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Steam Co-Gasification of Rice Husk and Sewage Sludge in a Fluidized Bed Gasifier

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Abstract:- Due to its environmental friendliness and substantial energy supply, biomass is a promising alternative among the various renewable energies. Gasification has been suggested as a viable approach to maximize the energy efficiency of biomass. In this study, steam was used to co-gasification of rice husk (RH) and sewage sludge (SS) at various temperatures. In this present work the H_2 content is increased and the syngas production dropped as the SS ratio in blends increased. Due to the reduction and steam oxidation of Fe species in SS during the co-gasification process, the synergistic interaction was more important at higher temperatures, which encouraged the H_2 production. At SS ratio=0.80 and temperature of 900°C, the highest effective gas content (82.92 vol%) and highest HHV (11.40 MJ/m^3) were optimised. It suggests that steam co-gasification of RH and SS is a method that has potential for producing the needed syngas for a safe and effective waste management procedure.

Keywords: *Steam Co-Gasification, Sewage Sludge, Rice Husk, Syngas.*

NOMENCLATURE	
A/F	Air-To-Fuel Ratio
CCE	Carbon Conversion Efficiency
CGE	Cold Gas Efficiency
EP	Electrostatic Precipitator
ER	Equivalence Ratio
FBG	Fluidized Bed Gasifier
GR	Gasifying Ratio
HHV	Higher Heating Value
LHV	Lower Heating Value
RH	Rice Husk
SS	Sewage Sludge
TEM	Transmission Electron Microscope
TG	Thermo Gravimetric
TGA	Thermo Gravimetric Analyzer
TRE	Tar Removal Efficiency
T1	Thermocouple-1
T2	Thermocouple-2

I. INTRODUCTION

Global warming is a significant environmental issue in the modern era because of the high energy demands of the developed world. Thus, there is a critical need to lower greenhouse gas emissions and the reliance on fossil fuels for energy production.A thermochemical process called "biomass gasification" transforms biomass into producer gas that contains gaseous species. In instance, steam fluidized bed gasification creates a fuel gas with a large amount of methane and carbon dioxide, as well as hydrogen and carbon monoxide. In this regard, biomass gasification can offer a solution to this issue because it emits no net CO_2 into the atmosphere [1]. The technology for gasifying lignocellulosic biomass to provide renewable fuels and chemicals is considerably developed [2]. A process called gasification converts biomass into valuable gases that can either be used as a direct fuel source or refined into more value liquid fuels and chemicals [3]. Gasification breaks down and transforms the main biomass substitutes (cellulose, hemicellulose, and lignin) into a gas product known as syngas, solid char, liquid tar, and other contaminants (ammonia, hydrogen sulphide, and others) at high temperatures (600°C-1000°C) and low oxygen levels (0.20-0.45 of equivalence ratio, ER) [4]. Recovery systems that can extract energy from garbage can help to partially tackle the global environmental problem of waste management. Gasification is one of the Waste-to-Energy solutions that is currently accessible as an alternative to conventional combustion facilities [5]. In addition to the benefits of incineration, such as the elimination of pathogenic germs and the decrease of volume, this technique also offers higher energy recoveries and less expensive atmospheric emissions control [6]. The gasification of sewage sludge is becoming more popular in this context [7]. Waste produced in wastewater treatment facilities that are liquid or semi-liquid is known as sewage sludge. This trash makes an intriguing fuel for gasification applications due to its physical and chemical characteristics [8]. A combustible gas (syngas), primarily made up of H_2, CO, CO_2, CH_4, and N_2, is the principal by-product of the gasification of sewage sludge (in gasification with air). Many uses for syngas exist, including the creation of heat and power, chemical synthesis, and fuel cells. However, to eliminate the contaminants it contains, the majority of these applications require elaborate and expensive gas cleaning systems [9]. Presently, the use of agricultural waste (such as rice husk, rice straw, and sugar cane bagasse) for the production of thermal energy or electricity has attracted a lot of interest. These feedstock are not the subject of the "food or fuel" debate because they do not endanger the availability of food [10]. In 2020, the globe will consume about 450 million tonnes of rice, up 6.6% from the 422 million tonnes consumed in 2007, according to [11]. The two countries that produce the most rice together, China and India, account for around 50% of global production. Almost 90% of the rice produced worldwide is produced in only the Asia region. In recent years, the fluidized bed technology for the energy valorization of biomass residues, including sawdust, rice husk, and sugar cane bagasse, has undergone a significant development. Due to the flexibility of its fuel and the potential for a clean operation, fluidized bed reactors have been widely demonstrated to be an efficient technology for high specific capacities. They are therefore regarded as the best option for converting biomass to electricity [12]. According to [13] the main characteristics of the fluidized bed technology are: homogeneous temperature distribution in the reaction chamber, good gas-solid contact, wide tolerance to variations in fuel quality, easy starting and shutting down, quick heat-up, high carbon conversion efficiency, and relatively low investment.

