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Development of a Gasifier for Effective Utilization of Rice Husk for Electric Power Generation

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Abstract: *Nigeria is purely an agrarian nation and the people depend on Agriculture for their survival. Agricultural waste has been proposed as an alternative energy resources to meet fossil fuel crisis. One of the missing links to wealth creation in Nigeria is lack of economic exploitation of abundant Agricultural wastes. Rice husk is a biomass waste readily available which is not used as animal feed due it high Silica contain causing irritation in the stomach and hence has become a serious threat to the environment when burnt or left rot in farms and along road sites. The sustainable use of this rice husk for bioenergy applications such as electricity generation at low cost and mitigate greenhouse gas emissions is imperative. The study was aimed to evaluate the Performance of downdraft gasifier using rice husk as feed stock for production of heat and power generation. The experimental factors considered in this studies were feed stock mass and particle size each at three level, the feedstock mass selected were namely; (1.0 kg, 1.5 kg, and 2.0 kg); while the particle sizes considered were namely (0.6mm, 1.86 mm and 2.36 mm) respectively, the treatments were laid out in a complete randomized design (CBD) with two replications. The collected data were subjected to the analysis of variance (ANOVA) and the results of the investigation revealed that, 2.0 kg mass at all particle sizes had a significant influenced and gave maximum temperature values of 104 ^oC, 467 ^oC and 1194 ^oC during the gasification processes, while 1.5 kg exhibited closer to the 2.0 kg mass than 1.0 kg. Similarly, as affected by particle size, rice husk at 2.36 mm produced the highest temperature during the gasification process than all other experiment. Similarly, regression R^2 analysis discovered strong degree of relationship of about 95% between the time and temperatures during the gasification. Based on the findings, a community could generate power using rice husk gasification system to meet their electricity demand in most economical way, thereby reducing emission, waste and saving cost which translates to sustainable development.*

Key words: *Feedstock; Particle size; Gasification; Rice husk; and Power*

1.0 Introduction

The bedrock of development of any nation is electricity. Access to electricity could transform the lives of people, communities and nations. Access to cheap, reliable, and sustainable energy is a precursor for attaining and sustaining socio economic development.

In fact, it is fundamental requirement for poverty reduction. Currently about 90% of the world primary energy consumption is from fossil (petroleum, gas and coal), (Melgara *et al.*, 2009). However, depleting of these fossil energy sources, the rate at which carbon dioxide (CO_2) is released into the atmosphere when they are burnt and increasing demand of the world energy due to population coupled with technological advancement are the current challenges. These challenges have served as motivation globally to develop alternative and renewable energy like biomass and solar that can help the present generation to meet their energy demand without jeopardizing the ability of the future generation to meet their energy demand. About 120 million tonnes of rice husks are generated annually in the world (Omatola and Onojah, 2012). In Nigeria about 2.0 million tonnes of rice is produced annually and 400 thousand tonnes of rice husk is generated out of it (Abalakar, 2012). These large quantities of biomass resources in Nigeria offer much potential for renewable energy and can play a significant role in meeting the country's energy demand if properly harnessed in modern and sustainable way. Direct combustion has been the major way of utilization of biomass in Nigeria especially in rural areas. Fuel wood is used by over 60% of Nigerians living in the rural areas. Nigeria consumes over 50 million metric tonnes of fuel wood annually with alarming rate of deforestation. The rate of deforestation is about 350,000 hectares per year, which is equivalence to 3.6% of the present area of forests and woodlands, whereas reforestation is only at about 10% of the deforestation rate (Sambo, 2009). Biomass is the oldest source of energy and currently accounts for approximately 10% of primary energy consumption. Many of the developing country has growth their interest in bio-fuel development and providing greater access to clear hinging fuel while helping to address the issue such as increase in the fuel price, energy security and global warning biomass traditionally available in the form of solid. Solid biomass includes crop resident, forest waste, animal waste, vegetable seeds municipal waste, food waste and plant and power by adopting appreciate method. Due to the increasing price and undesirable to environmental effects of fossil fuels, production of energy from renewable resources has gained much attention in recent years. Biomass is considered to be one of the most promising resource for the production of furthers fuels. In many cases because of large water content and high dying cost, biomass is not a suitable food stock for conventional thermo-chemical gasification technologies supercritical and hydrothermal gasification processes after attractive alternatives for the conversation of wet biomass to useful product into smaller molecules. 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 (Muh'd, 2014) and likewise in large quantity. Such abundant feed stock is 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 (Ohimain, 2012). Numerous researches have been done on rice husk to electricity generation in the literature. In order to provide evidence of the knowledge gap that justified the need of this work. Therefore, the current study employed the use of rice husk at different feedstock mass and particles sizes with a view to evaluate the performance of the gasifier on gas production and electricity power generation

2.0 Materials and Methods

2.1 Site Description

The study was carried out in the Entrepreneur Centre of the University of Maiduguri, 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 Abubakar et al (2019).

