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Operation of the TAMU Fluidized Bed Gasifier Using Different Biomass Feedstock

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Abstract. *The fluidized bed gasifier (FBG) developed at the Texas A&M University, College Station, Texas was tested using poultry litter, wood chips and cotton gin trash (CGT) as feedstock. The FBG has a diameter of 305 mm and operates at a temperature approximately 760°C (1400°F) and a feeding rate about 70 kg/hr. The synthesis gas produced was analyzed. Preliminary tests showed that the gas quality is lower than the previous runs due to a decrease in hydrogen production.*

This initial evaluation suggests that further testing of the gasifier should be made to optimize the operating conditions and be able to produce the expected gasification products. It is also proposed to do additional tests using other available feedstock such as high biomass sorghum and switchgrass.

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Keywords. Fluidized bed gasifier, poultry litter, woodchips, cotton gin trash

Introduction

Current sources of energy are obtained primarily from fossil fuels. These fuels are stable chemical compounds which can release or absorb thermal energy and produce heat and mechanical power. However, they are nonrenewable and as the demand for energy keeps on rising, their supply will become a problem. Biomass, like fossil fuels, contains high percentages of carbon and hydrogen and can be a good alternative source of energy (LePori and Soltes, 1981). Even though raw biomass has significantly less energy content than petroleum, it has certain advantages compared to fossil fuels because it is renewable and with enormous reserves.

Gasification is one of the thermo-chemical processes that can convert biomass into a useful product known as producer gas or syngas (synthesis gas). Without complete combustion of the fuel, conversion occurs in an oxygen deficient (partial oxidation) at high temperatures. The partial oxidation process of the biomass takes place at temperatures of about 800°C (1400°F) and produces primarily combustible gases (synthesis gases) consisting of carbon monoxide (CO), hydrogen (H_2) and traces of methane and some other products like tar and char (Rajvanshi, 1986).

Fluidized bed is one technology that offers several unique and versatile characteristics for biomass gasification. The turbulent, fluidized state of inert particles in the bed creates a near isothermal zone and enables accurate control of reaction temperatures. Thermal energy stored in large mass of inert particles is rapidly transferred to solid fuel at stable temperatures. Violent agitation of solids provides efficient conversion reactions and allows introduction of fuels having wide variations in composition and particle size (LePori and Soltes, 1981).

This study made an evaluation of the operation of the fluidized bed gasifier developed at Texas A&M University at College Station, Texas. The study used poultry litter, wood chips and cotton gin trash as the feedstock.   The main objectives of the study include the following: a) evaluate the performance of the FBG using different feedstock, b) describe operation parameters such as temperature and fluidizing pressures and c) evaluate gas quality.

Materials and Methods

The TAMU Fluidized Bed Gasifier

The gasification system used was developed by the Texas A&M University at College Station, Texas and is protected under US Patent No. 4848249. It is a 305mm (1-ft) diameter skid-mounted fluidized bed gasifier with a rating of 70 kg/hr (2 ½ lbs/min). The needed instrumentation was installed to enable the automatic measurement of temperature and pressure in the gasifier during operation.

Figure 1 shows the schematic diagram of how the gasifier was instrumented. K-type thermocouples (Omega CAIN-14U) were installed to measure the temperature at four different locations in the gasifier. Differential pressure transducers (Omega PX274 and Dwyer 677) were put in place to determine the pressure inside the gasifier during operation. An Omega OM-320 data logger was likewise connected to continuously monitor the temperature and pressure profiles.