II. MATERIALS AND METHODS

- *Rice Husk*

Rice husk of average particle diameter 200–300 μm was taken as the feedstock. It was displayed in Fig. 1 below. The ultimate and proximate analysis of Rice husk was shown in Table 1.

Fig 1 Rice Husk

- *Sewage Sludge*

The sewage sludge sample was collected from a water treatment plant and then dried via solar driers. The proximate and ultimate analysis of the sewage sludge sample was shown in Table 1

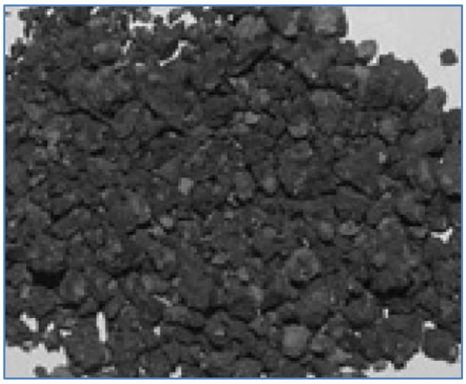

Fig 2 Sewage Sludge

Table 1 Proximate and Ultimate Analysis of Rice Husk and Sewage Sludge

Property Value	Value	
Moisture content (wt%)	9.4	20.0
Proximate analysis (wt%, dry basis)		
Volatile matter	81.02	44.0
Fixed carbon	14.58	5.1
Ash content	4.40	30.9
Ultimate analysis (wt%, dry basis)		
C	49.70	51.2
H	5.98	8.2
N	0.56	7.1
S	0.45	1.7
O (by difference)	43.32	- 31.8
HHV (MJ/kg)	18.30	- 15.0

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➢ *Experimental Work*

The experimental set-up, as depicted in Figure 3, is made up of six main parts: a fluidized bed reactor, biomass feeding, steam, air, and preheating, gas metering, cleaning, and sampling, temperature control, and gas on offline analysis. Two independently regulated electric heaters that provide heat for startup and reduce heat loss during operation encircle the reactor, which was made of stainless steel pipe. The reactor was 1400 mm tall, with a

