International Journal of Information, Engineering & Technology

Volume 10, Issues 3, PP 1-9, ISSN: 2360-9194, July, 2019
Double Blind Peer Reviewed International Research Journal
garcjournalssubmit@gmail.com
Journal Series: Global Academic Research Consortium (garc)

Performance Evaluation of Downdraft Gasifier Using Two Agri-Waste in Semi-Arid Region of Maiduguri, Nigeria

[1]Abubakar A.B., [2]Bunu M. [3]Modu M. Tijjani and [3]Sadiq A. Goni
[1]Department of Mechanical Engineering, Ramat Polytechnic Maiduguri P.M.B 1070, Borno State, Nigeria
[2]Department of Agricultural Engineering Technology, Ramat Polytechnic Maiduguri P.M.B 1070, Borno State, Nigeria
[3]Department of Electrical and Electronic Engineering, Ramat Polytechnic Maiduguri P.M.B 1070, Borno State, Nigeria

Abstract: *Biomass is the oldest source of energy and currently accounts for approximately 10% of primary energy consumption. The study was aimed to evaluate the performance of the existing electrical gasifier to identify the most effective moisture level with different sieve sizes of sawdust and bagasse on the gas production. The experimental factors considered in this studies were moisture content and sieve size each at four level, the moisture content level selected were namely ; (0%, 15%, 20% and 25%); while the sieve sizes considered were namely; (1.18 mm, 25mm.36 mm, 3.35mm and 4.75 mm respectively. The sawdust and bagasse considered were introduced from the top and moves downward. Oxidizer (air) was introduced at the top and flows downward. The treatments were laid out in a complete randomized design (CBD) with two replications. The collected data were subjected into the analysis of variance (ANOVA) at P(≤ 0.05) and the results of the investigation revealed that 15 % moisture level at all sieve sizes used gave the highest gas production time, while 20% and 25% moisture level exhibited closer. And also, matrix correlation among the sieve sizes as affect by moisture content on gasification time at probability level of 0.05% established a very good relationship among the gasification time of all most averagely of 95% respectively.*

Key words: *Gasifier; Blower; Energy; Electrical Bagasse and Sawdust*

1.0 INTRODUCTION

The world is currently facing energy crises taken into account that fossil fuel which is a crucial source of primary energy are marine depletion and are largely responsible for environmental gradation (Adam *et al.,* 2015). According to a report by Abdurrahman et al, 2016 oil and natural gas resource could last for another 40-60 years, while coal which is estimated to last longer may be available for another 100 years. The growth in world population and the economic development anticipated in developing countries such as south Africa are exported to contribute greatly to the accumulation of greenhouse gases (GHGS) in the atmosphere and its consequences with a direct influence on the energy rivalry (Anthony *et al.*, 2016). Presently about 25% of biomass is used by developed countries so produce heat (Sahibo, 2013). Nigeria biomass energy resources is estimated to be 144 million tones/years (Diyoke et al 2014). Generally accepted definition of biomass are defined by the United Nation Framework climate change which emphasized that biomass is an non fossilized and biodegradable organic material originating from plants, animals and micro-organisms that also includes products, by products, residues and waste from agriculture, forestry and related industries (Diana, 2012). Biomass gasification of sugarcane baggsse and empty fruit Bunch. The effect of operating temperature and particle size on hydrogen production: faculty of chemical and natural resources engineering University Malaysia Pahang (Bhauram, 2012). Biomass is the organic material from recently living things including plant matter from trees, bagasse and agricultural crops the chemical composition of biomass varies among species, but basically consist of high, but variable moisture content, a fibrous structure consisting of lignin, carbohydrates or sugar and ash (Diana , 2012).

