Science Journal of Energy Engineering
2022; 10(4): 35-39
http://www.sciencepublishinggroup.com/j/sjee
doi: 10.11648/j.sjee.20221004.11
ISSN: 2376-810X (Print); ISSN: 2376-8126 (Online)

Experimental Analysis of Four Agricultural Biomass Fuel (Wood Charcoal, Maize Straws, Palm Kernel Sawdust and Rice Husks) Subjected to Fixed Bed Gasification Process

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To cite this article:
Nsah-ko Tchoumboue. Experimental Analysis of Four Agricultural Biomass Fuel (Wood Charcoal, Maize Straws, Palm Kernel Sawdust and Rice Husks) Subjected to Fixed Bed Gasification Process. *Science Journal of Energy Engineering*. Vol. 10, No. 4, 2022, pp. 35-39.
doi: 10.11648/j.sjee.20221004.11

Received: October 20, 2022; **Accepted**: November 16, 2022; **Published**: January 13, 2023

Abstract: The production of syngas from gasification is a heathy way to convert agricultural residues into energy. In fact the gasification characteristics, konwn as the temperature and the plasma duration, were assessed. The gasification process consisted in introducing into a designed updraft gasifier four types of biomass (maize, rice husks, charcoal and kernel palm) of a well known quantity (2, 4, 6, 8, and 10 kgs). The biomass choice was done because of their abundance and they can assure the renewal of resources in an industrial project setting. Air used as a gasifying agent, was introduced in the gasifier through a control valve. Air supply in the gas producer to favor the biomass conversion was done using a fan of 12 Volts turned by photovoltaic solar panels of 100 W each. The main results of this study were as follows. Whatever the quantity of biomass used, the highest gasification temperature was recorded with the charcoal followed by the palm kernel. The plasma or flame duration was the highest during the gasification of 10 kgs of charcoal followed by the palm kernel. The palm kernel and the maize straws are more advisable for the gasification purpose in rural areas of Cameroon.

Keywords: Gasification, Syngas, Plasma, Agricultural Biomass, Fixed Bed Gasifier, Calorific Value

1. Introduction

Energy is a major challenge for Man and the economic activities. The improvement of life conditions and the economic development of Sub-Saharan countries need an increase in energy production [1]. At the global level, energy is designated as a priority for the 2015-2024 decade and is one of the sub-2criteria of the Sustainable Development Goals. Developing countries are concerned with this situation where the energy needs are increasing faster. In fact around 3 billions of persons in rural areas of Asia and Sub Saharan countries don't have access to energy [2]. In order to resorb the problem of energy access in those rural areas, population mostly use wood and fuels for cooking, heating and lighting through generators [3]. The main observation is that the way or the manner those populations are using those resources actually create some drawbacks such as greenhouses effect and gas emissions. Added to wood, there are many other lignocellulosic materials available in rural areas of Cameroon and which can meet the requirement for thermochemical conversion processes (combustion, pyrolysis) [4]. In Cameroon, the maize straw and palm kernel represent about 3 to 4 millions of tons' equivalent petrol per year [5]. Amongst those processes, gasification known as a process which treated a biomass with a limited amount of gasifying medium to convert it into valuable gas such as methane, carbon dioxide and hydrogen. The gas can be further converted into heat and energy to power generating units [6, 7]. Scientific literature has been published on various factors to improve gasification process such as pretreatments of feedstocks, air-fuel ratio and type of gasifier [8-11]. For the moment, most research have been mainly conducted at the level of laboratory but less have been carried out at the industrial level. The second point is that none or less of this process technology exist at the level for rural areas of developing countries. It is still important to carry out research in order to determine the best feedstock associated to the quantity to produce syngas. The relevant input in this work is the plasma production directly at the outlet of the gasifier. The main objective of this study is to assess the gazification of four biomasses (Charcoal from wood, maize straws, kernel palm and rice husks) under some known operating parameters.

2. Materials and Methods

2.1. Provenance and Processing of Samples

Four types of biomasses (charcoal, maize straws, rice chaff and kernel chaffs) were chosen and collected around the neighboring farms. The four biomasses were used as such.

Figure 1. *Palm kernel.*

Figure 2. *Rice husks.*

Figure 3. *Maize straws.*

Figure 4. *Wood charcoals.*

The four biomasses were sun dried until all of them have the same humidity which correspond at 13% for this study. After humidity calibration, each biomass was sent to the gasification process. Prior to the gasification process, each of the selected biomass was submitted to a bomb calorimeter and the AOAC methods for the calorific value determination and the bromatological analysis respectively.