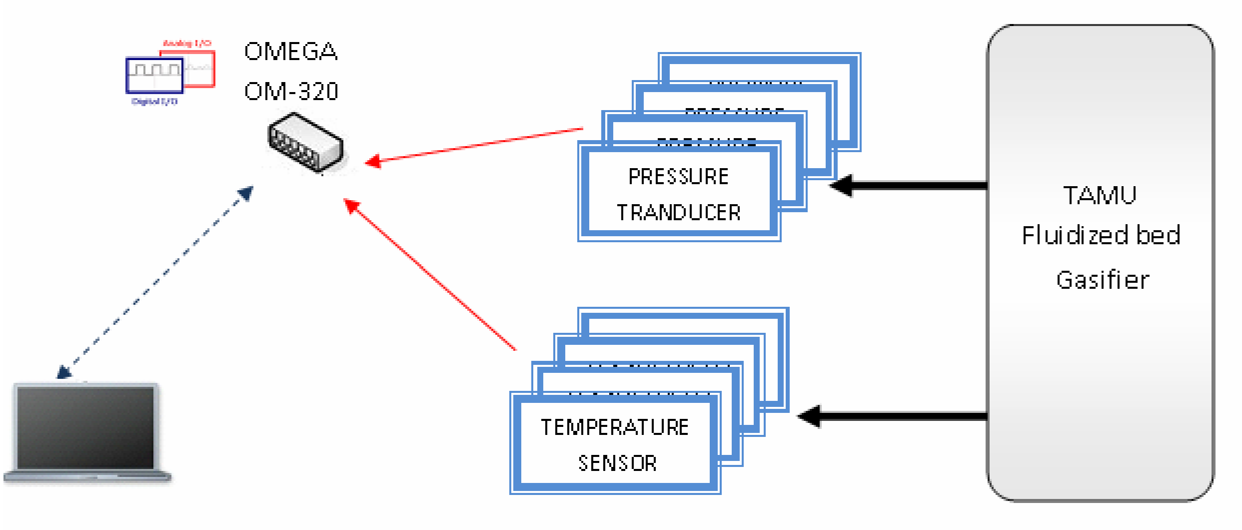

Figure 1. Schematic diagram showing the instrumentation of the gasifier

Feedstock Used

Wood chips and poultry litter were used as feedstock in this study. Preliminary trial runs using were also conducted using cotton gin trash. These feedstocks, particularly the poultry litter and cotton gin trash, have a high potential as energy source as they are very abundant. In the state of Texas, approximately 1.5 M dry tons of trash and 0.35 M tons of litter have been estimated (Bullock et al, 2008). Moreover, they can provide a net recoverable heat of about 6 M MMBtu/year and 0.6 M MMBtu/yr, respectively.

The proximate analysis and heating values of the different feedstock were obtained. The ash, fixed carbon (FC) and volatile matter (VM) contents were analyzed using a thermogravimetric method according to ASTM standards (E 1755 and E 3175). The heating value was measured from the combustion of the biomass using a Parr 6200 bomb calorimeter. (HHV) is a measure of biomass energy per mass or volume of manure results from combustion of biomass using a calorimeter (Mukhtar and Capareda, 2006). The proximate analysis gives a good initial indicator of biomass quality, while a high heating value (HHV) provides a measure of biomass energy per mass or volume of manure. In addition, char produced from the 1st and 2nd cyclone was also determined from the proximate analysis and heating values of the feedstock.

Operation of the Gasifier

For each run of the gasifier, pre-weighed buckets of woodchips, dried poultry litter or CGT were used. The buckets were fed into the gasifier in a timely manner (Figure 3). The bed of the gasifier was fluidized and preheated using an air compressor and natural gas burner, respectively. The gasifier was run for 60 and 120 minutes for the poultry litter and woodchips, respectively.

The pressure was measured at different locations within the system to determine the operating parameters. The pressure at the bed base and upper base of the fluidized-bed gasifier and the pressure drop across the laminar flow element (Meriam LFE 50MC2-2) were determined. The pressure drop across the laminar flow element was used to measure primary air entering the gasifier.

The temperature inside the gasifier was measured at different locations during operation. It was measured at points T1, T2, T3, and T4. The temperature at T1 was measured just below the bed base where the air enters, while the temperatures at T2, T3 and T4 were obtained at about 15.24 cm (6 in), 25.4 cm (10 in) and 66.04 cm (26 in) from the bed base, respectively.