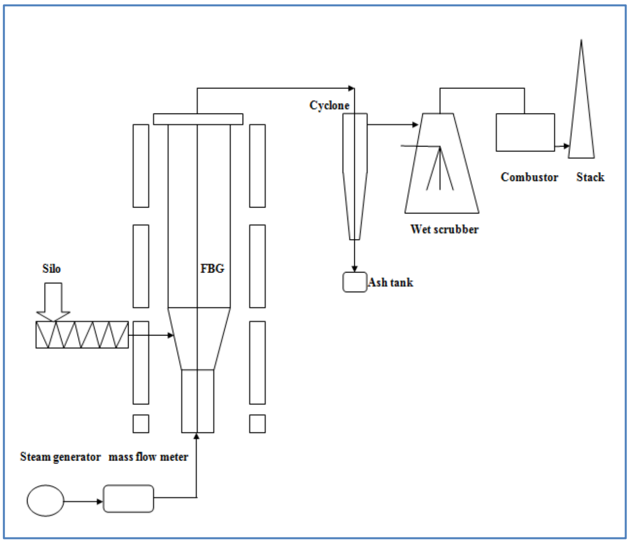

Fig 3 Scheme of the Experimental System

fluidized bed diameter of 40 mm and a freeboard diameter of 60 mm. Two pressure taps were put at heights of 40 and 1060 mm above the distributor to monitor the reactor's fluidizing condition. A pressure tap was included in the biomass feeder for pressure management. To enhance air dispersion, an air distributor was positioned at the base of the reactor. The distributor is 3 mm thick and consistently has 25 holes punched through it. The biomass was fed using a metering motor with variable speed. The mass flowrate of steam produced by a steam generator was measured using a steam flowmeter. The feedstock was continually fed into the reactor bed using a screw feeder that was controlled by a speed controller once the empty reactor reached the required experimental temperature. Gasification begins when the gasifier's interior hits 950°C. Super-heaters were used to raise the building's steam temperature to roughly 800°C before it entered the gasifier through a properly insulated steam conduit. Using a clock and precision weight scale, the steam's released mass and mass flow rate was calculated. The amount of hydrogen produced increased when steam was used as a gasifying agent. The steam that was offered at the bottom of the gasifier was produced by the wind box. The cyclone was attached to the top side of the gasifier, and the solid particles included in the product gas were removed by the cyclone. The gas analyzer examines several gases such as CO, CO_2, H_2, O_2, and CH_4. The producer gas analysis was done in gas chromatography-thermal conductivity detector (GC-TCD) and a gas chromatography-flame ionization detector (GC-FID),

III. RESULTS AND DISCUSSION

➢ *Product Distribution*

The gas and solid yields after steam gasification of RH and SS with different ratios at different temperatures are shown in Fig. 4.As can be seen, as the gasification temperature rose from 750 to 900 °C, the solid yield decreased. For instance, when the gasification temperature was raised from 750 to 900°C, the solid output for the steam co-gasification of RH: SS=5:5 decreased from 24.75 to 12.07 wt%.It was clarified that the gasification temperature affected the gasification results and that high temperatures favoured the formation of gas phases because they increased char reactivity, boosted the water gas shift reaction, and reduced reaction resistance [14].

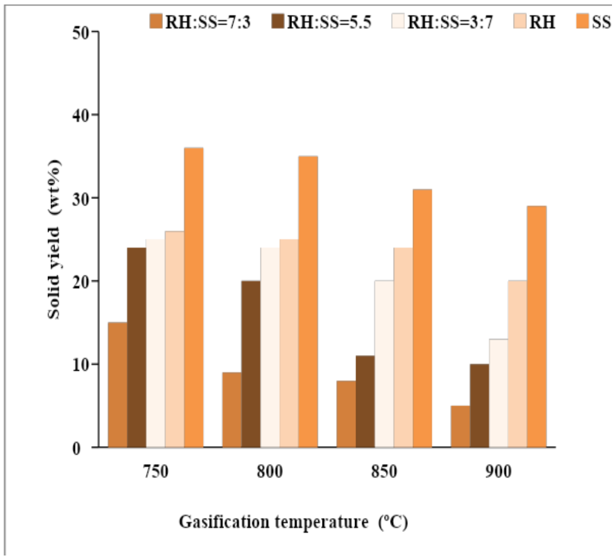

Fig 4 The Production Yield of (a) Char From Steam Co-Gasification of RH and SS with different Mass Ratios at different Temperatures

- *The Production Yield of (B) Gas:*

The gas and solid yields after steam gasification of RH and SS with different ratios at different temperatures are shown in Fig. 5.It was intriguing to learn that gasifying a single RH offered the lowest solid yield, but gasifying an SS produced the highest solid yield, in terms of how the RH and SS ratio affected the yield distribution from co gasification. This is a result of the low ash content of RH and the high ash level of SS. With an increase in the SS ratio in the sample, the solid yield for co-gasification increased (RH:SS was declining). For instance, the solid yield grew from 7.47 to 21.87 wt% while the SS ratio increased from 0 to 1 at the steam co-gasification temperature of 850°C. Most likely, increasing the SSratio in the gasification sample would raise the ash concentration, which would therefore produce more solid material following reaction and lower the gas output.

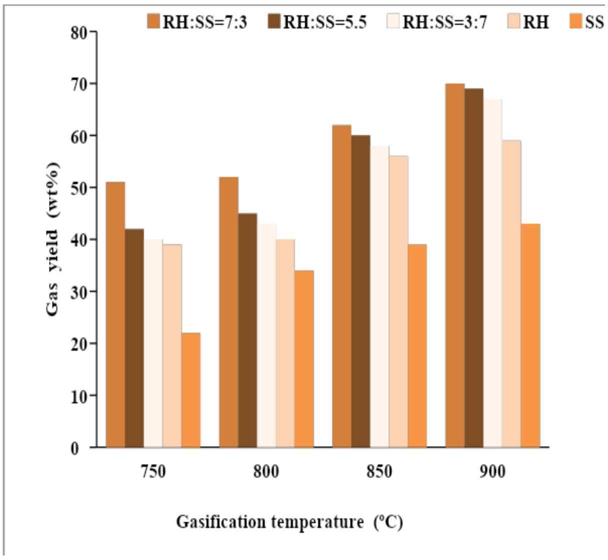

Fig 5 The Production Yield of (b) Gas from Steam Co-Gasification of RH and SS with different Mass Ratios at different Temperatures

➢ *Syngas Composition:*

- *RH:*

The gas compositions for the gasification of RH and SS with different ratios and different temperatures were presented in Fig. 6. It obviously showed that the CO content was increased and CO_2 content was decreased with the increase of temperature.

