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Performance Evaluation of Agricultural Residues Gasification in Nigeria Using Aspen Plus

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In Nigeria, bioenergy is the best source of hydrogen for alternative energy production.Therefore this study considers processing of hydrogen via Agricultural-residues gasification.Hydrogen is a form of clean energy that can be produced to use a variety of domestic renewable energy sources.. Plant material as an alternative energy source can be used in place of fossil energy, which are a finite and potentially depleting resource. The purpose of this study is to determine the energy efficiency of hydrogen processed from Agricultural-Residues(rice husks and straw) through energy and exergy assessments. The ASPEN HYSYS program is used to simulate the gasification process. The results indicate that rice husk and rice straw could be used as raw resources in the gasification process to produce hydrogen. The energy efficiency of the system is 33.15 percent for rice husk as well as 30.16 percent for rice straw, respectively.the system's exergy efficiency was 28.20 percent for rice husk as well as 30.16 percent for rice straw, respectively. compared to other hydrogen manufacturing processes . the agricultural residues hydrogen production process has relatively low energy and exergy efficiencies. Energy recovery techniques should be used to improve the energy and exergy efficiency levels of the Agricultural-residues gasification.

Key Word: Energy analysis; Exergy; analysis; hydrogen;Gasification,Agricultural residue

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1. Introduction

Clean energy has grown in importance as a source of electricity. Due to the fact that it provides greater energy security and has a lower environmental impact than conventional sources of energy [Tezer et al., 2022]. Hydrogen is a desirable energy source due to the fact that it is a clean and eco-friendly fuel. Nowadays, researchers are concentrating their efforts on electricity generation via hydrogen and fuel cells, as the process is more efficient than other forms of electrical devices [Adam et al.2015]. Thus, hydrogen is a renewable energy source that can be used in place of conventional renewable energy sources due to its numerous advantages over traditional combustion from automobiles or factories, which produces fog, smoke, and dust [Adeniji et al.,2013]. H2 is combustible, it produces no pollution and can also be used as a fuel for home appliances,

internal combustion engines, and turbines. Numerous raw materials, such as algae, plant material, and fresh water, can be used to generate hydrogen. [Anthony et al.,2016]
Biomass gasification is a partial combustion process that converts carbon-based solids to a gaseous product composed of hydrogen (H2) and carbon.Biomass gasification is a partial combustion process that converts carbon-based solids to a gaseous product composed of hydrogen (H2), carbon monoxide (CO), carbon dioxide (CO2), and water. (H2O), methane (CH4), and some light rxn. Biomass provides energy and heat that can be used to generate steam for industrial processes (Beohara et al.,2012)

Solid waste and biomass: A relatively homogenous carbon-based material is needed for a proper and efficient gasification process. As a result, many waste materials cannot be treated via gasification, and certain types require extensive pretreatment. Rather than they are several types of waste that are ideal for the process, including waste from paper mills, mixture of plastic waste, forest sector waste, and agriculture waste (Bhauram et al.2012). Gasification is a broad term that refers to the thermochemical processing of a liquid or solid carbon-based feedstock (raw material) into a flammable gaseous product (ignitable gas) through the addition of a gasification agent (another gaseous compound). Thermochemical conversion modifies the chemical structure of the biomass through the application of high heat. The gasification agent enables the feedstock to be converted rapidly into gas via a variety of heterogeneous reactions.

The combustible gas is depleted of CO2, CO, H2, CH4, and H2O, as well as minute quantities of hydrocarbon, inert gases contained in the gasifying agent, and various pollutants such as small char particles, ash, and tars (Diana et al.,2012). In Nigeria, bioenergy is the best source of hydrogen for alternative energy production. As a result, this study considers hydrogen production via biomass gasification. The purpose of this study is to determine the energy efficiency of h2 production from rice husk and straw through energy and exergy assessments. The ASPEN HYSYS program is used to simulate the gasification processstocThe results indicate that rice husk and straw could be used as feedstock in the gasification process to produce hydrogen. The energy efficiency of the system is 33.15 percent for rice husk as well as 30.16 percent for rice straw, respectively. Additionally, the system's exergy efficiency is 28.20 percent for rice husk as well as 30.16 percent for rice straw, respectively. When compared to other hydrogen manufacturing processes like steam methane reforming as well as coal gasification, (Gala,2017) the biomass-based hydrogen production process has relatively low energy and exergy efficiencies. Energy recovery techniques should be used to improve the energy and exergy efficiencies of the gasification process.

