DOI: 10.51975/21360202.som
Journal of the Nigerian Society of Chemical Engineers, 36(2), 2021

THERMAL AND EMISSION CHARACTERISTICS OF CARBONISED AND UNCARBONISED RICE HUSK BRIQUETTE, A COMPARATIVE APPROACH

***Ejikeme, E. M., Enemuo, M.S., and Ejikeme, P.C.N**
Department of Chemical Engineering,
Enugu State University of Science and Technology, Enugu, Nigeria
*ebemoca@yahoo.com

ABSTRACT
Production of briquettes from carbonized and uncarbonized rice husk using a locally fabricated hydraulic press was studied. Proximate and Fourier Transform Infrared Spectroscopy (FTIR) analyses, thermal characteristics, and emission properties of the briquettes were determined. Thermal and emission characteristics were determined in real-time measurements during Water Boiling Test (WBT) using Laboratory Emissions Monitoring System (LEMS) equipment. The burning rates of the uncarbonized and carbonized briquettes were 14.35541g/min and 6.478456g/min respectively. The specific fuel consumptions of the briquettes were 96.5502g/L and 80.12107g/L for uncarbonized and carbonized respectively.The energy consumption rate of uncarbonized briquette was 203.4046KJ/min while that of carbonized was 157.6007KJ/min. It took uncarbonized sample average cooking power of 1.598235KW and 0.543518KW for thecarbonized briquette. High power particulate matter of uncarbonized briquette was 13.20391mg/MJ while that of carbonized was 0.510256mg/MJ. High power carbonmonoxide of uncarbonized and carbonized briquette were 0.443276g/MJ and -0.00964g/MJ respectively. Both briquettes were categorized as tier four in line with the International Workshop Agreement (IWA), International Organization for Standardization (ISO) standard specification for stove testing.

***Keywords**: Briquette, Carbon Monoxide, Carbonization, Cassava Starch, Rice Husk*

1.0. INTRODUCTION

The limitations of fossil fuels and the attendant pollution problems associated with the consequential effect on health have ignited the interest of researchers towards the search for alternative energy resources for domestic and industrial purposes. This search found abundant solutions in the energy benefits of biomass as a renewable energy resource. This choice is large because it is biodegradable, significantly available, environmentally friendly, and sustainable. The need for sustainable energy is rapidly increasing in the world.To this end, renewable energy has been identified as a veritable alternative to fossil fuels in a sustainable and environmentally friendly manner (Chukwueyem etal., 2015). Renewable energy is clean or inexhaustible energy like hydrogen energy and nuclear energy and it can reduce environmental pollution (Siti-Farhana, 2011).It is interesting to note that this biomass is mainly products of agricultural processing activities which may require that they are consigned to agricultural wastes bins, hence constituting environmental pollution. Solving the problem of environmental pollution can be very expensive, cumbersome, and herculean, therefore reducing the occurrence of thorough biomass processing and utilization remains the best available option.

In Nigeria rice husk which is a form of biomass is abundant from rice processing. Disposal of this husk is very difficult and has constituted a lot of environmental problems to the public. During burning a lot of smoke is released to the environment and this can lead to death when inhaled or to an accident due to blurred vision on highways. Other emissions like particulate matter constitute health hazards to the inhabitants. Hence channeling the biomass to useful purposes contributes significantly to the biomass indirect disposal methods. Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries (Bhattacharya and Salam 2002).

The rice husk can be directly applied for energy generation. It can also be modified for the same purpose. However, various techniques have been applied for the biomass modification process and all aimed at improving the energy generation capacity of the biomass and reduce possible thermal emissions from the product.

A known form for biomass modification is the production of briquettes. One of the promising technologies by which biomass could be converted to energy is briquette technology (Oladeji 2011).The biomass that was not useful due to low density was collected and compressed into solid fuel for convenient use and handling.This can be burned in the same way as wood or charcoal(Adekoya 1989); (Ajit etal., 2017). In this way, a briquette can be produced. Briquetting increases the bulk and energy densities of the biomass material, which in turn reduces transport costs. These make it easier for the end-user to handle. Agricultural residues are difficult to handle especially in their raw state because they are bulky and when burnt is very smoky and they also burn very fast (UNEP 2007).There is a remarkable improvement in the combustion characteristics of compressed biomass when compared with the loose one (Husain et.al., 2002).

The densification of biomass materials for energy generation can be achieved through hydraulic compaction of the biomass or a combination of it with an additive for an improved briquette product. These briquettes are used for the generation of energy for domestic uses like cooking and lighting or for industrial uses in generating energy for turbines and heat exchangers. In the course of their use, these briquettes exhibit certain characteristics. Therefore, evaluation of the burning, thermal, and combustion characteristics of these briquettes is considered very imperative and apt. These characteristics define the burning, thermal, and combustion profile of the briquettes and accordingly position them in the purity chart of the briquettes.

The characteristics of the briquettes to be evaluated include but are not limited to the ignition time, boiling time, burning rate, particulate matter, carbon monoxide, and carbon dioxide emissions, and thermal efficiency. These emissions are capable of causing deaths if inhaled in large quantities. The World Health Organization (WHO) estimates that more than 1.5 million people die annually due to smoke from the combustion of solid fuel (WHO 2006).Nigeria experiences one of the highest numbers of smoke-related deaths in the world. It is therefore eloquently important to establish the levels consistent with the produced rice husk briquettes to assign positions to them in the comity of commercially available briquettes through the process of characterization of the briquettes

This study is therefore intended to evaluate the thermal and combustion characteristics of rice husk briquette for purposes of determining their thermal and combustion integrity as a viable alternative for domestic energy supply.