Therefore contrary to into smaller molecules. Therefore contrary to conventional thermo chemical process dying of much as 90% water could become as economically favorable to processes. Furthermore with the acid of his technologies hydrogen or methane can be generated at an elevated pressure, hence diminishing themed for pressurizing the final gas plant (Jingjing *et al*., 2001) and likewise in large quantity. Such abundant feed stock are wood waste (including wood sawdust), and rice husk are some of abundant biomass resources in Nigeria. The total amount of waste wood generated in Nigeria was put at 32.45 million tons of these waste comes from the activities of sawdust alone (Rezaiyan *et al*., 2005). Ever increasing consumption of fossil fuels and rapid depletion of known reserve are matters of serious concern in the world. The utilization of renewable energy sources is an effective approach towards alleviating these constrains. All over the world, the discharge of the agricultural and forest wastes namely causing serious environmental problems. This agricultural and forest waste however has a significant clarified value and a high percentage of amorphous silica which limits its use as criminal feeds and mostly lift to rot or decay in the environment creating hazardous effort to both human and animal health. Therefore, there is need for investigating the moisture content level with different sieve sizes of agricultural waste selected namely; bagasse and sawdust as well as to ascertain the gasification period of the gasifier.

2.1 Historical Background and Current Status of Gasification Technology

Gasification was discovered independently in both England and France in 1798, and through 1850 technology had been developed to the point that it was possible to light much of London with manufactured gas or "down gas" from coal and manufactured gas soon crossed the Atlantic to the United State and through 1920, most American cities and downs supplied gas to the residents for lighting and cooking through the local "gas works" (Doherty *et al*, 2008).

2.2 Biomass

A generally accepted definition of biomass are defined by the United Nation Framework climate change which emphasized that biomass is an non fossilized and biodegradable organic material originating from plants, animals and micro-organisms that also includes products, by products, residues and waste from agriculture, forestry and related industries (Diana, 2012).

(a)Biomass as a Fuel

Biomass simply refers to organic materials originated from plants (wood, crops etc.) and animal wastes. Different biomass conversion processes produce heat, electricity and fuels. Among all biomass conversion processes, gasification is one of the most promising (Mavukwana, et *al*, 2013).

(b)Component of Biomass

Cellulose, hemicelluloses, lignin and extraeskes are found to be the main compkonents of biomas. Cellulose and hemicelluloses are formed by long chains of carbohydrates (such as glucose, whereas lignin is a polymeric lignin has a close relationship with hemicelluloses as it exist as a glue fixing the bunches of cellulose chains and plant tissues together. This is gives mechanical strength to the plant. Lignin is rich in carbon and hydrogen, which are the main heart producing element. Hence lignin has a higher heating value than carbohydrates (Diyoko, *et al*., 2012).

2.3.1Gasification Process

While biomass gasification is the conversion of an organically derived, carbonaceous feedback by partial oxidation into a gaseous product, synthesis gas or "syngas", consisting primary of hydrogen (H2) and carbon monoxide (Co), with lesser amount of carbon dioxide (Co_2), water (H_20) methane (CH4), higher hydrocarbons (C_2+), and nitrogen (N_2) (Diana, 2012).

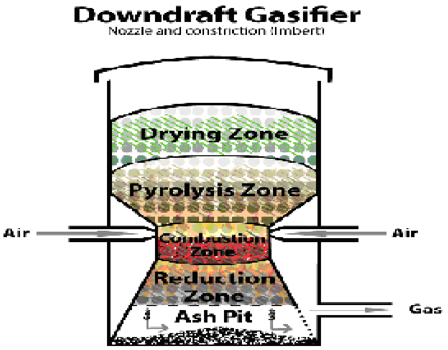
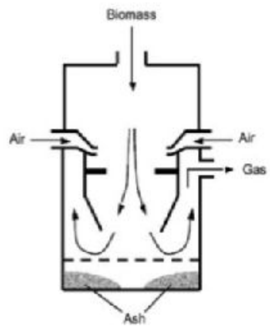
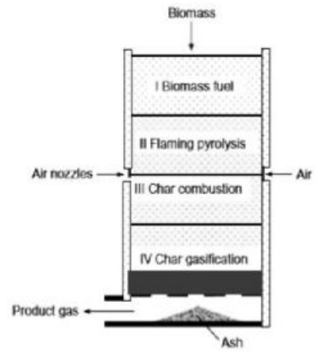
2.3 Drying

In this stage, the moisture content of the biomass is reduced and occurs at about 100 – 200^0C with a reduction in the moisture content of biomass of less than 5% (Jamilu, 2016) Resulting water vapour together with water vapour formed at combustion zone partly lead to production of hydrogen and remaining is going with producer gas (Ramzan, *et al*, 2011).