2.2. Gazification Process

2.2.1. Experimental Setup

For the gasification process, a homemade updraft gasifier (figure 5) was designed in order to study the yield of syngas produced. It is made up of a supplying feedbox, a firebox, a cyclone for separating particles; a radiator for cooling of the gas and finally a filter for the filtration of gas product before its usage in the generator. Air supply in the gasifier to favor the biomass conversion was done using a 12 Volts fan turned by photovoltaic solar panel of 100 W.

Figure 5. *Experimental updraft gasifier.*

2.2.2. Effect of Biomass on Gasification Process

In order to study the behavior of the selected biomasses on the gasification process, each biomass, previously weighed, was introduced separately and manually on the gasifier.

2.2.3. Effect of Mass Quantity on Syngas Production and Generator Functioning

The second trial consisted to vary independently the quantities of 2, 4, 6, 8 and 10 kg of each combustible type in the gasifier which was reconnected to the generator.

2.3. Data Collection

1) syngas production

The syngas production was noticed by the production of plasma (flame) as presented in figure 6. A chronometer gave the duration of the plasma and was set just at the starting point of the gasifier.

Figure 6. *Flame production (Plasma).*

2) Gasification temperature

A temperature probe was installed around the firebox level inside of the gas producer. Value acquisition was done for a period of 4 hours.

2.4. Statistics Analysis

For the statistical analyses, the data obtained were analysed using the software package SPSS 23.0.

3. Results and Discussion

3.1. Bromatological Analyses of Biomasses

The bromatological analyses of biomasses is presented in table 1.

Table 1. *Bromatological analyses of biomasses.*

Fuels type	Dry matter (%)	Calorific value (kcal/kgMS)	in % of dry matter				
			cellulos	Lipids	Proteins	nitrogen	ash
Wood charcoal	97, 23	8592,55				0,90	6,00
Rice husk	95,56	3837,41	42,98	4,67	2,04	0,33	21,72
Maize straws	95,40	4595,39	36,49	3,7	4,06	0,65	2,91
Palm kernel	97,09	5123,80	29,27	26,02	3,42	0,55	8,89

Independently of the combustible type, the highest calorific value was obtained with wood charcoal and the lowest calorific value was observed with the rice husk. For specific agricultural biomass namely rice husk, maize straws and palm kernel, their calorific value change but remain in an interval between 4000 and 5000 Kcal/kgMS. This result is slightly different from those of [8]. This could be due to the environmental factors.

3.2. Temperature Evolution with Time

The gasification temperature evolution in function of time is illustrated by figure 7.

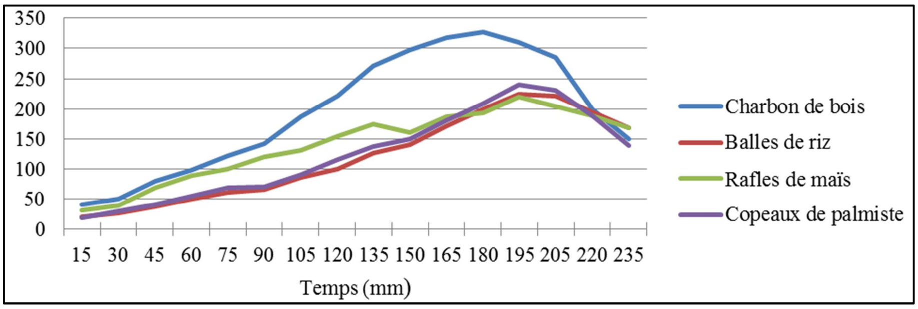

Figure 7. *Temperature evolution within the time.*

Whatever the combustible type, the temperature curves present the same profile during the time spend for the trial except for the maize straws where a temperature dropped significantly in the gasifier. Independently of the time, the highest temperature in the gasifier was observed during the gasification of wood charcoal followed by the maize straws. However, there is no differences in temperatures evolution between the palm kernel and the rice husks.

3.3. Effect of the Combustible Quantity on the Gas Production

The effect of the combustible quantity on the gas production is illustrated by figures 8 and 9.

1) Time spent before the gas production

From the figure above, the lowest time spent before the syngas production (through the plasma or flame), was observed with the wood charcoal as a combustible independently of the mass used. On contrary, the palm kernel show the highest time spent before gas production. The minimum time spent before syngas production was fixed between 31 and 32 minutes. The time spent before syngas production was practically the same for the rice husks and maize straws.