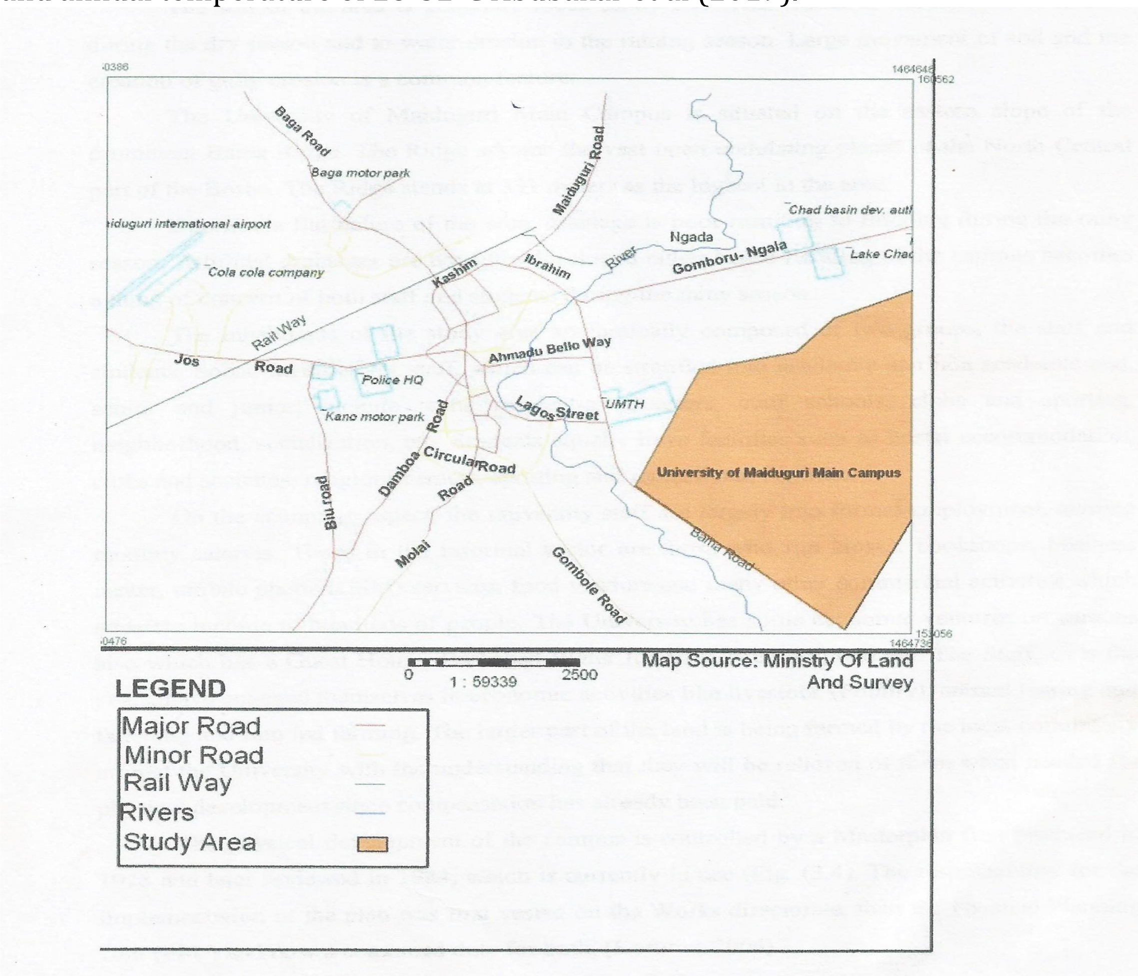


Figure 3.1 Maiduguri Road Map Showing the Study Area (Abubakar., *et al* 2019)

2.3 Treatment and Experimental Design

The experimental factors considered in this studies were feedstock mass (rice husk) and particle sizes each at three level, the feedstock mass level selected were namely; (1.0 kg, 1.5 kg, and 2.0 kg); while the particle sizes considered were namely (0.6mm, 1.86 mm and 2.36 mm) respectively. The treatments were laid out in a complete randomized design (CBD) with two replications.