2.0. MATERIALS AND METHOD

All materials used were sourced locally. They include the following:

Risk husk: The rice husk sample was collected from Adani in Uzo-Uwani LGA of Enugu State, Southeast Nigeria.

Cassava starch: Cassava Starch sample which was used as a binder was procured from the Abakpa Nike market in Enugu, Enugu State, South Eastern Nigeria.

2.1. Briquette production method

The Carbonization of the biomass sample was carried out at a temperature of 400^0C using a muffle furnace. After allowing it to cool to room temperature the biomass sample was weighed using a digital weighing balance. The corresponding weight of the binder was also determined with the same weighing balance. The binder mixed with 50ml of water was heated in a heater with a magnetic stirrer until it gelled. Another 50ml of water was added to ensure proper mixing of binder and biomass. The biomass-binder mixture was transferred into the mold of a locally fabricated hydraulic press briquette machine (Figure 1)and compacted to form a briquette. The briquette was removed after 20minutes of dwelling time. After the ejection of the briquette from the mold cavity, it was allowed to dry until a constant weight was achieved.

Figure1. LocallyFabricated Hydraulic Press Briquette Machine

2.2. Proximate analysis of biomass and briquette

The method of Akouwah et al (Akouwah et. al., 2012) was employed for the proximate analysis of the samples

2.3. Determination of Thermal properties

The ignition time, boiling time, burning rate, thermal fuel efficiency, and other emission characteristics of the briquette during combustion were determined in real-time measurements during the Water Boiling Test (WBT) using the Laboratory Emissions Monitoring System(LEMS) equipment (ARC, Oragon U.S.A) set up (Figure2) at the National Stove Eligibility Laboratory in the National Centre for Energy Research and Development (NCERD), University of Nigeria Nsukka (UNN).

Figure 2 Laboratory Emissions Monitoring System (LEMS)

2.4. Water boiling test using LEMS.

A modified Water Boiling Test (WBT) was carried out where a standard stove and standard pot with provision for temperature probe were used and the fuel (briquettes) varied. One liter of water was used. The pot was weighed first after which the pot and water were weighed to determine the weight of water used. The LEMS start-up process was initiated and allowed to acclimatize with the environment.20g of briquette was introduced into the standard stove and lit up. When the ignition was complete, the pot with a measured weight of water was kept on the stove and both immediately lifted into the hood of the LEMS. Real-time monitoring of the briquette combustion process was done by the computer-controlled LEMS and real-time data generated.

2.5. Calorific Value Determination

The calorific value was measured using a bomb calorimeter available at the National Centre for Energy Research and Development, University of Nigeria Nsukka. A standard method was adopted usinga bomb calorimeter (model XRY-1A, make: Shanghai Changji, China)(AOAC 1975). It involves igniting the sample under the influence of high pressure of oxygen gas in an oxygen bomb calorimeter. Consequently, there was a release of very high energy that was absorbed by the surrounding water inside the bomb Calorimeter. The temperature of the water showed great increase and this was used to estimate the energy value of the sample. One gram of the sample was molded into pellets and burnt in the oxygen bomb calorimeter. The calculated heat of combustion represented gross energy.

2.6. Fourier transformed Infrared Spectroscopy (FTIR)

The surface functional groups and structure were studied using Fourier Transform Infrared Spectroscopy [Buck 530 IR] England. The FTIR spectra of the carbonized and uncarbonized samples were scanned at a wavelength of 600–4000nm. This was done at Ahmadu Bello University Zaria.

3.0. RESULTS AND DISCUSSION

3.1. Proximate And Ultimate Analysis

Table 1 shows the results of the proximate and ultimate analysis of uncarbonized rice husk, carbonized rice husk, uncarbonized rice husk briquette, and carbonized rice husk briquette.

Moisture content is one of the main parameters that determine briquette quality (Aina etal., 2009). Briquettes with lower moisture content have higher calorific values (Akowuah etal., 2012). The moisture content of the briquettes produced from both carbonized and uncarbonized rice husks was lower than that of the loose sample. This low moisture content suggested good storability and the combustibility of the briquettes. The volatile matter content of the carbonized briquette was lower than the uncarbonized one. The higher volatile matter content of the uncarbonized one is an indication of the quick ignition period of the briquette and commensurate rise in the length of the produced flame (Deepak and Jnanesh 2015). The carbonized briquette though may not ignite so fast as that of the uncarbonized one but will give out fewer emissions in the course of their combustion. The fixed carbon is high for the carbonized briquettes. Fixed carbon is the percentage of carbon (solid fuel) accessible for char combustion after distilling off volatile matter. It showed that the carbonized briquette has a higher heating value compared to the uncarbonized one.