2) Duration of gas production

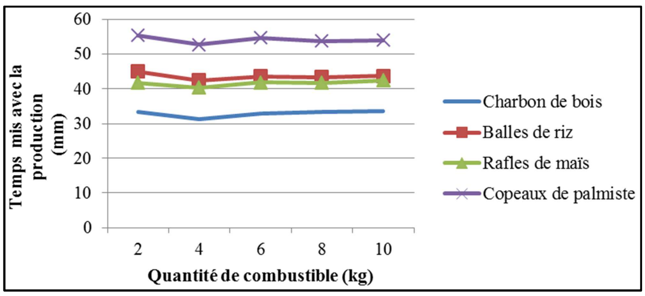

Figure 8. *Effect of the combustible quantity on the gas production.*

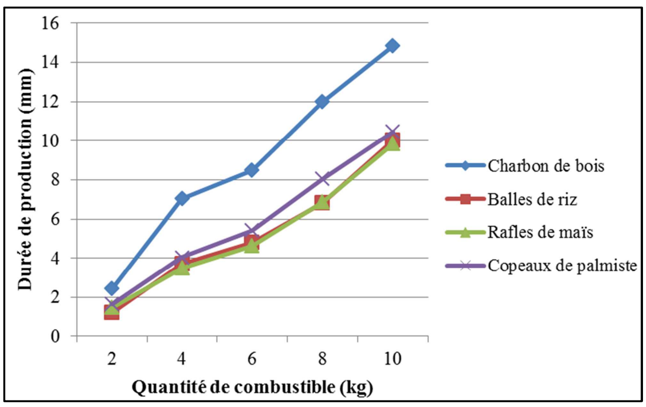

Figure 9. *Fuel mass effect on the syngas duration.*

Regardless the fuel type, it appears logically that the increase in fuel mass input the highest the syngas production. The charcoal wood presents the highest syngas production whatever the fuel mass input. Between agricultural fuels, there is no difference between them except at the level of the fuel quantity 8 kgs where syngas production was the highest with palm kernel.

3.4. Time Duration of the Generator as a Function of Fuel Type and Fuel Quantity

The effect of fuel type and fuel quantity on the generator functioning time is summarized in table 2.

From the table 2, it appears that whatever the fuel quantity used and the fuel quantity, the highest time of generator functioning was observed for 10 kgs of charcoal. The lowest value was given by the maize straws at 2 kgs of fuel input. As concerned with agricultural fuels, although the palm kernel presents the highest time of functioning when the gasifier was supplied at 10 kgs During the all trial, the quantity of 2 kgs of fuel whatever the type, present logically the lowest functioning durations.

Table 2. *Time duration of the generator as a function of fuel type and fuel quantity.*

Fuel types	**Generator functioning time (minutes)**				
	2 kg	**4kg**	**6kg**	**8kg**	**10kg**
Wood charcoal	1,23e±0,75	3,03d±0,91	4,97c±1,01	7,30b±0,87	9,70a±1,01
Rice husks	0,55e±2,05	1,23d±2,35	3,10c±2,05	4,60b±2,55	5,73a±2,10
Maize straws	0,50e±2,55	1,20d±2,45	3,03c±2,10	4,27b±2,45	5,90a±2,08
Palm kernel	0,64e±0,54	1,97d±1,00	4,33c±0,74	5,47b±1,34	7,40a±0,88

3.5. Discussion

From our results, the highest calorific value was observed with the wood charcoal as compared to agricultural fuel origin. Our results are in conformity with those of [12, 13] which showed that the calorific value of dry wood fuel is higher than that of sorghum and cotton sick. This difference could be due to the proportion and quality of chemical component and especially their content in lignin, cellulosic and hemicellulose. In fact, more the Carbone percentage in a fuel, the highest calorific value it deserves. On the other hand, the highest ash and nitrogen content the lowest is calorific value.

The temperature curves present the same profile during the time spend. However, the temperature values were the highest for charcoal followed by maize straws fuel. The fuel particle size compared to other combustibles (palm kernel and rice husks) can explain the higher temperature produced for charcoal and maize fuels. Although the temperatures values are not in the same estimations [14], our results are similar. The highest gasification temperature was observed with high particle size fuel.

The time spent before the gas production was the less for charcoal fuel followed by maize straws fuel. This similarity could be explained by the physical characteristics of particles once more. The highest time spent before gas production was observed with the palm kernel fuel compared to the agricultural fuels. In fact, with the limitation of air inside the gasifier, the combustion process took much time to start with the palm kernel fiber due to its physical characteristics.