2.3 Pyrolysis (Devolatilization)

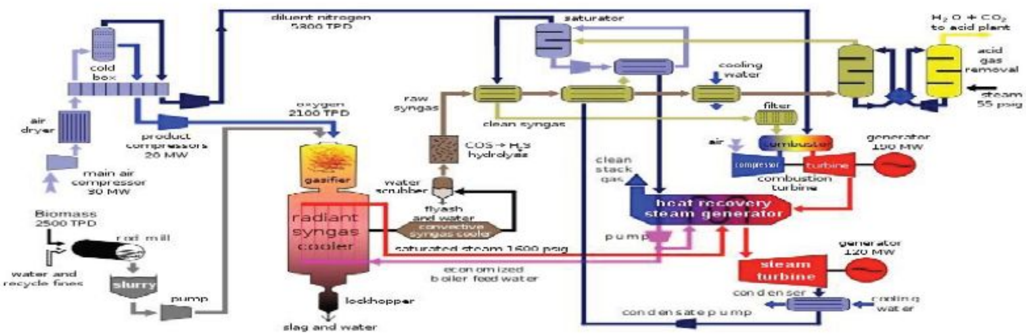
Pyrolysis is the use of heat (Pyro) so break down carbon based materials (lysis) without oxygen (Jamilu, 2016). Devolatilization occurs at temperatures up to about 700^0C and release light permanent gases (such as H_2, CO, CO_2, CH_4, H_2O, HN_3), for which is the condensable hydrocarbon vapours and the remaining devolatilized solid waste residue known as char (Arena, 2012).

2.4 Classification of downdraft gasifier

<table>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>Figure 1:Down draft gasifier source (Sanjay, 2015)</td>
<td>Figure 2: Imbert downdraft Gasifier Source (Emun et al, 2010).</td>
<td>Figure 3: Stratified Downdraft Gasification Design Source: (Jamilu, 2016)</td>
</tr>
</table>

2.5 Operation principle of the downdraft gasifier

The sawdust and bagasse used as biomass were introduced from the top and moves downward. Oxidizer (air) was introduced at the top and flows downward. Syngas was extracted at the bottom at grade level as shown in figure 4 below



Source: en.wikipedia.org

Source: en-wikipedia.org

3.0 Material and Methods

3.1 Site Description

The study was carried out in the Entrepreneur Centre of the University of Maiduguri. Maiduguri is the capital of Borno State. It lies between latitudes 11° 45`N and 11° 51`N, Longitudes 13° 2`E and 13° 9`E and 345m above mean sea level with a mean annual rainfall of about 625mm and annual temperature of 28-32°C Adeniji *et al* (2013). The climate of Maiduguri is generally semi-arid with moderate variation in temperatures; the mean monthly minimum temperature is lowest (13.5°C) during the period of strongest and most constant north east winds (Harmattan) in December and January; and highest (24.7°C) in April (Adeniji *et al*., 2013) The mean monthly maximum temperature is highest (40.2°C) prior to and during the onset of the rains in April and the lowest (31.3°C) during the peak rainy period of August.

3.2 Treatment and Experimental Design

The experimental factors considered in this studies were moisture content and sieve size each at four level, the moisture content level selected were namely ; (0%, 15%, 20% and 25%); while the sieve sizes considered were namely (1.18 mm, 25mm.36 mm, 3.35mm and 4.75 mm) were tasted on the two agricultural waste sawdust and bagasse..The treatments were laid out in a complete randomized design (CBD) with two replications.