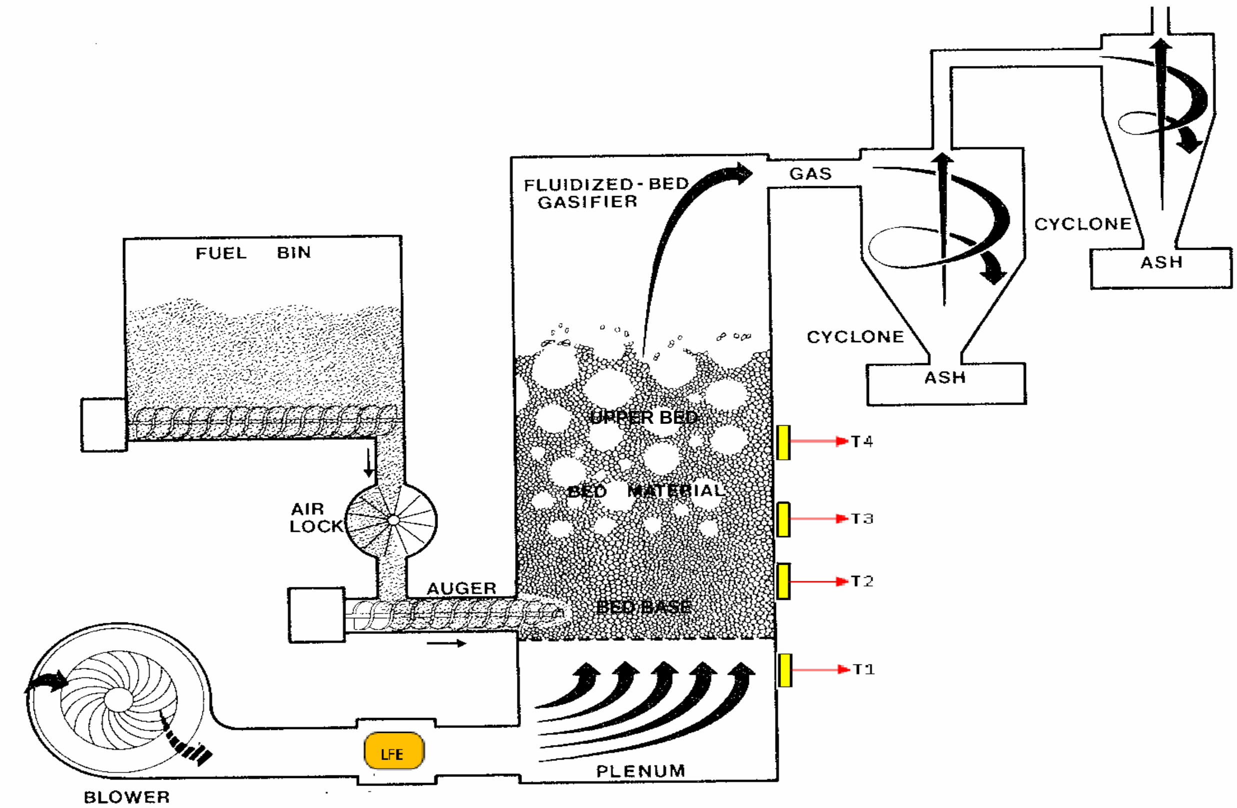

Figure 3. Operation of the fluidized bed gasifier (LePori, 1981)

Gas samples were taken after the 2nd cyclone. A gas analyzer (DeJaye DJCH4/C2H6) was installed and used to measure the partial composition of the synthesis gas during the operation. Gas samples were collected from 1 liter Tedlar bag and to be used for future analysis. Further analysis of the gas composition was done using a gas chromatograph (SRI Model 310).

In addition to the measurement of the pressure and temperature in the gasifier during operation as well as the analysis of the gas produced, the char generated in the 1st and 2nd cyclones was likewise determined. The same procedure for the proximate analysis and heating value measurement of the feedstock samples was followed.