The fuel used has also an influence on the power of gas producer. The main observation was that the palm kernel sawdust fuel produced the highest gas calorific value through the generator functioning. The strong oil content in palm kernel could have increased the combustion and consequently the gas production.

4. Conclusion and Recommendations

The fuel type and quantity have affected all the parameters studied in this article. In fact, the highest temperatures values within our experimental gasifier were obtained for the charcoal as a fuel. The particle size and the chemical composition could be the main reason. although wood charcoal remains an ideal fuel for the gasification process, agricultural biomass residue, and those particularly studied here, could also be used for the purpose. Following the results obtained, gasification process could be implemented in Cameroon using maize straws, palm kernel sawdust and rice husk with respect to their physical characteristics, calorific energy and availability.

References

[1] Somya M.; Upadyay kumar R. 2021: Review on biomass gasification: gasifiers, gasifying mediums, and operational parameters. Materials Science for Energy Technologies. Vol 4, pp 329-340. https://doi.org/10.1016/j.mset.2021.08.009

[2] Tangka, J., K., Ketuma, C., T., Ajaga, N., Viyoi, C., T., 2016. Modelling of the Operation of a Small Generator Set Powered by Scrubbed Biogas from Cow Dung. British Journal of Applied Science & Technology. 14 (1): 1-8.

[3] Berndes, G., Hoogwijk, M., et van den Broek, R., The contribution of biomass in the future global energy supply: a review of 17 studies. Biomass and Bioenergy, 2003. 25 (1): p. 1-28.

[4] Nsah-ko Tchoumboué., Tangka, J. K., Njila, R., Djoussé Kanouo, B. M., Sogang Signing, H. B., Womeni, H., Ndomou, S. C. 2018: Oil production and energy input from extraction of Jatropha curcas L.: Effect of seeds form, preheating temperature and applied pressure. The International Journal of Engineering and Science (IJES). Volume 7, Issue 8, PP 69-75.

[5] Tchouate H., Pépin M., 2003. Renewable Energy Contribution to of electric sustainable Development: Cameroon case study, Doctoral Thesis, University of Louvain, Belgium 83p.

[6] Xu, Donald J., Byambajav, E., Ohtsuka, Y. 2010: Recent advances in catalysts for hot gas removal of tar and NH3 from biomass gasification. Fuel, 89 (8), pp. 1784-1795.

[7] Chauvin A., Faraud V., 2008. Simulation of wood gasification and experimental study in a 10 kWel pilot gasifier internship report, Marseille polytechnic school. 8-74p.

[8] Ren, J., Cao, J. P., Yang, F. L., Wei, X. Y., 2019: Recent advances in syngas production from biomass catalytic gasification: A critical review on reactor, catalysts, catalytic mechanisms and mathematical models. Renewable sustainable Energy Review., 116. P. 109426. http://10.1016/j.rser.2019.109426

[9] Meng, X., De Yong, W., Fu, N., Verkooijen, A. H. M. 2011: Biomass gasification in a 100 kW_{th} Steam-oxygen blown circulating fluidized bed gasifier: Effects of operational conditions on product gas distribution and tar formation. Biomass bioenergy, 35 (7), PP. 2910-2924. http://10.1016/j.biombioe.2011. 03.028

[10] McCaffrey, P., Thy, P., Oliveira M., Wang, L., Torres, L., Aktas, T., Chiou, B. S., Orts, W., Jenkings, B. M., 2019: Air and Steam gasification of almond biomass. Frontiere Energy Resource., volume 7, p. 84. http://10.3389/fenrg.2019.00084

[11] Molino, A., Larocca, V., Chianese, S., Musmarra, D., 2018: Biofuels production by biomass gasification: A review. Energies, 11 (4) (2018), p. 811, http://10.3390/en.11040811

[12] Madadien, E., Orsat, V., Lefsrud, M., 2017: Comparative study of temperature impact on air gasification of various types of biomasses in research scale downdraft reactor. Energy Fuels, 31 (4), (2017), pp. 4045-4053. http://10.1021/acs.energyfuels,6b034

[13] Teixeira, G., 2012. Gazeification de charbon de granules de bois: comportement thermochimique et mecanique d'un lit fixe continu. 2012, Institut National Polytechnique de Toulouse (France), 2012.

[14] Wongsiriamnuay, T., Kannang, N., Tippayawong, N., 2013: Effect of operating conditions on catalytic gasification of bamboo in a fluidized bed. International Journal of Chemical Engineering., 2013, pp1-9.