Table 1:Proximate and Ultimate Analysis of The Samples

Parameter	UCR	CR	UCRB	CRB
Moisture (%)	8.2	1.3	8.4	2.6
Ash (%)	15.1	6.8	15.8	3.8
Volatile matter (%)	67.0	32.9	65.5	22.5
Fixed carbon (%)	9.7	5.9	20.3	71.1
Bulk density	0.2941	0.4621	-	-
Carbon (%)	51.0	27.5	60.8	83.0
Hydrogen (%)	5.7	3.0	6.1	4.4
Nitrogen (%)	1.9	2.0	1.7	1.7

UCR= Uncarbonized Rice Husk, CR= Carbonized Rice Husk, UCRB= Uncarbonized Rice Husk Briquette, CRB= Carbonized Rice Husk Briquette

3.2. FTIR Analysis

Figures 3 to 5 show the FTIR analysis of the uncarbonized rice husk, carbonized rice husk, and carbonized rice husk briquette. Many peaks present on the uncarbonized rice husk spectrum disappeared on the carbonized spectrum while the remaining ones were weak to a great extent. This is consistent with the breaking of many bonds on the carbonized rice husk leading to the liberation and elimination of volatile species during carbonization. Many bands decreased dramatically indicating the decrease in functionality from the main matrix.

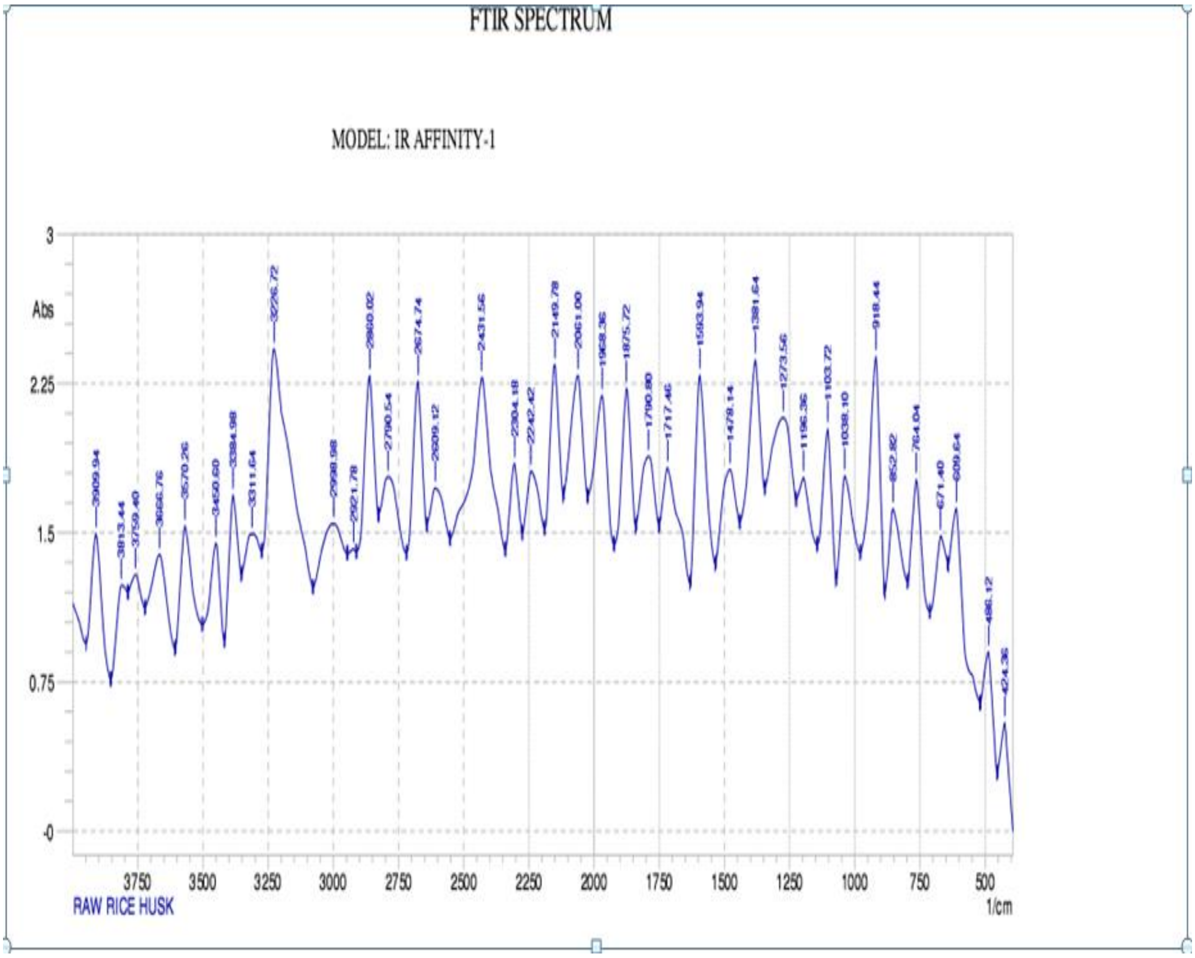

Figure. 3 FTIR of Uncarbonized Rice Husk

DOI: 10.51975/21360202.som
Journal of the Nigerian Society of Chemical Engineers, 36(2), 2021