Results and Discussion

Biomass Properties

The proximate analysis showed that woodchips had the highest content of fixed carbon and volatile matter while generating the lowest ash residue among the three feedstock analyzed (Table 1). Cotton gin trash had the second highest values of fixed carbon and volatile matter while poultry litter had the lowest. However, poultry litter had the highest ash content, followed by the cotton gin trash. In terms of heating value, woodchips also exhibited the highest, followed by cotton gin trash, then by poultry litter. This indicates that approximately 18,000 MJ of biomass energy can be produced from 1 metric ton of woodchips, with only 18 kg of ash generated. These data somehow indicate that woodchips would be a better feedstock in terms of proximate analysis and heating value. Almost similar values and trends were observed in cotton gin trash, poultry waste, and woodchips as shown by Jenkins and Ebeling (1985), Priyadarsan (undated), and Jenkins (1980), respectively.

Table 1. Proximate Analysis and high heating value of the feedstock used

	Proximate Analysis			HHV(db)
Biomass	%ASH(db)	%VCM(db)	%FC(db)	MJ/kg
Poultry litter	39.74 ± 0.98	55.20 ± 2.15	5.06 ± 1.48	10.2391 ± 0.6797
Woodchips	1.80 ± 0.89	85.44 ± 0.19	12.76 ± 0.58	17.8588 ± 0.5839
Cotton gin trash	12.87 ± 0.46	76.94 ± 0.80	10.18 ± 0.57	13.5159 ± 0.7775

Pressure Profile in the Gasifier

Figure 4 shows the pressure profile of the fluidized bed gasifier during operation using poultry litter. The pressure at the laminar flow element had an average of 5 in of water. This pressure at LFE is equivalent to an airflow of 65 cfm. The bed base and upper bed has an average value of 26 and 7 in of water, respectively. These results satisfy the operating parameters for the gasifier. The difference in pressure between the bed base and upper bed of the gasifier (Delta P bed) had an average value of 17 in of water and the varying values signify that the gasifier bed was fluidizing.

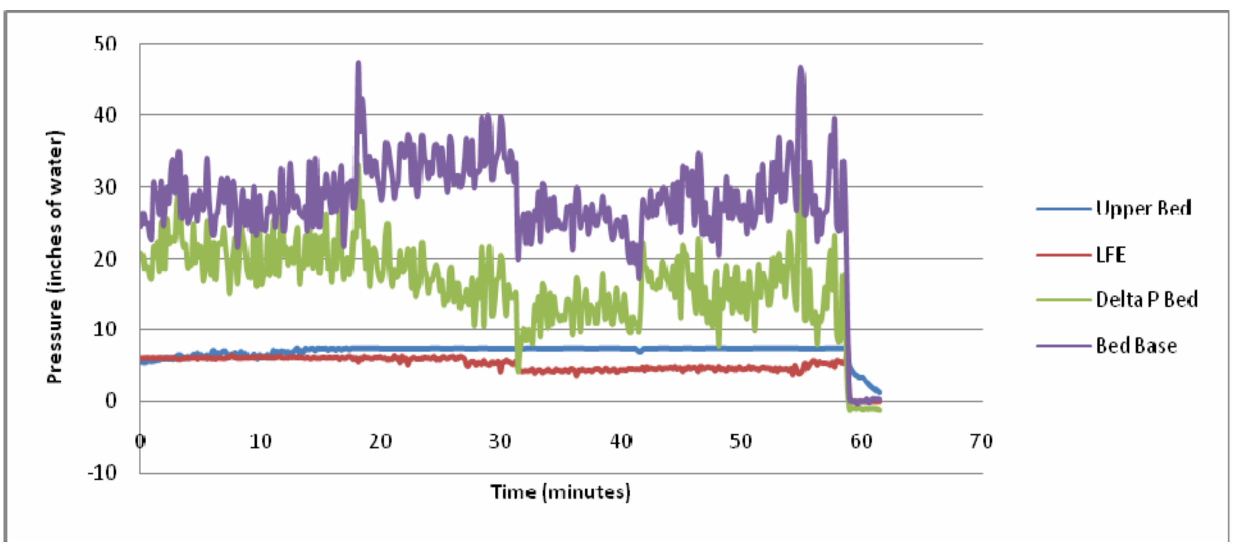

Figure 4. Pressure profile of the gasifier using poultry litter

The pressure profile in the gasifier using wood chips is shown in Figure 5. An average of 4 in of water pressure in LFE indicates a 52 cfm air flow. The upper bed and bed base were within operating conditions having an average value of 27 and 6 in of water, respectively.