2.4 Feed Sock Preparation

The rice husk was collected from mills along Baga road and Bulumkutu markets in Maiduguri, Borno State. The performance evaluation of the adopted gasifier was carried out at the center of entrepreneurship development university of Maiduguri. Initially the rice husk was sorted, cleaned and sun dried, followed by sieving to the required particle sizes using a sieve obtained from the Civil Engineering Department of Ramat Polytechnic. The feed stock was sieved into different particle sizes such as 1.18mm, 2.36mm, 3.35mm and 4.75mm respectively. The moisture content of the feedstock was conditioned to 10%, 15% and 20% and considered the dried portion as control (0%).

2.5 Properties of Rice Husk

Rice husk is a potential material, which is amenable for value addition. The usage of rice husk either in its raw form or in ash form is many. Most of the husk from the milling is either burnt or dumped as waste in open fields and a small amount is used as fuel for boilers, electricity generation, bulking agents for composting of animal manure, etc. (Bronzeoak, 2003; Asavapisit and Ruengrit, 2005). The exterior of rice husk is composed of dentate rectangular elements, which themselves are composed mostly of silica coated with a thick cuticle and surface hairs. The mid region and inner epidermis contain little silica (Bronzeoak, 2003). Similarly, Jauberthie *et al*., (2000) confirmed that the presence of amorphous silica is concentrated at the surfaces of the rice husk and not within the husk itself. The chemical composition of rice husk is similar to that of many common organic fibers and it contains of cellulose 40-50 percent, lignin 25-30 percent, ash 15-20 percent and moisture 8- 15 percent [Hwang and Chandra, 1997]. After burning, most evaporable components are slowly lost and the silicates are left. The typical properties of rice husk are indicated in Table 2.2. No other plant except paddy husk is able to retain such a huge proportion of silica in it.

2.6 Thermal Decomposition of Rice Husk

There are two distinct stages in the decomposition of rice husk - carbonization and decarbonation. Carbonization is the decomposition of volatile matter in rice husk at temperature greater than 300°C and releases combustible gas and tar. Decarbonation is the combustion of fixed carbon in the rice husk char at higher temperature in the presence of oxygen (Fig. 2.1) [Maeda et al., 2001]. The melting temperature of RHA is estimated as 1440°C, that is, the temperature at which silica melts (Bronzeoak, 2003). However, Production of rice gasification processes and power generation processes in (Fig 2.2 and Fig 2.3) was adopted as reported in (Abubakar *et al.,* 2019)

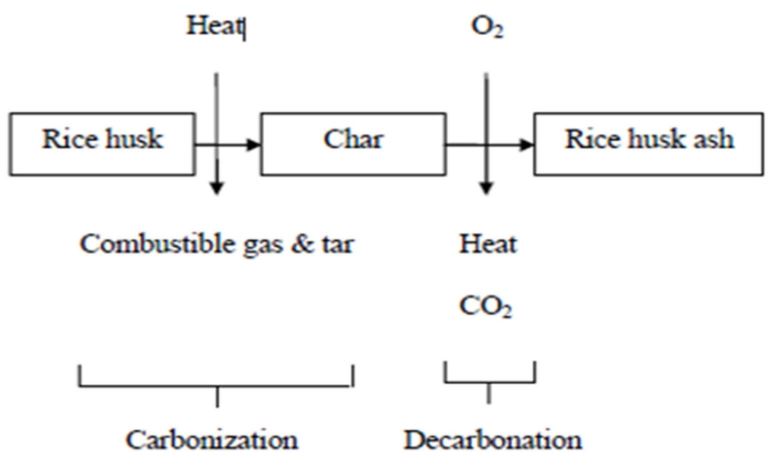


Fig.2.1: Thermal decomposition process of rice husk (Maeda *et al*.,2001)