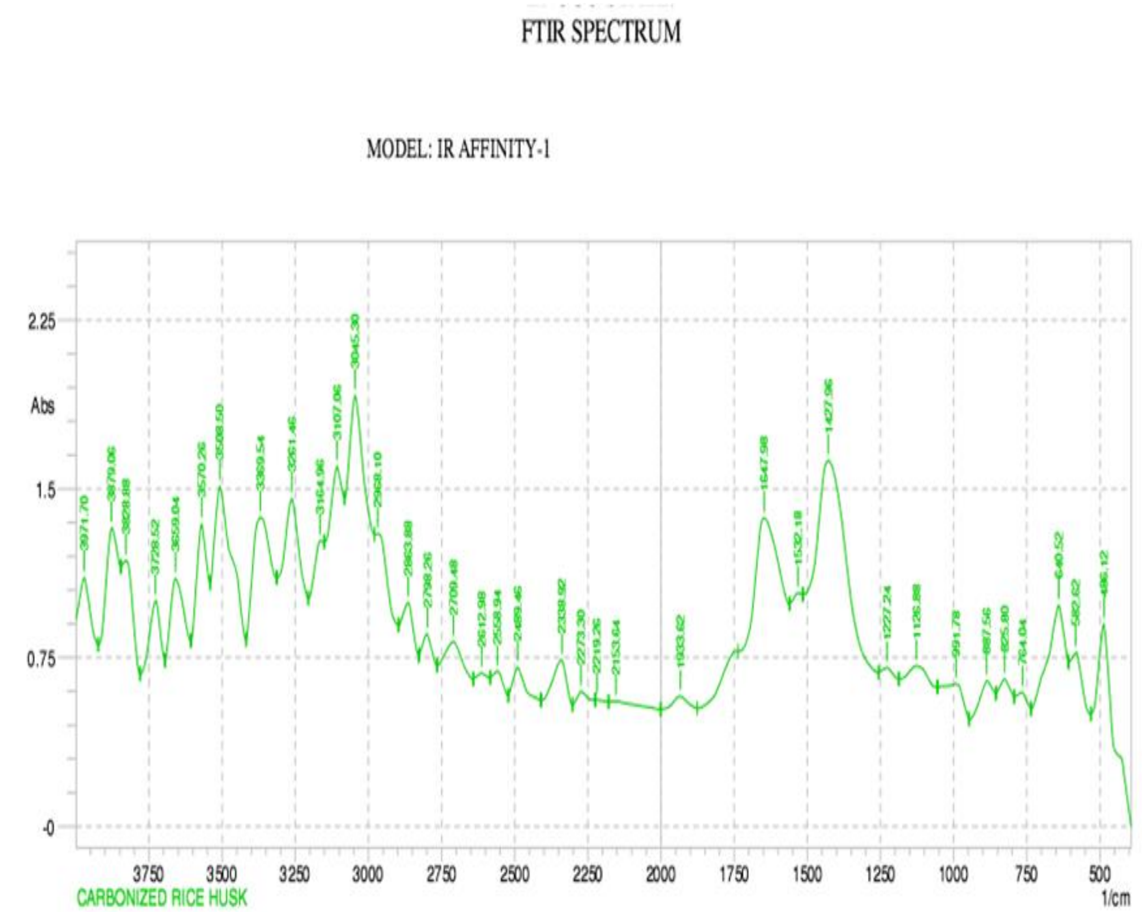

Figure 4. FTIR of Carbonized Rice Husk

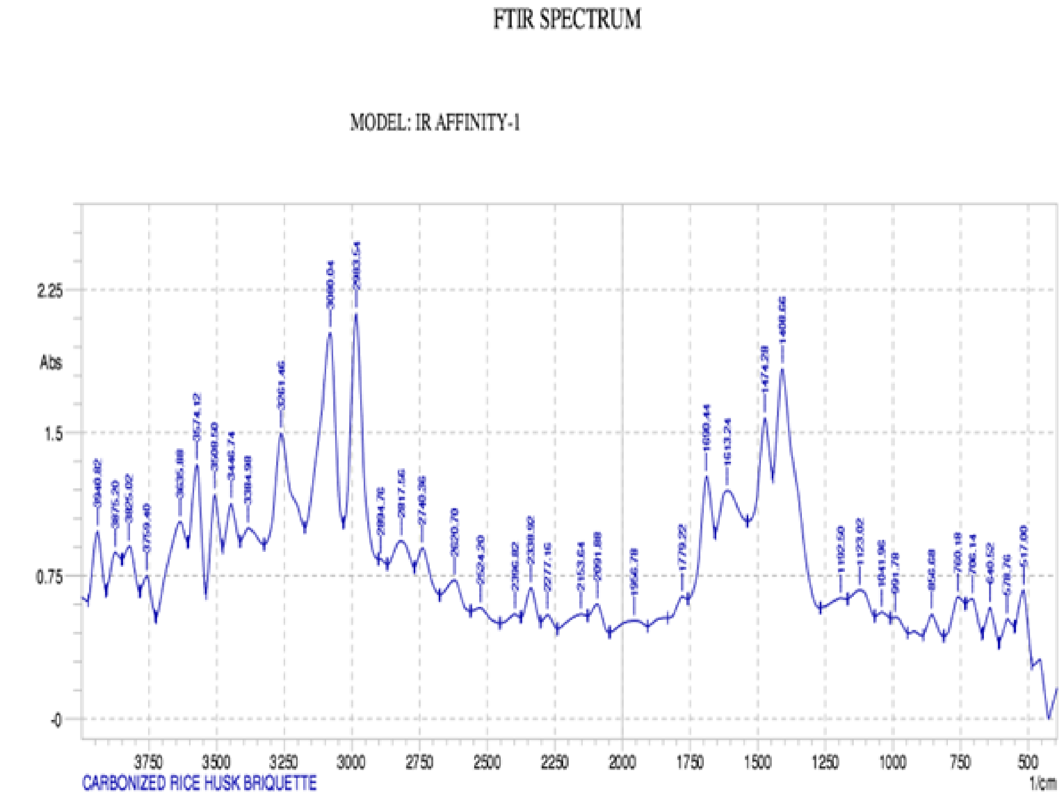

Figure 5. FTIR of Carbonized Rice Husk Briquette

3.3.Briquettes Thermal And Emission Characteristics

Thermal performances and emission characteristics of the briquette produced from carbonized and uncarbonized rice husks were presented in Table 2, while Table 3 shows the IWA ISO standard specification for stove testing(IWA 2012).