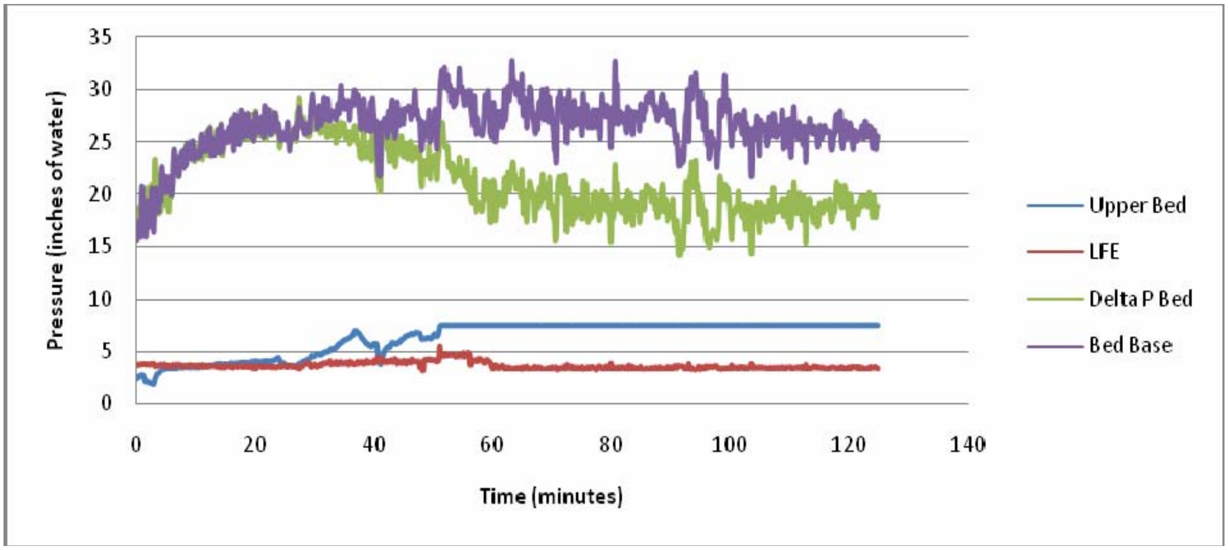

Figure 5. Pressure profile of the gasifier using woodchips

Temperature Profile in the Gasifier

Figure 6 shows the temperature profile in the gasifier using poultry litter as feedstock. As shown, the gasifier took 25 minutes to reach the operating temperature of about 760°C (1400°F). As observed, there was no increase in temperature at location T1, while a similar pattern of increase was observed in locations T2, T3 and T4.