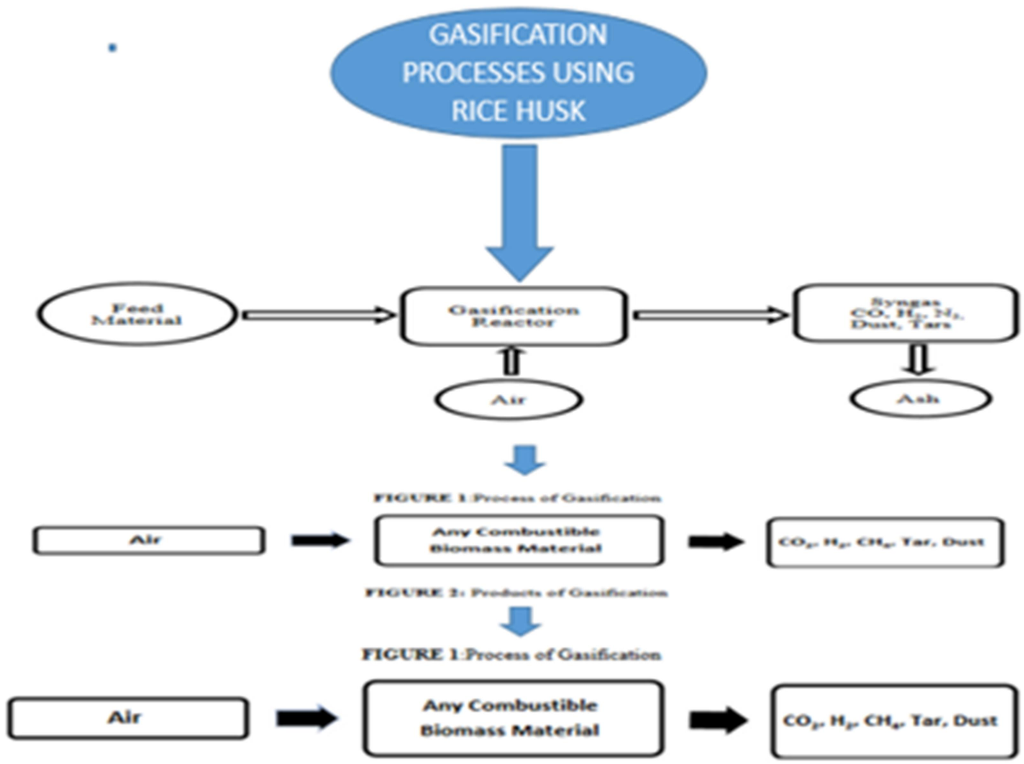


Fig 2.2: Production of gasification (Abubakar *et al.,* 2019)

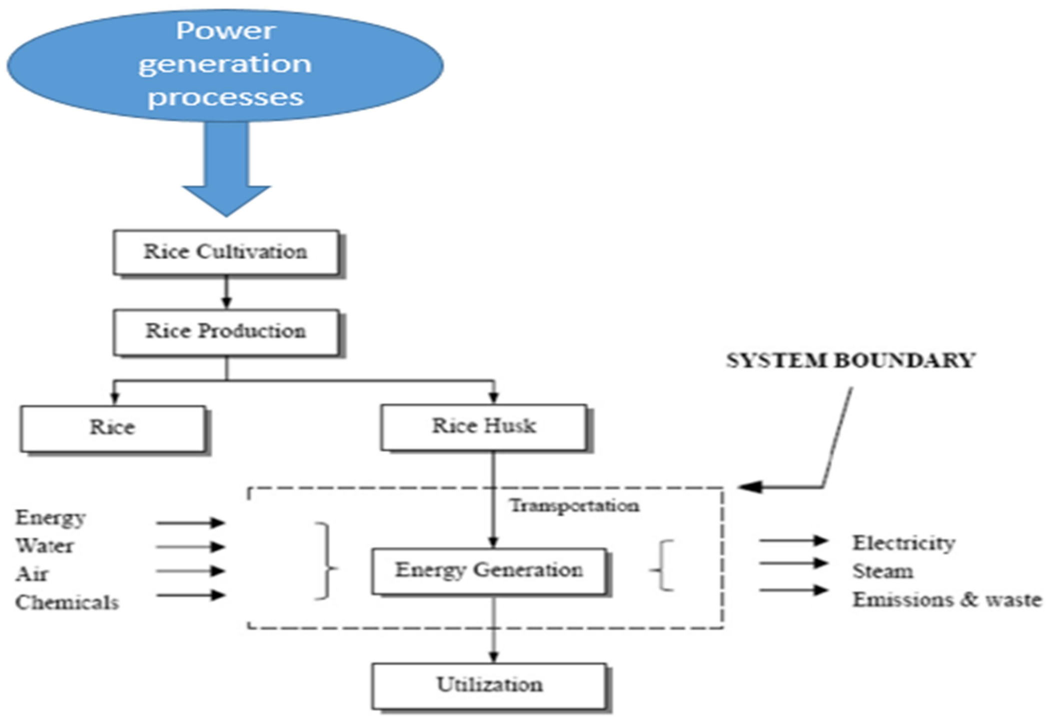
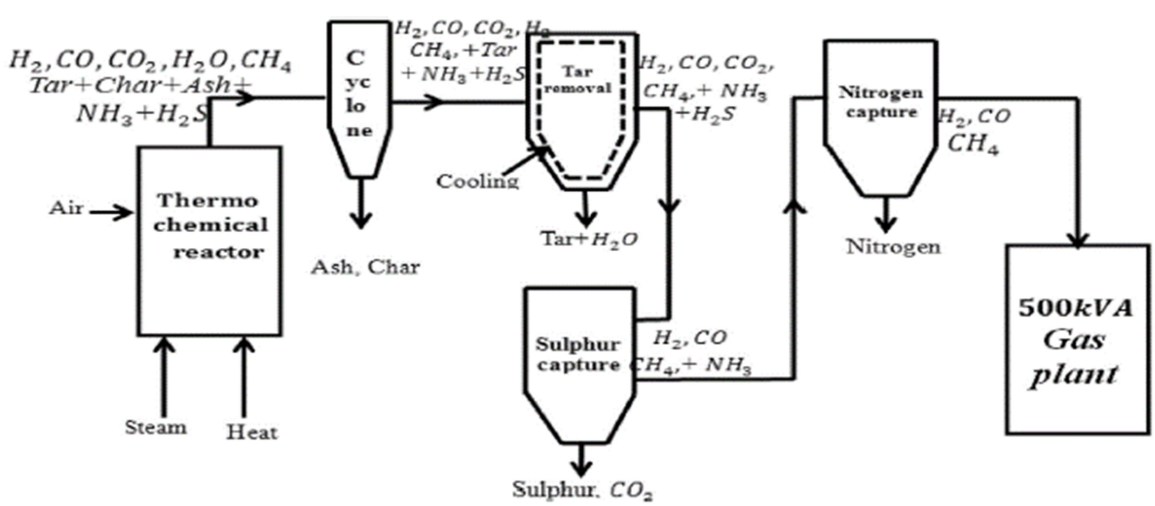