Uncarbonized rice husk briquette contains high particulate matter ($PM_{2.5}$) of 13.2039mg/MJ and high carbon monoxide (CO) of 0.4433mg/MJ. The carbonized rice husk briquette showed a significant reduction with particulate matter ($PM_{2.5}$) of 0.5102mg/MJ and carbon monoxide (CO) of -0.00964mg/MJ. This reduction can be attributed to the breaking of many bonds on the carbonized sample leading to the liberation and elimination of volatile species.

It was observed that the thermal efficiency of the briquette produced from the carbonized rice husk increased to 0.46 compared to 0.203 recorded for the uncarbonized rice husk briquette. The Energy consumption rate of the carbonized rice husk briquette was lower than the uncarbonized one. The low carbon monoxide content of the briquette produced from the carbonized rice husk made the briquette to be classified as smokeless one and a substitute for coal briquette concerning environmental pollution. The specific fuel consumption of uncarbonized briquette was 96.5502g/liter compared to 80.12107g/liter for the carbonized one.

Table 2 shows the IWA specification standard for briquette. IWA standard provides a framework for rating cooking stoves against tiers of performance for a series of performance indicators including fuel use (efficiency), total emission, indoor emission, and safety. The higher the tier number, the higher the quality of the briquette produced. From the result, briquette produced from both carbonized and uncarbonized rice husk lied on tier 4. This confirmed that the produced briquettes were of high quality.

The burning rate of the uncarbonized one was 14.35541g/min compared to 6.478456g/min recorded for the carbonized one. The burning rate suggests the quantity of fuel consumed during combustion. It shows that uncarbonized one consumes more fuel than the carbonized sample. It took 12minutes for the uncarbonized rice husk briquette to boil one liter of water compared to 6minutes taken for the carbonized one.

Table2 Thermal Performance of The Briquettes

	Units	**Uncarbonized rice husk briquette**	**Carbonized rice husk briquette**
IWA Performance Metrics			
High Power Thermal Efficiency	%	0.203931	0.462201
High Power CO	g/MJ	0.443276	-0.00964
High Power PM	mg/MJ	13.20391	0.510256
Basic Operation			
Time to boil Pot # 1	Min	12	6
Burning rate	g/min	14.35541	6.478456
Thermal efficiency	%	0.203931	0.462201
Specific fuel consumption	g/liter	96.5502	80.12107
Temp-corrected specific consumption	g/liter	94.65706	78.96294
Firepower	Watts	2626.679	3390.077
Equivalent Dry Fuel Consumed	G	86.13243	77.74147
Energy Consumption			
Temp-Corrected Time to Boil	Min	11.82654	5.882353
Energy Consumption Rate	kJ/min	203.4046	157.6007
Temp-Corr Specific	kJ/liter	1920.924	1341.215

DOI: 10.51975/21360202.som
Journal of the Nigerian Society of Chemical Engineers, 36(2), 2021

	Units	Uncarbonized rice husk briquette	Carbonized rice husk briquette
Energy Consumption			
Specific Energy Consumption Rate	MJ/min/L	0.228007	0.162425
Dry Fuel Consumed		87.2355	77.91
Total Energy Consumed	KJ	1895.309	1236.057
Energy Delivered to the Cooking Pot	MJ	0.564083	0.385677
Average Cooking Power	kW	1.598235	0.543518

Figures 6 to 9 show the carbon dioxide, carbon monoxide, and particulate matter emissions at pot temperature and relative humidity during the test for the briquette. Carbon dioxide emission was highest immediately the briquettes were introduced and gradually decreased as the burning time increased. The reduction in carbon dioxide emissions was because the combustion was slowing down. As the combustion was coming to an end, the carbon dioxide increased. Much of the particulate matters were released initially as the burning test started and decreased as time increased.