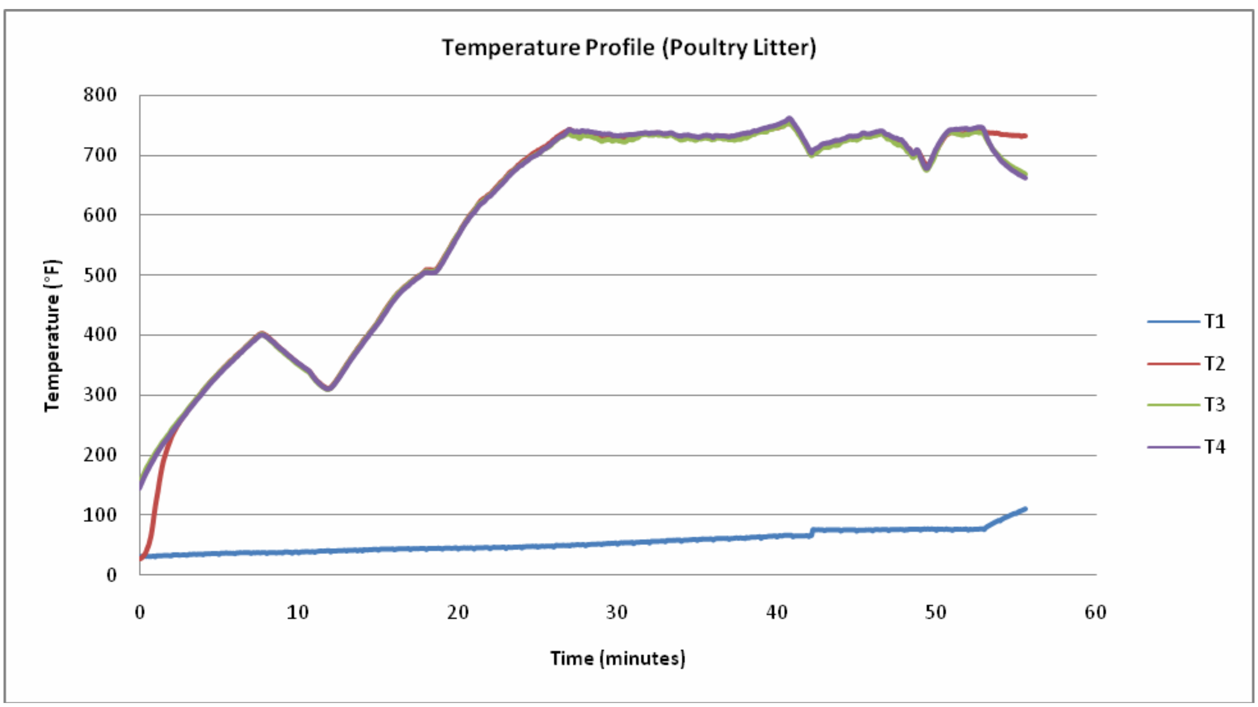

Figure 6. Temperature profile in the gasifier using poultry litter

During operation, the temperature was relatively maintained at locations T2, T3 and T4. This indicates that the turbulent, fluidized state of inert particles in the bed creates a near isothermal zone enabling an accurate control of reaction temperatures. The thermal energy stored in large mass of inert particles is rapidly transferred to solid fuel at stable temperatures.

The temperature profile in the gasifier using wood chips is shown in Figure 7. As seen in the figure, the startup time took about 50 minutes before attaining the desired temperature of 760°C (1400°F). The extended start-up time was mainly caused by the biomass build-up in the gasifier bed during the last run of the poultry litter. After attaining the desired temperature, a stable temperature of 700°C was observed during the entire operation.