Figure 2.3 Power general processes (Abubakar *et al.,* 2019)

2.3. Mathematical modelling of rice husk power generation

In this study, the output energy of the system, Eout , is a function of the output power (Pout) and the Capacity Utilization Factor (CUF) and was calculated using model developed by (Kaundinya et al.,2009)

$$E_{out}=P_{out} \times 8760 \quad (1)$$



Putting the CUF of the plant into consideration, the annual energy output is:

$$E_{out} = P_{out} \times 8760 \times CUF \quad (2)$$

Where:
Eout is the annual output energy of the system in Wh or kWh or MWh or GWh. Pout is the rated power of the system in Wh or kWh or MWh or GWh. CUF is the Capacity Utilization Factor.
The power rating of the rice husk gasifier was calculated using,

$$P_{out} = \frac{M_{rh} \times 1{,}000 \times CV_{rh} \times \eta_g}{365 \times 3{,}600 \times t_g} \quad (3)$$

Where:
M_{rh} is the annual availability of rice husk in the study area;
η_g is the conversion efficiency of the gasifier system;
t_g is the operating hour of the gasifier system in a day;
CV_{rh} is the calorific value of the rice husk

3.0 RESULTS AND DISCUSSION

3.1 Effect of different mass of feedstock on gasification temperatures of rice husk at 2.36mm particle size

The experimental results were analysed using the Analysis of Variance one-way ANOVA as presented in the following tables below. Table 3.1 Shows the effect of 2.36 mm particle size rice husk and different mass of feedstock on gasification temperatures (thermocouple 1, 2, 3) produced by the gasifier during the gasification processes had significantly influenced the thermocouple of the gasifier at ($p \leq 0.05$) probability level. From the table, it was seen that the temperatures of the gasifier increased with increase in mass. Higher temperatures at T_1, T_2 and T_3 were observed with 2.0 kg of rice husk with maximum values of 117 °C, 471 °C and 1109 °C respectively. It was narrowly followed by 1.5 kg (rice husk) with corresponding temperature values of 111 °C, 452 °C and 920 °C respectively. Finally, the least gasification temperatures were observed with 1.0 kg mass. This should also be expected to the fact that higher the mass to the gasifier the higher the temperature of gasifier as reported by Abubakar., et *al* (2019). for more details, see table 3.2

Table 3.1: Effect of different mass of feedstock on gasification temperatures of rice husk at 2.36 mm particle size

Treatment	Temperature		
Mass (kg)	Thermocouple 1 (°C)	Thermocouple 2 (°C)	Thermocouple 3 (°C)
1.0	87	327	653
1.5	111	452	920
2.0	117	471	1109

Table 3.2: Shows The Analysis of Variance of the Experiment

ANOVA						
Source of Variation	SS	Df	MS	Fstat	P-value	F crit

Between Groups	947504.2	2	473752.1	24.14502	0.00135	5.143253
Within Groups	117726.7	6	19621.11			
Total	1065231	8				

From the result/summary fstat>fcript. There is a significant difference among the treatments at P>0.05