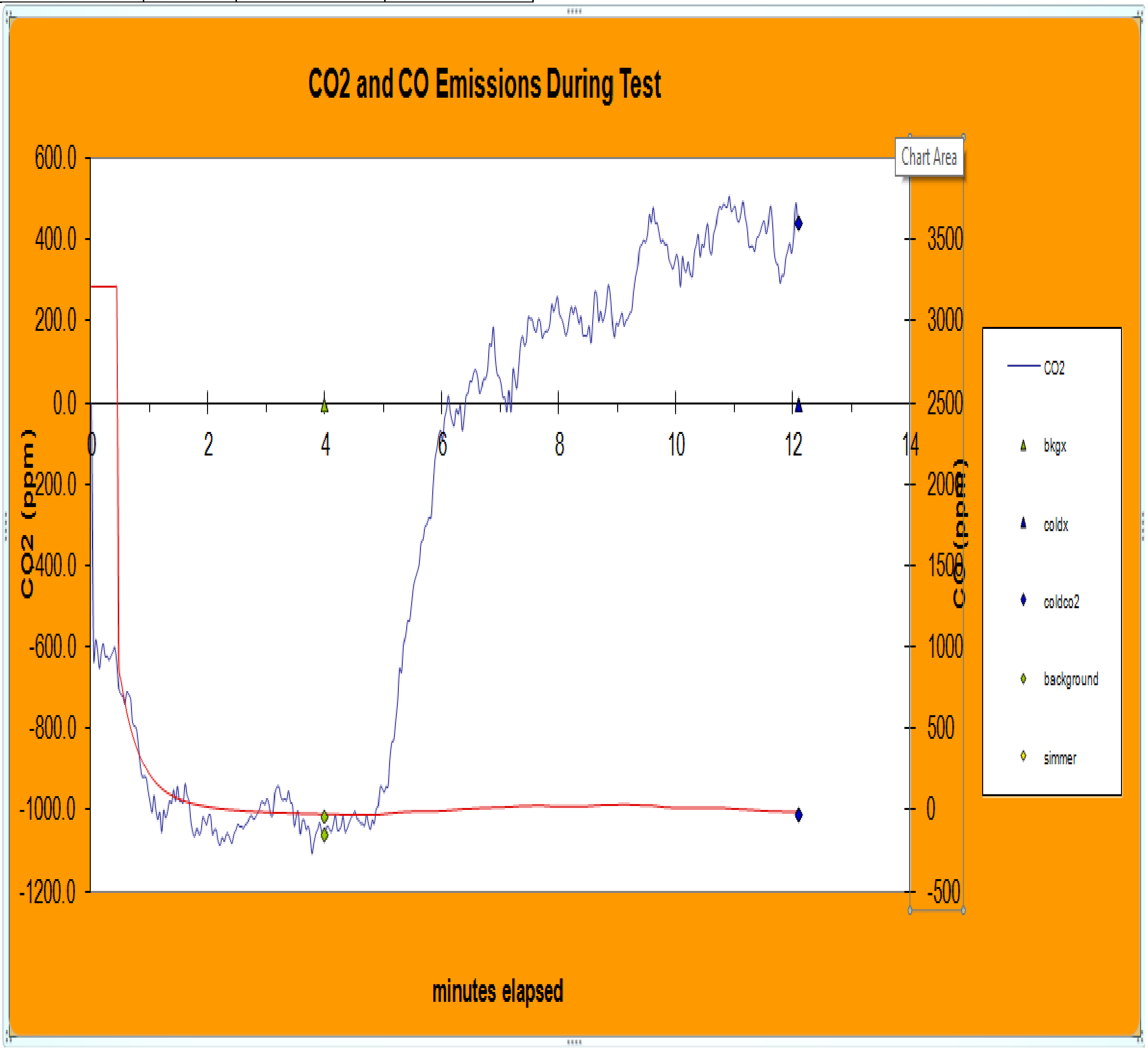

Figure 6 CO_2 and CO Emissions During the Test For Briquettes Produced from Uncarbonized Rice Husk