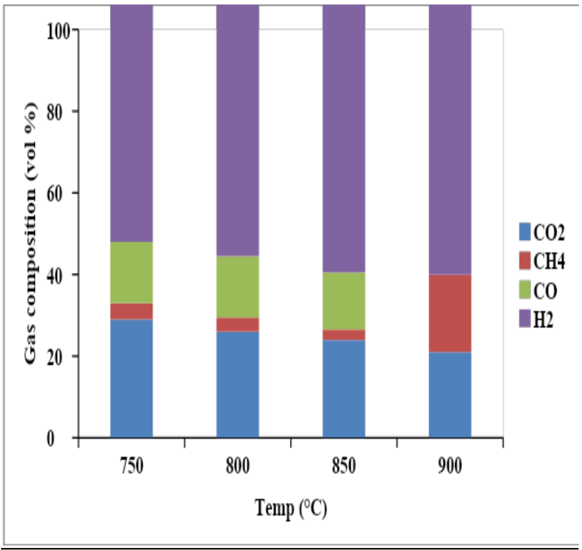

Fig 6 Gas Compositions for the Steam Co-Gasification of (a) RH at different Temperatures

Detail: For RH, the CO content increased from 14.40 to 22.10 vol% and the CO2 content reduced from 28.84 to 17.96 vol% when the gasification temperature was raised from 750 to 900°C. High temperature encouraged the gasification of CO2 and preferred partial carbon oxidation to increase the generation of CO [15].

- *RH:SS=7:3,*

The gas compositions for the gasification of RH and SS with different ratios and different temperatures were presented in Fig. 7. It obviously showed that the CO content was increased and CO_2 content was decreased with the increase of temperature.

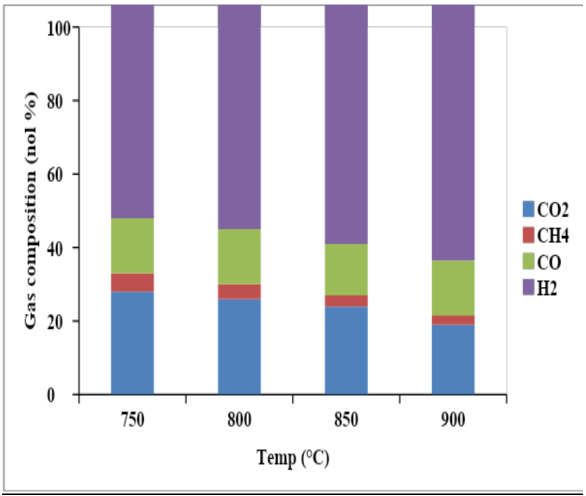

Fig 7 Gas Compositions for the Steam Co-Gasification of (c) RH:SS=5:5at different Temperatures

High temperature encouraged the gasification of CO2 and preferred partial carbon oxidation to increase the generation of CO [16].

- *RH:SS=5:5,*

The gas compositions for the gasification of RH and SS with different ratios and different temperatures were presented in Fig. 8. It obviously showed that the CO content was increased and CO_2 content was decreased with the increase of temperature.

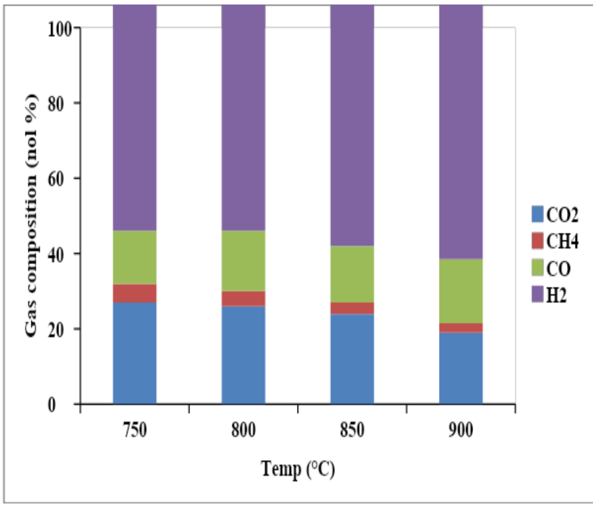

Fig 8 Gas Compositions for the Steam Co-Gasification of (c)RH:SS=5:5, at different Temperatures

High temperature promoted the CO_2 gasification and preferred to partial oxidation of carbon to enhance the CO production [17].