3. 3 Feed stock preparation

The sawdust was collected from Baga road wood market, while the bagasse was also collected from Bulumkuttu market Maiduguri, Borno State. The performance evaluation of the adopted gasifier was carried out at the center of entrepreneurship development university of Maiduguri. Initially dried raw agricultural waste sawdust and bagasse were sieved into different particle sizes such as 1.18mm, 2.36mm, 3.35mm and 4.75mm respectively. And a speed of 3203 rpm was used for the blower. The moisture content of the agricultural waste were raise to 15%, 20% and 25% and considered the dried portion as control (0%)

3.4 Results and Discussion

The experimented results on the effect of different moisture content levels (0%, 15%, 20% and 25%) with sieve sizes (1.18mm, 2.36mm, 3.35mm and 4.75 mm) of sawdust and bagasse biomass gasification were presented in following table below.

Table 1: Effect of Moisture content level on gasification time for Sawdust and Bagasse biomass at 1.18mmsieve size

Treatment	Sawdust	Bagasse
Moisture (%)	**Gasification Time in (sec)**	
0	1278	1206
15	680	624
20	553	138
25	450	133
SE±	0.32	0.45

As illustrated in the Table 1, the effect of moisture levels and sieve size (1.18 mm) considered on the two agricultural waste were significantly p≤ 0.05 influenced the time taken for gasification to occur. The highest time of (680 sec and 624 sec) taken for the gasification for both waste were observed at 15% moisture level, which was closely followed by 20% moisture level with corresponding gasification period of (553 sec and 138 sec) respectively. While the shortest period for the gasification was remarkably recorded at 25% moisture level. The findings was similar to those obtained by Senthil et al 2016. However, the fluctuation in the gasification period at the control that is (0%) could be attributed to the climatic condition since the experimentation was carried out in an open environment.

Table 2: Effect of Moisture Content Level on the Gasification time for Sawdust and Bagasse biomass at 2.36mm sieve size

Treatment	Sawdust	Bagasse
Moisture (%)	**Gasification Time in (sec)**	
0	1989	1573
15	610	513
20	324	370
25	125.	241
SE±	0.86	0.76

As presented in Table2, the variation in moisture levels used for sawdust and bagasse at (2.36 mm) sieve size were significantly≤ 0.05 affected the gasification period. The longest duration taken for the gasification (610 sec and 513 sec) for the sawdust and bagasse used were observed at 15% moisture level. It was closely followed by 20% with gasification period of 324 sec and 370 sec respectively, while the least gasification period occurred at (25%) moisture level. The finding is in agreement with (Joseph *et al.,* 2016). Though, the fluctuation in the gasification period at the control (0%) could be attributed to the climatic condition since the experimentation was carried out in an open environment.

Table 3: Effect of Moisture content level on combustion time of Sawdust and Bagasse at sieve size 3.35 mm

Treatment	Sawdust	Bagasse
Moisture (%)	**Gasification Time in (sec)**	
0	1200	1440
15	729	610
20	534	489
25	313	367
SE±	0.66	0.16

The different moisture content levels and sieve size used as treatment were significantly ($p \leq 0.05$) affected the duration for the gas production period as shown in Table 3. The maximum gasification period of (729 sec and 610 sec) for both agricultural waste were observed at 15% moisture level, whereas 20% moisture level exhibited closer gasification period of (534 sec and 489 sec) respectively. And also, the minimum gasification period of 313 sec and 367 sec occurred at 25% moisture level. Similarly, (Abubakar *et al.*, 2016) reported an increase in moisture level could be attributed to the reduction in gas production period. However, the fluctuation in the gasification period at the control that is (0%) could be attributed to the climatic condition since the experimentation was carried out in an open environment.