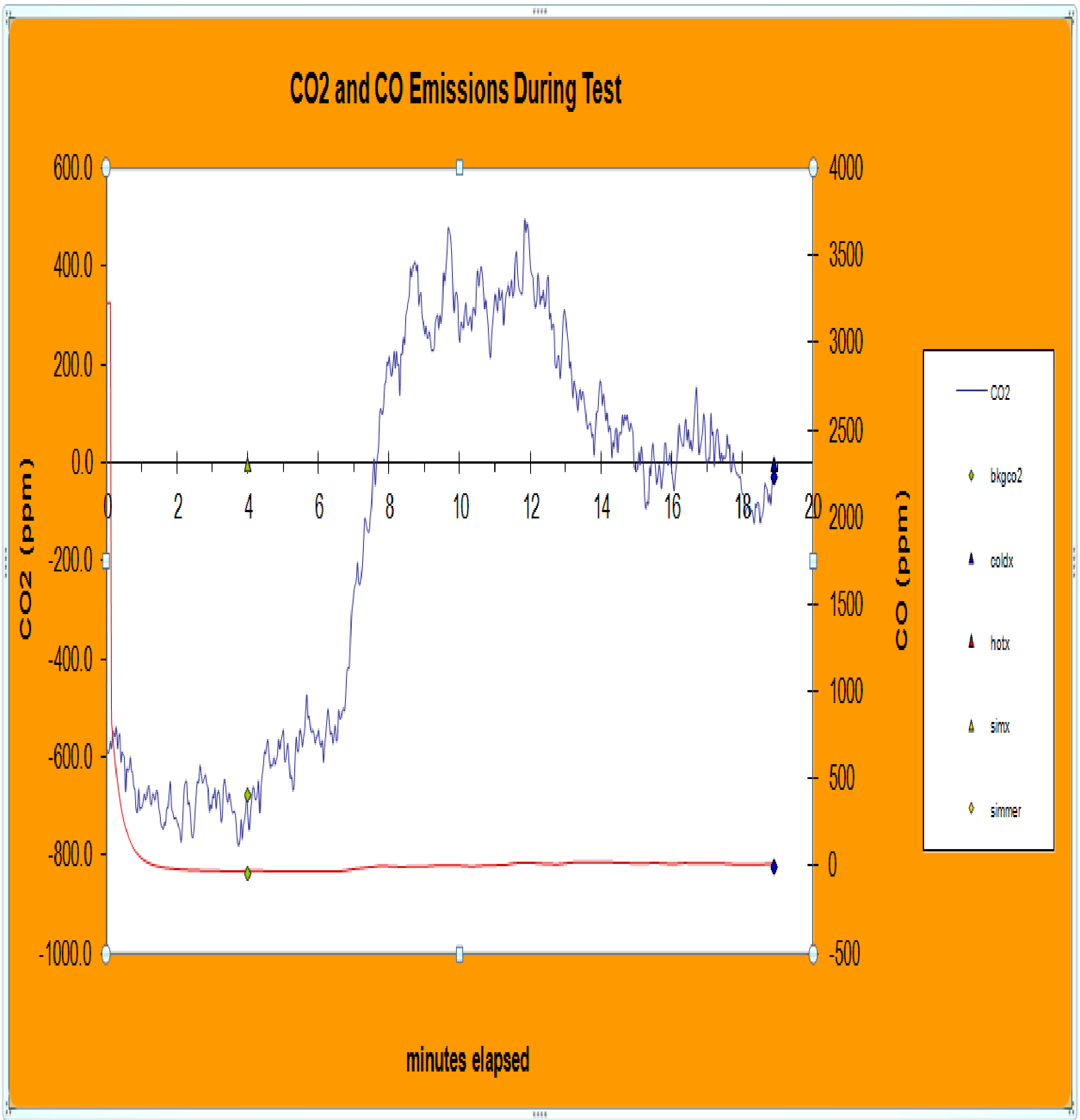

Figure 7 CO_2 and CO Emissions During The Test For Briquettes Produced From Carbonized Rice Husk

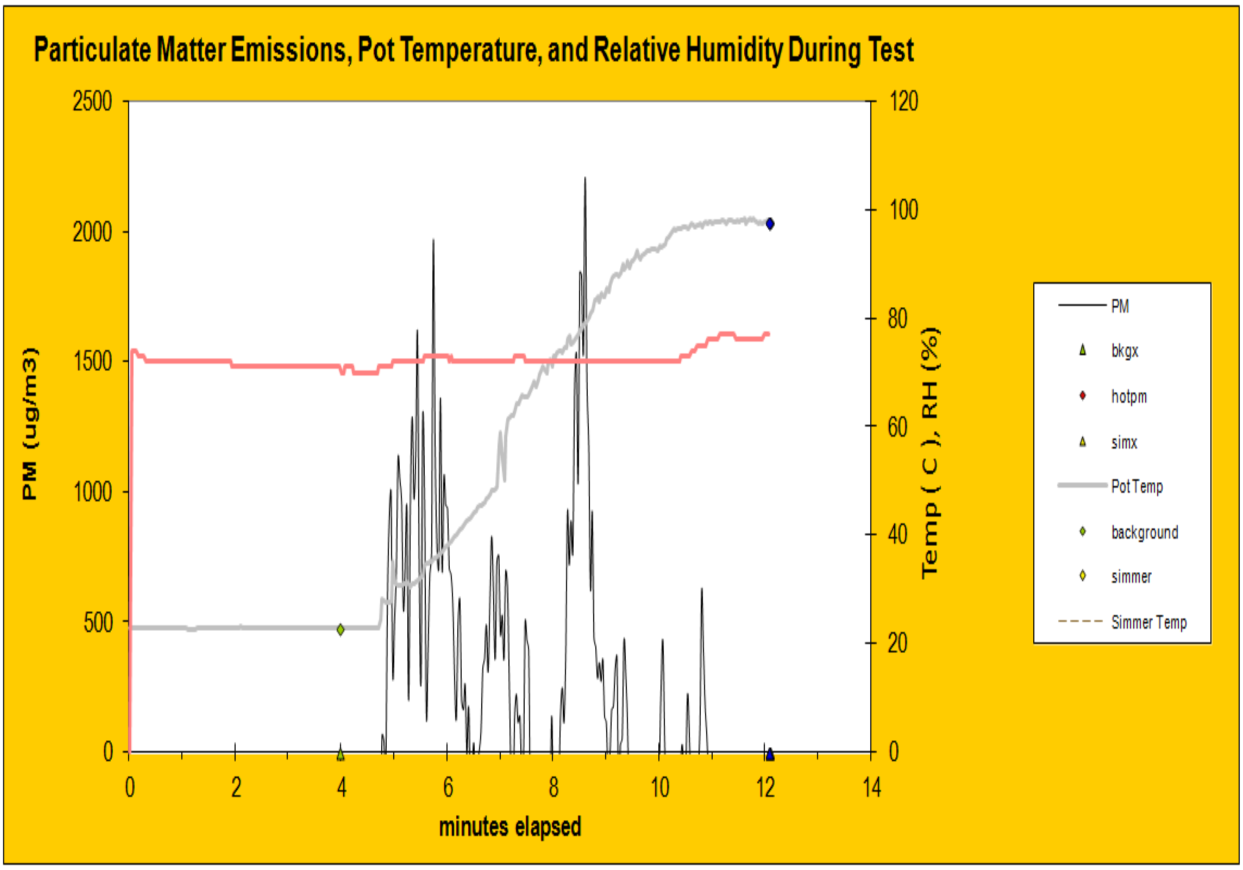

Figure 8 Particulate Matter Emissions, Pot Temperature, and Relative Humidity During the Test for Briquettes Produced from Uncarbonized Rice Husk