- *RH:SS=3:7*

The gas compositions for the gasification of RH and SS with different ratios and different temperatures were the presented in Fig. 9. It obviously showed that the CO content was increased and CO_2 content was decreased with the increase of temperature. High temperature encouraged the gasification of CO2 and preferred partial carbon oxidation to increase the generation of CO [17].

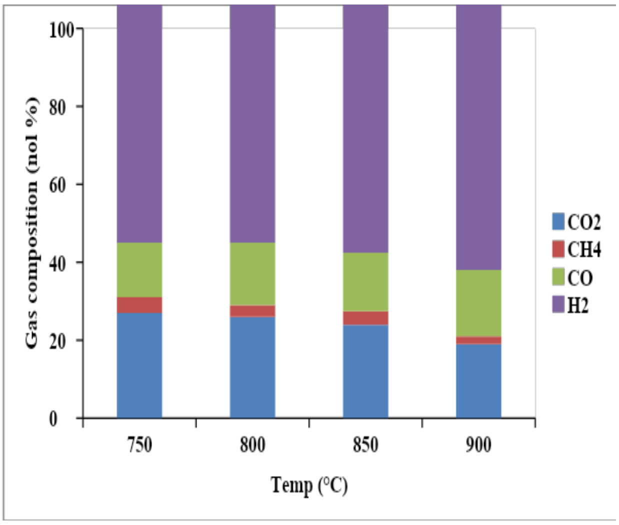

Fig 9 Gas Compositions for the Steam Co-Gasification of (d) RH:SS=3:7, at different Temperatures

- *SS at Different Temperatures:*

The gas compositions for the gasification of RH and SS with different ratios and different temperatures were presented in Fig. 10. It obviously showed that the CO content was increased and CO_2 content was decreased with the increase of temperature.

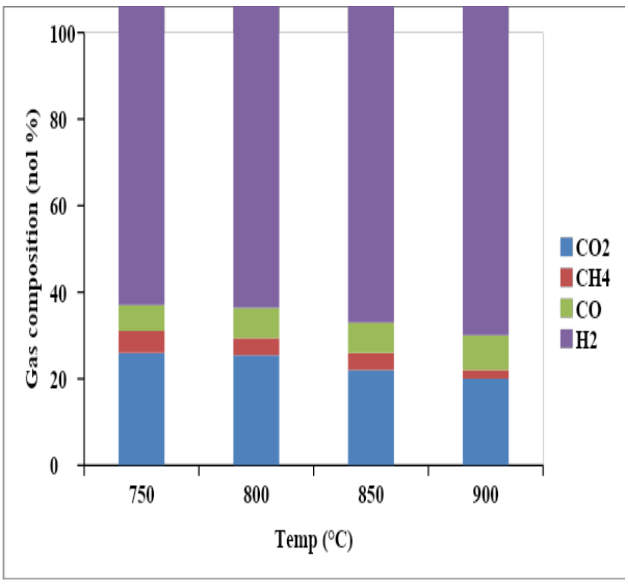

Fig 10 Gas Compositions for the Steam Co-Gasification of SS at different Temperatures

In detail, when gasification temperature increased from 750 to 900 °C, the CO content was increased from 7.77 to 18.53 vol% and CO_2 content was reduced from 26.93 to 17.58 vol% for SS. High temperature promoted the CO_2 gasification and preferred to partial oxidation of carbon to enhance the CO production [17].

IV. CONCLUSION

Steam co-gasification of RH and SS in different mass ratios and different temperatures was investigated to explain the product distribution, and synergistic analysis of the gasification results.

- Findings indicated that the H_2 content increased and the syngas production dropped as the SS ratio in blends increased. Due to the reduction and steam oxidation of Fe species in SS during the co-gasification process, the synergistic interaction was more important at higher temperatures, which encouraged the H_2 production.
- At SS ratio=0.80 and temperature of 900°C, the highest effective gas content (82.92 vol%) and highest HHV (11.40 MJ/m^3) were optimised.
- It suggests that steam co-gasification of RH and SS is a method that has potential for producing the needed syngas for a safe and effective waste management procedure.

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