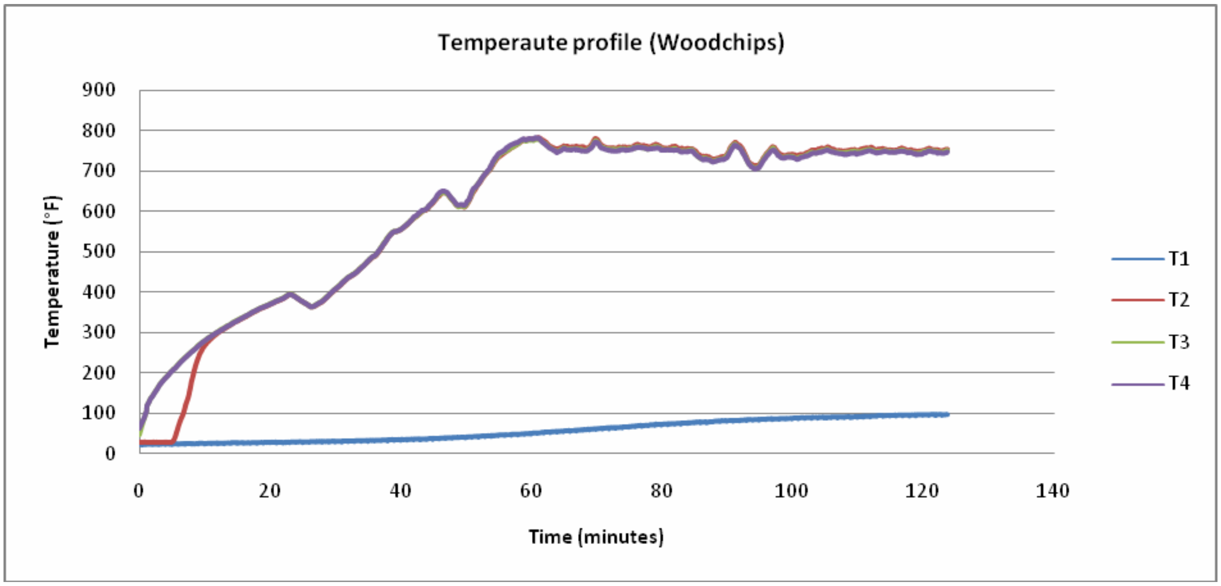

Figure 7. Temperature profile in the gasifier using woodchips

Generally, temperature profile for poultry litter and woodchips demonstrate similar trend during operation. Difference in the startup time was experienced due to the initial state of the bed. A near isothermal zone was also obtained using the different feedstock.

Composition of the Product Gas

The analysis of the synthesis gas showed a combination of products resulting from the gasification process. Figure 8 shows the average composition of the gaseous product using poultry litter as feedstock. A relatively higher percentage of nitrogen was measured while there was only a trace of ethane detected. The nitrogen concentration has an average value of 70.02% while there was only 0.15% of ethane. Hydrogen has an average of 1.92% and methane has an average of 3.97%. Other gases determined were oxygen at 6.83%, carbon dioxide at 9.09% and 8.01% of carbon monoxide and other undetermined gases.

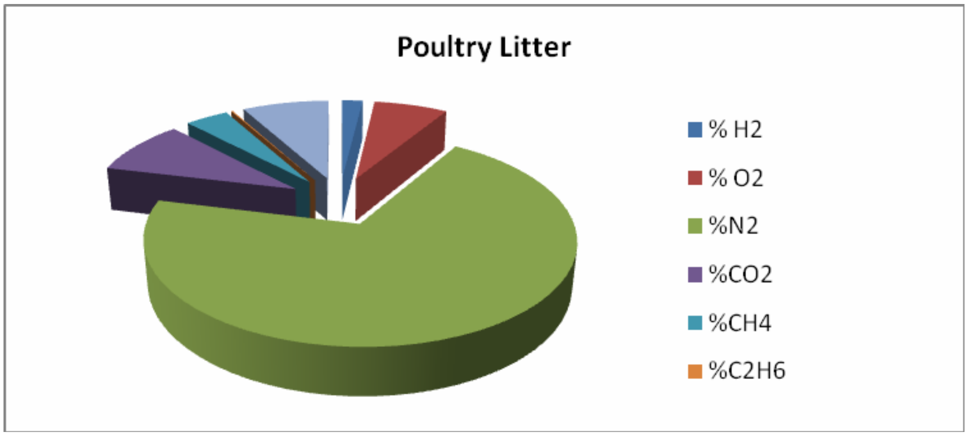

Figure 8. Product gas composition using poultry litter

Figure 9 shows the gas analysis using wood chips. Similar to the poultry litter, a relatively higher percentage of nitrogen was measured while there was only a trace of ethane detected. The nitrogen concentration has an average value of 65.29% while there was only 0.35% of ethane. Hydrogen has an average concentration of 2.20% while methane has an average of 2.36%. Other gases measured were oxygen at 16.70%, carbon dioxide at 7.11%, and 5.99% of carbon monoxide and other undetermined gases.