Renewable energy has grown in importance as a source of electricity. Due to the fact that it provides greater energy security and has a lower environmental impact than conventional energy sources [Diyoko et al., 2014]. Hydrogen is a desirable energy source due to the fact that it is a clean and environmentally friendly fuel. Nowadays, researchers are concentrating their efforts on electricity generation via hydrogen and fuel cells, as the process is more efficient than other forms of electrical equipment [Melgara etal.,2009]. Thus, hydrogen is a renewable energy source that can be used in place of conventional renewable energy sources due to its numerous advantages over conventional combustion from vehicles or factories, which produces fog, smoke, and dust [Muzee,2012]. When hydrogen is combustible, it produces no pollution and can also be used as a fuel for household appliances, internal combustion engines, and turbines. Numerous raw materials, such as algae, biomass, and fresh water, can be used to generate hydrogen.

Biomass gasification is a partial combustion process that converts carbon-based solids to a gaseous product composed of hydrogen (H2), carbon monoxide (CO), carbon dioxide (CO2), and water. (H2O), methane (CH4), and some light rxn. Biomass provides energy and heat that can be used to generate steam for industrial processes.Solid waste and biomass: A sufficient amount of solid waste and biomass is required for a proper and efficient gasification process.It is necessary to use a homogeneous carbon-based material. As a result, numerous types of waste cannot be recycled.Rather than that, there's several forms of waste that are directly suitable for the process; these include waste from paper mills, mixed plastic waste, and waste from the forest industry.
The gasification agent enables the feedstock to be converted rapidly into gas via a variety of heterogeneous reactions.CO2, CO, H2, CH4, H2O, trace quantities of higher hydrocarbons, inert gases contained in the gasification agent, and various contaminants such aschar particles, ash, and tars of various sizes (Omatola etal.,2012)

