473/1/BINGQ-IQ-21P59.pdf

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Conflicts of Interest: "The authors declare no conflict of interest."

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