Table 4: Effect of Moisture content level on combustion time of Sawdust and Bagasse at sieve size 4.75mm

Treatment	Sawdust	Bagasse
Moisture (%)	**Gasification Time in (sec)**	
0	1464	972
15	635	902
20	439	663
25	310	489
SE±	0.14	0.36

As demonstrated in the Table 4, the treatment used for sawdust and bagasse wastes at 4.75mm sieve size were affected by the variation in moisture content level. The highest gasification period of (635 sec and 902 sec) were observed at 15% moisture level, conversely followed by 20% moisture content level with corresponding gasification period of (439 sec and 663 sec) respectively. While the shortest period for the gasification was remarkably recorded at 25% moisture level. The findings was similar to those obtained by (Wilson *et al*., 2008).Also, the analysis of variance revealed that there is a significance difference between the means of the gasification period exhibited by the two agricultural waste as shown table 4.8. It seem the fluctuation in the gasification period at the control that is (0%) could be attributed to the climatic condition since the experimentation was carried out in an open environment. For more detail see figure 5.

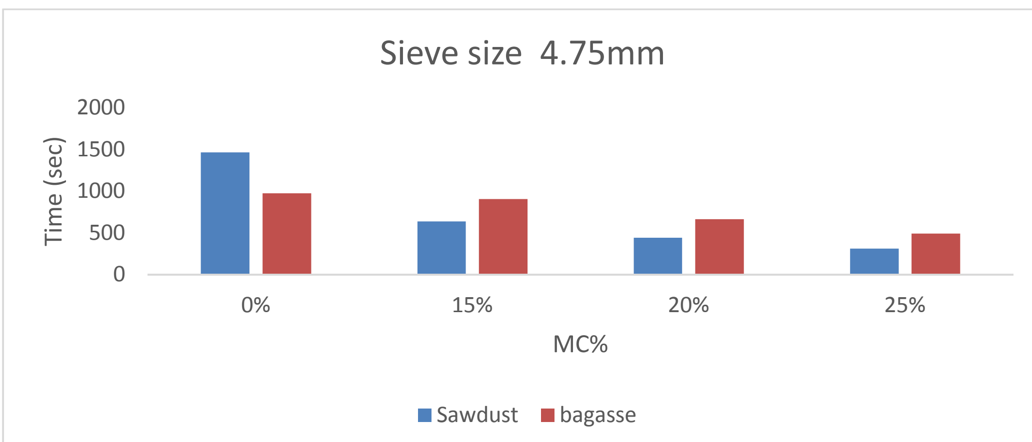


Figure 5: showing gasification occurrence time versus moisture level

Table 5: Matrix Correlation Coefficients among the Sieve Sizes (mm) as affect by Moisture Content for both Agri-Waste on gasification period of the gasifier

	Sd 1.18mm	*Sd 2.36mm*	*Sd 3.35mm*	*Sd 4.75mm*	*Bd 1.18mm*	*Bd 2.36mm*	*Bd 3.35mm*	*Bd 4.75mm*
Sd 1.18mm	1							
Sd 2.36mm	0.99	1						
Sd 3.35mm	0.877	0.973	1					
Sd 4.75mm	0.919	0.929	0.977	1				
Bg 1.18mm	0.963	0.964	0.969	0.969	1			
Bg 2.36mm	0.974	0.98	0.959	0.996	0.949	1		
Bg 3.35mm	0.984	0.974	0.966	0.998	0.953	0.979	1	
Bg 4.75mm	0.819	0.808	0.918	0.821	0.891	0.774	0.788	1

Sd = sawdsust and Bd= Bagasse

As presented in Table, the matrix correlation among the sieve sizes as affect by moisture content on gasification time at a confident level of 0.05% established a very good relationship of all most averagely of 95% respectively

3.5: Conclusion

The study was aimed to evaluate the performance of the existing gasifier to identify the most effective moisture level with different sieve sizes of sawdust and bagasse on the gas production. The collected data were subjected to the analysis of variance (ANOVA) and the result were as follows:

(i) Results of this investigation showed that 25% moisture level at all sieve sizes used had a significant influence gas production time

(ii) The 15% moisture level exhibited closer to the 20% moisture level. It is therefore suggested 25% and 20% are the best among the others.