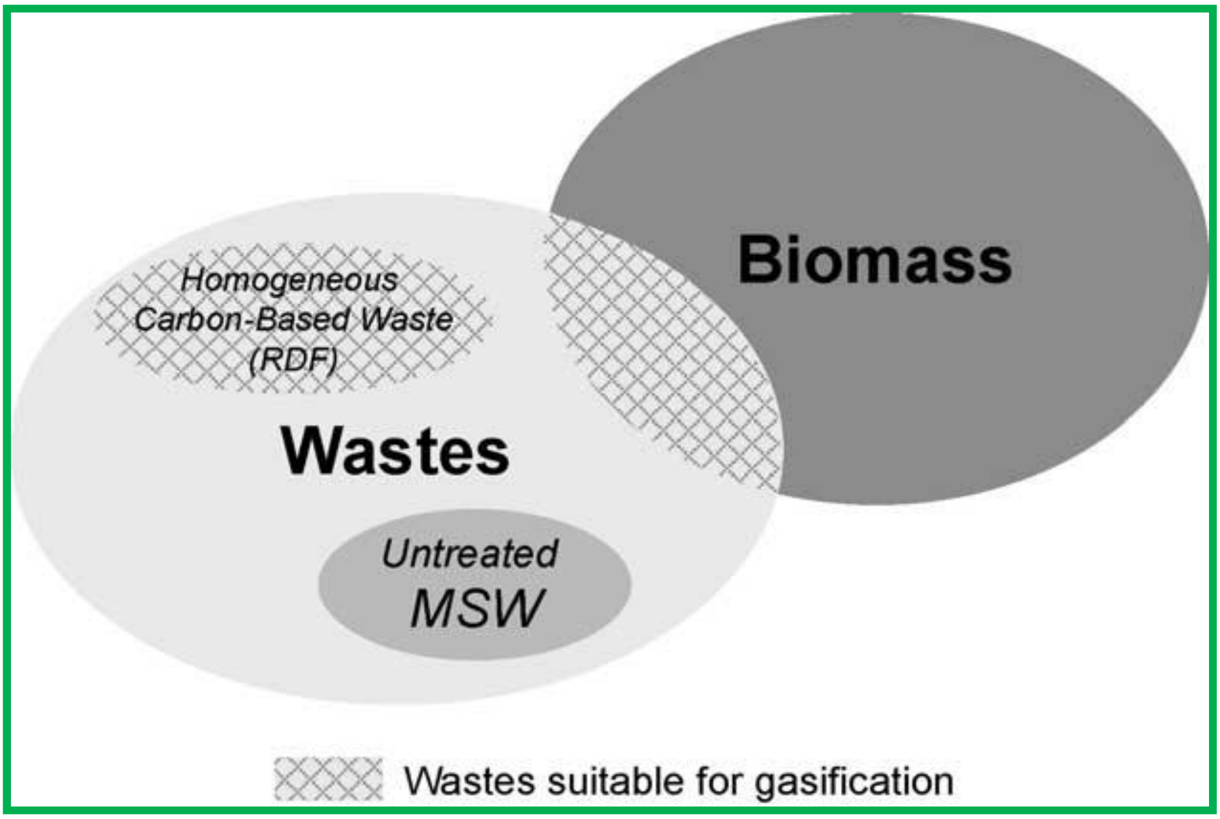

Fig 1: Wastes suitable for gasification

Rice husk is a potentially valuable material. Numerous applications exist for rice husk in either its raw or ash form. The majority of milled husk is either burned or dumped as waste in open fields, while a limited fraction is used as fuel for power generation, electricity generation, bulking agents for animal manure composting, and so on (Omatola et al.,2012). Rice husk's exterior is made up of dentate rectangular elements that are primarily composed of silicon dioxide and are covered in a thick cuticle and surface hairs. Rice husk has a chemical composition similar to that of many other common organic fibers, containing 40-50 percent cellulose, 25-30 percent lignin, 15-perent ash, and 8-15 percent moisture [Omatola et al.,2012]. Following combustion, the majority of evaporable components are gradually lost, leaving the silicates.

2. Materials and Procedures

Gasification of biomass, such as wood waste and agricultural residues, generates a combustible gas composed of carbon monoxide (CO), carbon dioxide (CO2), hydrogen (H2), and trace amounts of methane (CH4). Syngas is the name given to this gaseous byproduct. Gasification reactions, which include a series of oxygen-containing reactions and an added gas phase reaction, are [Pitchandi ,2012].

Biomass Pyrolysis or Devolatilization - Char + Tars + Light gases (1)
Boudouard reaction -C + CO2 2CO HO = +172 kJ/gmol (2)
heterogeneous water gas shift reaction-C + H2O CO + H2 Ho = +131 kJ/gmol (3)

Simulation of hydrogen generation from rice paddies and rice industry biomass residues are abundant and can be used to produce energyThis work examines agricultural based hydrogen production via gasification from these perspectives. The purpose of this study is to assess the energy and exergy performance of the biomass gasification process. The ASPEN HYSYS simulation program is used to control the gasification of rice husk and straw. Due to the abundance of Agricultural residues from rice paddies in rice industry in Nigeria, rice husk and straw were chosen as raw materials for hydrogen production. In this study, the gasification process is developed using the HYSYS simulation program, as illustrated in Figure 2. Then Additionally, because the biomass gasification operates at thermodynamic equilibrium, the simulation employs a Gibbs reactor. The gasifier, reformer, shift reactor, and separator are the primary unit operations in gasification. The air to biomass ratio, the flow to biomass ratio, the process temperature, and pressure are the critical operating variables. Table

1 contains the compositions of rice husk and straw.
Due to the abundance of biomass residue from rice paddies and the rice industry in Nigeria, rice husk and rice straw were chosen as raw materials for hydrogen production. In this study, the gasification process is developed using the HYSYS process design and simulation program, as illustrated in Figure 1. Then Additionally, because the gasification process operates at thermodynamic equilibrium, the simulation employs a Gibbs reactor. The gasifier, reformer, shift reactor, and separator are the primary unit operations in gasification. The air to biomass ratio, the stream to biomass ratio, the process temperature, and pressure are the critical operating variables. Table 1 contains the compositions of rice husk and straw.