3.2 Effect of different mass of feedstock on gasification temperatures of rice husk at 1.86 mm particle size

As illustrated from the result of the ANOVA in table 3.4. The effect of 1.86 mm particle size and variation in mass of feedstock (Rice husk) had significantly ($p < 0.05$) affected the temperatures observed during the gasification process. The maximum temperatures values of 104 °C, 467 °C and 1194 °C for T_1, T_2 and T_3 were remarkably observed with 2.0 kg rice husk, it was followed by 1.5 kg rice husk during gasification period, while the lowest gasification temperatures at thermocouples T_1, T_2 and T_3 was recorded with 1.0 kg rice husk with corresponding gasification temperatures values of 102 °C, 433 °C and 910 °C respectively. This could be attributed to the fact that, higher the mass to the gasifier the higher the temperature of gasification as reported by Abubakar., et *al* (2019).

Table 3.3: Effect different mass of feedstock on gasification temperatures of rice husk at 1.86 mm particle size

Treatment (Feedstock)	**Temperatures**		
Mass (kg)	Thermocouple 1 (°C)	Thermocouple 2 (°C)	Thermocouple 3 (°C)
1.0	80	314	634
1.5	102	433	910
2.0	104	467	1194

Table 3.4: Shows the Analysis of Variance of the Experiment

ANOVA						
Source of Variation	SS	Df	MS	F stat	P-value	F crit
Between Groups	89928.22	2	44964.11	10.244337	0.790653	5.143253
Within Groups	1104152	6	184025.3			
Total	1194080	8				

From the result/summary fstat>fcript. There is a significant difference among the treatments at P>0.05

3.3 Effect of different feed rate on gasification temperatures of rice husk at 0.6 mm particle size

As illustrated in table 3.5. Feedstock mass variation experimented and 0.6 mm particle size on temperature of the gasification had significantly ($p<0.05$) influenced the temperatures of gasifier. The uppermost T_1, T_2 and T_3 were still observed best with 2.0 kg rice husk, it was closely followed by 1.0 kg and the least was obtained with 1.5 kg feedstock mass throughout the period of the experimentation and result of the experimented is tallied with the work of Abubakar *et al.*, (2019). For more details, see table 3.6

Table 3.5 Effect of different feedstock mass on gasification temperatures of rice husk at 0.6 mm particle size

Treatment	Temperatures		
Mass (kg)	Thermocouple 1 (°C)	Thermocouple 2 (°C)	Thermocouple 2 (°C)
1.0	54	221	621
1.5	92	422	680
2.0	96	452	721

Table 3.6: Shows the Analysis of Variance of the Experiment

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25950.89	2	12975.44	0.144144	0.868673	5.143253
Within Groups	540102.7	6	90017.11			
Total	566053.6	8				

From the result/summary fstat>fcript. There is a significant difference among the treatments at P>0.05

3.4 Effect of rice husk particles size and feedstock mass on gas flow temperatures

As presented in the figure 3.1, The plots revealed that, of all feedstock mass experimented, rick husk with particle size 2.36 mm produced the uppermost temperature of the gasifier during gas flow process at both 1.0 kg and 1.5 kg mass of feedstock, it was then closer by 1.86 mm particle size at same thermocouples T_1, T_2 and T_3 respectively, and the least gas flow temperatures recorded with 0.6 mm rice husk particle size. Conversely, 0.6 mm particle size at 2.0 kg produce higher temperatures during the gasification than 2.36 mm and 1.86 mm respectively.

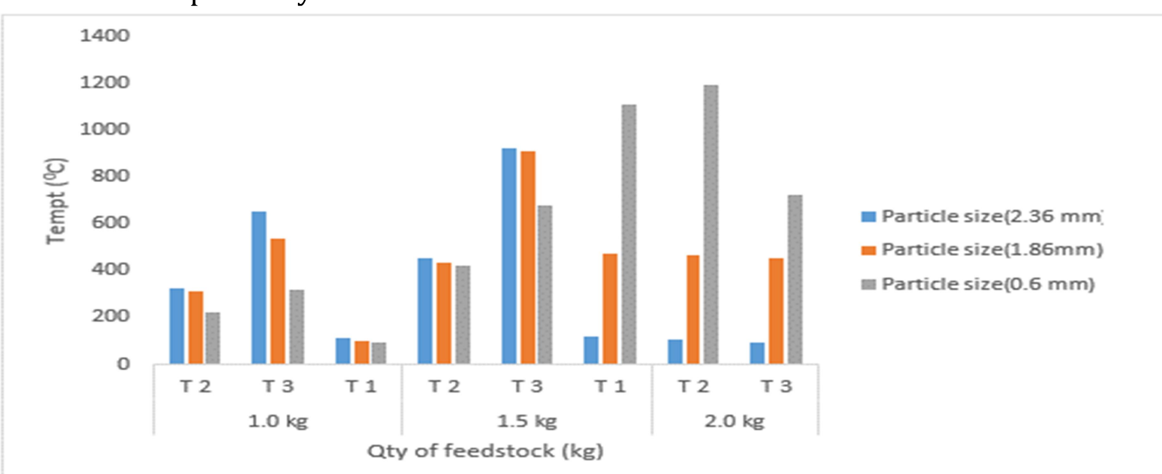


Fig 3.1: Temperatures of the gas flow at different particle sizes and feedstock mass