3.6: Recommendation

In view of the foregoing, it is recommended that, 25% and 20% could be used for production of gas with bagasse and sawdust in this region, in the event of non- availability of reliable energy source. It is recommended that further studies should be carried out on other agricultural waste using or adopting this approach with a view to re- validating the outcome of this research.

References

Adeniji F.A, B.G Umara, J.M Dibal, Amali A.A (2013) Variation of infiltration rate with Soil Texture. A laboratory study. *International Journal of Engineering and Innovative Technology* 3: (2) pp: 454-459

Abubakar A.B, (2014) performance evaluation of a downdraft gasifier using saw dust and baggase addictive (unpublished).

Abubakar A.B, Oumaru M.B and Oluwale F.A. (2017) Design and development of a blower for Downdraft Biomass Gsifier, APLD non Thesis seminar of the Department of Mechanical Engineering University of Maiduguri.

Adam R, W, R, mezzul, W.G, and Mc manus, (2015). Biomass sustainability criteria: greenhouse gas accounting issues for biogas and biome thane facilities. pp (95 – 109).

Bhauram and sentry R.C (2012) Biomass Gasification process in dowdraft Fixed reactor; A review. 6. (2); 425-433.

Diyoko. C., Idogwu, S, and Ngwaka, U.C. 9 (2014) an economic an economic assessment of biomass gasification on for rural electsfication in Nigeria international *journal of renewable energy technology research* 1. (3)1.17

Diana A. L, (2012). Biomass gasification of sugar cane bagasse and empty fruit Bauchi of chemical and material resource engineering university Malaysia phalange.

Doherty, W.; Reynolds, A.; Kennedy, D. Simulation of a Circulating Fluidised Bed Biomass Gasifier Using Aspen Plus: A Performance Analysis. In Proceedings of the 21st International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, Crakow-Gliwice, Poland, 24–27 June 2008; pp. 1241–1248.

Emun, F., Gadalla, M., Majozi, T., and Boer, D. Integrated gasification combined cycle (IGCC) Process simulation and optimization. *Comput. Chem. Eng.* 2010, *34*, 331–338.

Jingjing, L., Xing, Z., DeLaquil, P., and Larson, E.D. Biomass energy in China and its potential. *Energy Sustain. Dev.* 2001, *5*, 66–80.

Kuo, P.C., Wu, W., and Chen, W.-H. Gasification performances of raw and terrified biomass in downdraft fixed bed gasifier using thermodynamic analysis. *Fuel* 2013, *117*, 1231–1241.

Mavukwana, A.; Jalama, K.; Ntuli, F.; Harding, K. Simulation of Sugarcane Bagasse Gasification Using Aspen Plus. In Proceedings of the International Conference on Chemical and Environmental Engineering (ICCEE), Johannesburg, South Africa, 15–16 April 2013; pp. 70–74.

Ramzan, N., Ashraf, A., Naveed, S., and Malik, A. Simulation of hybrid biomass gasification using Aspen plus: A comparative performance analysis for food, municipal solid and poultry waste. *Biomass Bioenergy* 2011, *35*, 3962–3969.

Rezaiyan, J.; Cheremisinoff, N.P. Gasification Technologies: A Primer for Engineers and Scientists; CRC Press: Boca Raton, FL, USA, 2005.

Wilson, L., Yang, W., Blasiak, W., John, G., and Mhilu, C. Thermal characterization of tropical biomass feedstocks. *Energy Convers. Manag.* 2011, *52*, 191–198. 16. Skoulou, V.; Zabaniotou, A.; Stavropoulos, G.; Sakelaropoulos, G. Syngas production from olive tree cuttings and olive kernels in a downdraft fixed-bed gasifier. *Int. J. Hydrog. Energy* 2008, *33*, 1185–1194.