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Biomass	**Rice husk**	**Ricestraw**
Proximateanalysis		
Ash, %	12.65	10.39
VolatileMatter,%	56.46	60.70
Fixed Carbon,%	18.88	18.90
UltimateAnalysis		
Carbon,%	37.48	38.17
Hydrogen,%	4.41	5.02
Sulfur,%	0.04	0.09
Chlorine,%	0.09	-
Ash, %	12.65	10.39
OtherCharacteristic		
BulkDensity,kg/m3	150	125
HHV,kJ/kg	14755	13650
LHV,kJ/kg	13517	12330

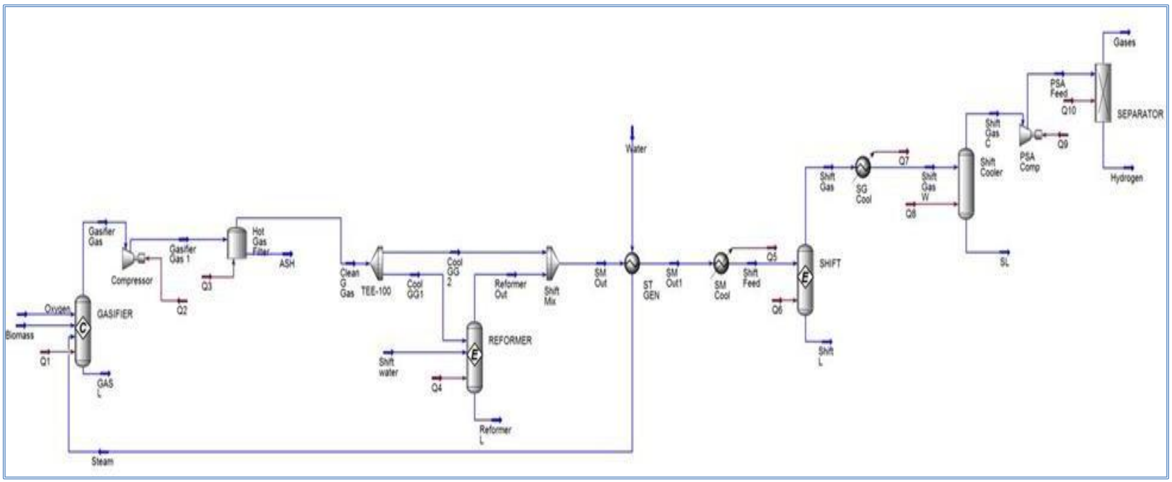

Fig 2. Hydrogen Processing From Agricultural Residue Gasification Using - ASPENHYSYS.

3. Results:

The performance of the system is evaluated in this work using process simulation. The mathematical model for biomass gasification was validated using the results from Lau 2002. The desired product of the biomass gasification process is hydrogen. The air to biomass ratio, the steam to biomass ratio, the gasification temperature, and pressure are all critical parameters that affect the efficiency of the biomass gasification process.
The efficiency of an exergy (Ex) or second law system is defined as the ratio of exergy output to exergy input. Exergy is a term that refers to a system's maximum work capacity. Exergy is a term that refers to the quality of energy. The optimal operating conditions in terms of maximum hydrogen yield are evaluated from this perspective. The optimal operating conditions, as determined by the results, are listed in Table 2 . The rate of hydrogen production from rice husk and straw is 1520 kg/hr.
The temperature and pressure of the hysys environment are typically set to 298.15 K and 0.101 MPa, respectively, in an exergy analysis. To maximize energy efficiency, it is necessary to conduct energy and exergy

analyses of the agricultural residues hydrogen production process. Table 3 and 4 compare the energy and exergy flow rates of rice husk and straw feedstocks. They discovered that the system's primary sources of energy and exergy are bioenergy and energy consumption.