3.5 Linear Regression between temperatures and time of gasification process

As presented in Figure 3.2, 3.4 and 3.5. The regression relationship R^2 was plotted between temperatures and time observed during the gasification using rice husk at different feedstock for the production of combustible gas which established a very good relationship averagely of 95%, the experimental results show the degree of relationship and slope between temperatures and time of gasification exhibited a significantly high regression coefficients values of R^2 of 0.89 ($P < 0.05$, slope = 0.3), 0.90($P < 0.05$, slope = 0.5) and 0.74 ($P < 0.05$, slope = 0.4) for T_1, T_2 and T_3 at 1.0 kg mass of feedstock respectively. This implies that the relationship between them exhibits a high tendency towards a clear tracked with the observed data from the gasifier. Similarly, the degree of relationship and slope between temperatures T_1, T_2 and T_3 and time of gasification at 1.5 kg mass of feedstock used exhibited a significantly high regression coefficients values of 0.92 ($P < 0.05$, slope = 0.3), 0.89 ($P < 0.05$, slope = 0.6) and 0.77 ($P < 0.05$, slope = 0.7 respectively. The result is in line as stated in Ahiduzzaman *et al*., (2009). Likewise, at 2.0 kg mass significant regression coefficient established between temperatures T_1, T_2 and T_3 and time of gasification with corresponding coefficients and slope values of 0.93 ($P < 0.05$, slope = 0.3), 0.91 ($P < 0.05$, slope = 0.2) and 0.67 ($P < 0.05$, slope = 0.4) respectively. Correspondingly, the longest gasification time and temperature was observed with 2.0 kg and 2.36 mm particle size than all other parameters experimented, equally, increase in the moisture content during the gasification led to increase in the gasification time as well decrease in temperature of the gasifier which is in line with the findings of Abubakar *et al*., (2016).

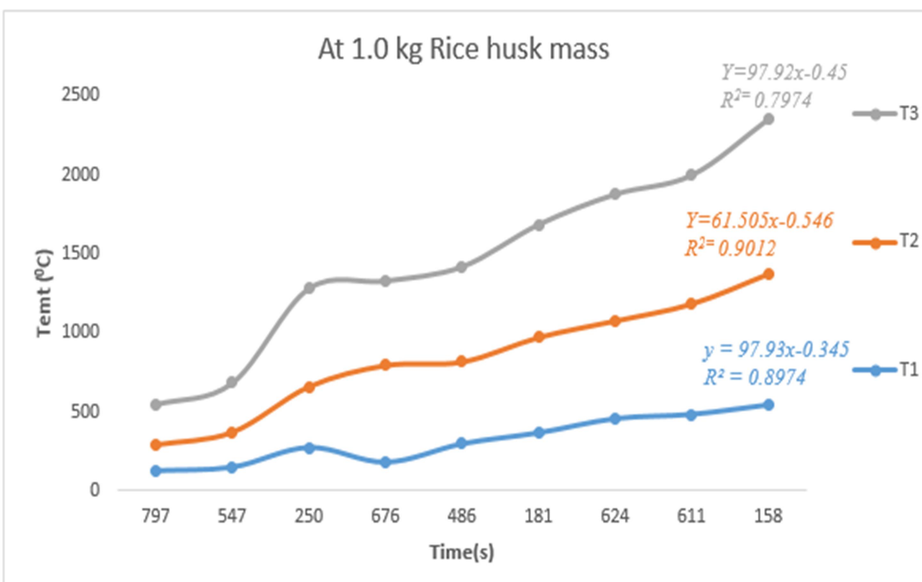


Fig 3.2: Plot showing regression (R^2) of gasification time and temperatures at (1.0 kg) mass