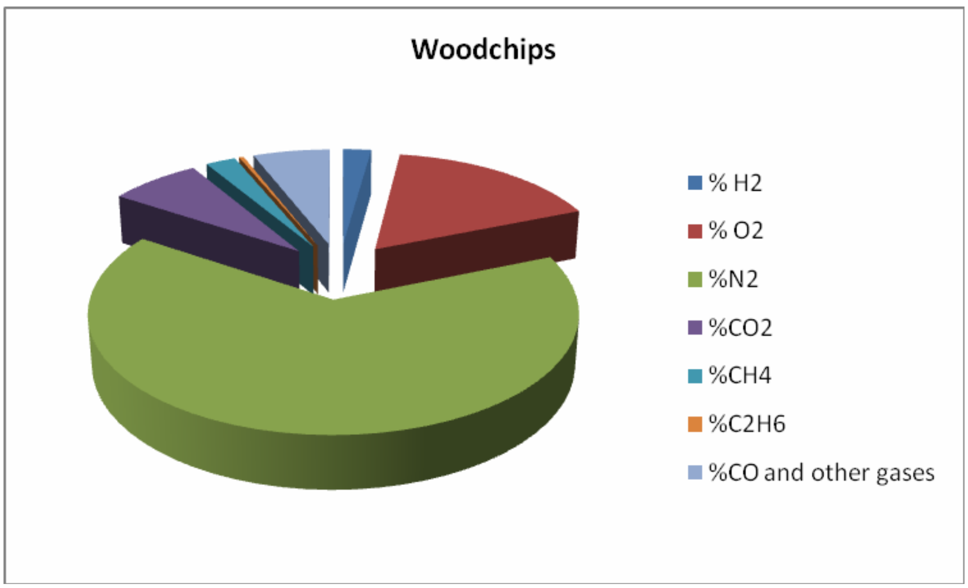

Figure 9. Product gas composition using woodchips

As observed, synthesis gas produced using poultry litter and woodchips did not generate the expected value of for hydrogen which should be around 4 – 8%. This could primarily be due to the operation of the gasifier which should be further optimized. Nevertheless, this initial study showed that the upgraded fluidized bed gasifier is operational and working.

Char Residue in the Cyclones

The analysis of the char deposited in the 1st and 2nd cyclones is shown in Table 2. It is a little bit surprising that a large percentage of the bed materials were determined in the char residue. This however decreased by almost a half from the 1st to the 2nd cyclone. Similar to the analysis of the feedstock samples, wood chips had lower ash content and higher heating value than poultry litter. The char in the 2nd cyclone also had a higher heating value than that in the 1st cyclone.

Table 2. Analysis of the char deposited in the cyclones

Biomass	% Bed Material	%ASH(db)	%VCM(db)	%FC(db)	HHV(db)MJ/kg
Char (1st cyclone)					
Poultry litter	53.21 ± 2.01	36.01 ± 2.64	11.45 ± 0.45	-0.67 ± 1.31	1.26 ± 0.38
Woodchips	56.35 ± 8.32	19.41 ± 5.50	10.15 ± 3.51	14.08 ± 2.21	4.06 ± 1.29
Char (2nd cyclone)					
Poultry litter	29.49 ± 2.80	46.31 ± 7.43	21.77 ± 1.22	2.43 ± 5.06	2.76 ± 0.11
Woodchips	25.74 ± 0.88	19.33 ± 0.34	14.81 ± 1.63	40.13 ± 2.12	11.50 ± 0.40

Conclusion

The operation of the fluidized bed gasifier developed at the Texas A&M University, College Station, Texas was tested using poultry litter, woodchips and cotton gin trash as feedstock. The pressure and temperature in the gasifier were monitored and the composition of the gas produced was analyzed during operation. The char residue in the 1st and 2nd cyclones was likewise analyzed.

The pressure in the gasifier indicates that the operating parameters for the gasifier were satisfied and that the bed was fluidizing. It needed a start up time of 25 and 50 minutes to reach to reach the operating temperature of about 760°C (1400°F) using poultry litter and wood chips, respectively. After this start up time, a near isothermal zone and a good control of reaction temperatures were obtained.

A relatively higher percentage of nitrogen and only a trace of ethane were measured in both poultry litter and wood chips. Other gases measured include hydrogen, methane, oxygen, carbon dioxide and carbon monoxide. The synthesis gas produced did not generate the expected value for hydrogen which should be around 4 – 8%. The operation of the gasifier should be further optimized. Nevertheless, this initial study showed that the upgraded skid mounted fluidized bed gasifier is operational and working.

This initial evaluation suggests that further testing of the gasifier should be done to optimize the operating conditions and be able to produce the expected gasification products. It is also proposed to do additional tests using other available feedstock such as the cotton gin trash.

Acknowledgement

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