Table 2. Operating parameters of The Agricultural residues Gasification Process.

Operating variables	**Operating Conditions**
Biomass feed rate	20820 kg/hr
Air to biomass ratio	0.31
Steam to biomass ratio	0.62
Gasifier temperature and pressure	1071 K, 791.8 kPa
Reformer temperature and pressure	1471 K, 681.5 kPa
Shift reactor temperature and pressure	472 K, 552.1 kPa
Separator temperature and pressure	361 K, 1472 kPa

Table 3. Energy and exergy of (rice husk) gasification process.

Rice husk	**Mass flow rate (kg/hr)**	**Energy flow rate (GJ/hr)**	**Exergy flow rate (GJ/hr)**
Input			
Biomass	20820	431.06	502.85
Air	6,188	1.75	0.73
Water	13,155	5.73	15.20
Energy (LPG)	2,035	102.21	102.21
Output			
Hydrogen	1,520	181.61	181.66
Off-gas*	1,665	104.73	101.83
Ash	10,408	202.54	235.02
Energy		26.26	26.27

Table 4. Energy and exergy flows of (rice straw) gasification process.

Rice straw	**Mass flow rate (kg/hr)**	**Energy flow rate (GJ/hr)**	**Exergy flow rate (GJ/hr)**
Input			
Biomass	20820	405.34	470.35
Air	6,188	1.75	0.73
Water	13,155	5.73	15.20
Energy (LPG)	2,041	101.81	101.82
Output			
Hydrogen	1,522	183.17	183.22
Off-gas*	1,826	115.93	112.98
Ash	10,448	217.22	253.73
Energy		26.14	26.14

Table 5. Energy and exergy efficiencies of Agricultural residue (rice husk and rice straw)

Biomass	**Energy efficiency (%)**	**Exergy efficiency (%)**
Rice husk	33.15	28.20
Rice straw	32.16	30.16

Energy and exergy efficiencies in the agricultural residues hydrogen production process are 33.15 percent, 28.20 percent, and 32.56 percent, 30.16 percent for rice husk and straw feedstocks, respectively, as shown in Table 5. Numerous variables impact the entire energy and exergy efficiencies, including the feedstock type, the

volume of hydrogen produced, and the amount of off-gas. Additionally, the system's exergy performance is reduced than its energy efficiency, indicating that the system's energy quality is poor. These figures are reasonable in light of the low hydrogen production yield and the high off-gas volume [11]. Additionally, the separation unit's temperature and pressure differences between the inlet (500.1 K, 1482 kPa) and outlet gases (366.33 K, 413.7 kPa) gases are the primary source of exergy loss during the gasification process.
Energy recovery techniques should be used to improve the energy and exergy efficiencies of the hydrogen processing from biomass gasification process. The reformer and shift reactors generate significant amounts of waste heat during the gasification process. As a result, energy efficiency can be increased by recovering waste heat and reducing the amount of energy consumed during the process.

4. Conclusion:

Hydrogen has become a critical component of the future energy economy. Hydrogen production from biomass gasification is evaluated in this study using process simulation. The purpose of this study is to determine the energy performance of a biomass gasification process in Thailand using rice husk and rice straw. The results indicated that the hydrogen producing rates from rice husk and straw are comparable at 1520 kg/hr and 1522 kg/hr, respectively, under optimal operating conditions. Additionally, the system's energy and exergy efficiencies are low; 33.15 percent and 32.16 percent energy efficiencies, respectively, and 28.20 percent and 30.16 percent exergy efficiencies, respectively, for rice husk and rice straw feedstocks. They are reasonable in comparison to the amount of hydrogen produced and the amount of off-gas produced. As a result, energy recovery methodologies should be used to optimize the energy and exergy efficiency of the agricultural residues hydrogen production process.

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