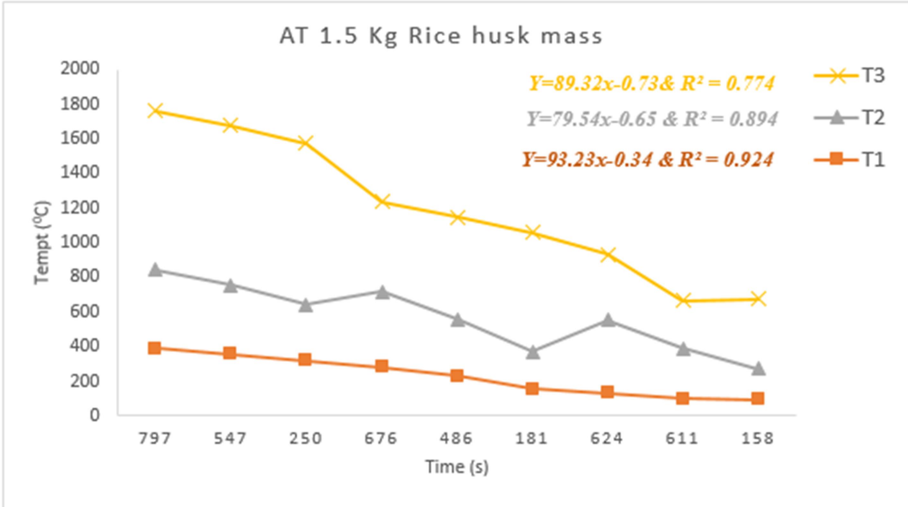


Fig 3.3: Plot showing regression (R^2) of gasification time and temperatures at (1.5 kg) mass

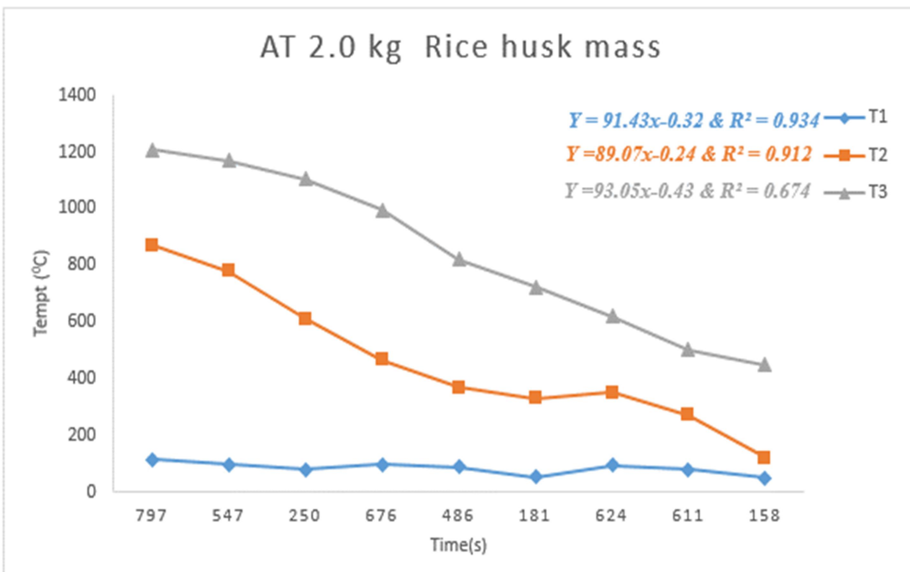


Fig 3.4: Plot showing regression (R^2) of gasification time and temperatures at (2.0 kg) mass

3.5 Conclusion and Recommendations

3.6 Conclusion

The study was aimed to evaluate the performance of the existing gasifier to identify the most effective feedstock (rice husk) and particle sizes at different mass and particles size on the temperatures and time of the combustible gas production from the gasifier for effect electricity generation. The collected data were subjected to the analysis of variance (ANOVA) and the result were as follows:

(i) Results of this investigation showed that 2.0 kg of all particle size used had a significant influence on the temperature of the gasifier during the gasification processes, which was followed by 1.5 kg and 1.0 kg for all particle size of the rice husk fuel.
(ii) Among all particle size of the biomass experimented, 2.36 mm particle size produced highest temperature during the gasification process and could be capable for electricity generation in order to supplement the effort of the Federal Government in power supply in the country.
(iii) Regression analysis revealed that strong positive relation exists between the time and temperature of the gasification.

3.7 Recommendations

(i) In view of the foregoing, it is recommended that, 2.0 kg rice husk mass and 2.36 mm particle size could be used effectively for production of heat in this region, in the event of non- availability of reliable energy source.
(ii) further research should be carried out using different agro-waste and gasification processes in order to generate power as to meet the electricity demand in most economical way, thereby reducing emission, waste and saving cost translating to sustainable development.
(ii) It is recommended that further studies should also be carried out on other agricultural waste using or adopting this approach with a view to re- validating the outcome of this

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