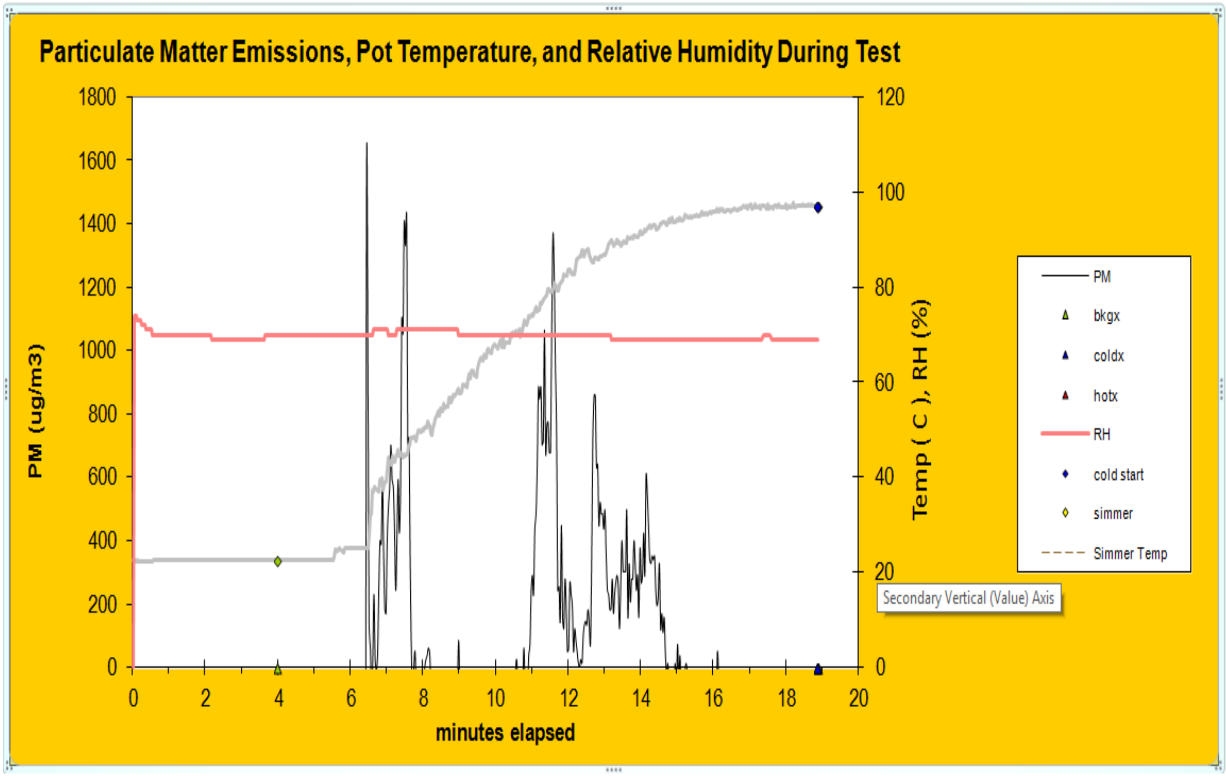

Figure 9 Particulate Matter Emissions, Pot Temperature, and Relative Humidity during the Test for Briquettes Produced from Carbonized Rice Husk

TABLE 3: IWA VITA WBT Ties_2012 Specification for stove testing

IWA VITA WBT Tiers	Units	Tier0	Tier 1	Tier 2	Tier 3	Tier 4
High Power Thermal Efficiency	%	<0.15	≥0.15	≥0.25	≥0.35	≥0.45
Low Power Specific Consumption	MJ/min/L	>0.05	≤0.05	≤0.039	≤0.028	≤0.017
High Power CO	g/MJ	>16	≤16	≤11	≤9	≤8
Low Power CO	g/min/L	>0.2	≤0.2	≤0.13	≤0.1	≤0.09
High Power PM	mg/MJd	>979	≤979	≤386	≤168	≤41
Low Power PM	mg/min/L	>8	≤8	≤4	≤2	≤1
Indoor Emissions CO	g/min	>0.97	≤0.97	≤0.62	≤0.49	≤0.42
Indoor Emissions PM	mg/min	>40	≤40	≤17	≤8	≤2
Safety	Index	<45	≥45	≥75	≥88	≥95

4.0 CONCLUSION

Briquettes were produced from carbonized and uncarbonized rice husk using a locally fabricated hydraulic press. The carbonized briquettes showed better proximate properties than the uncarbonized ones. The thermal properties of the briquettes improved due to the carbonization of rice husk before briquette production. Carbon monoxide emissions of the briquette equally reduced as a result of carbonization. The briquette was found smokeless due to the low carbon monoxide content and a great substitute for coal briquette concerning environmental pollution. Both briquettes were classified under tier four according to the IWA specification standard for briquette. This confirmed the produced briquettes of high quality.

REFERENCES

AjitKaur, M. R., and Krishnendu, K (2017) Densification of Biomass by Briquetting: A Review. *International Journal of Recent Scientific Research* . 2017; Vol8,10 : 20561-20568

Aina, O.M.,Adetognu, A.C., and Iyiola, K A (2009).Heat energy from value-added sawdust briquettes of Albiziazygia.*Ethiopian Journal of Environmental Studies and Management*; 2009; Vol 2,1pp.42-49.

Akowuah, J.O., Kamaushuir, F.,and Miotchual, S.J.(2012).Physico-chemical characteristics and market potential of sawdust charcoal briquette. *International Journal of Energy and Environmental Engineering;* 2012; Vol 3, 20 pp1-6

A.O.A.C. (1975).Official Methods of Analysis, 12th edition, Association of Officials Analytical Chemist, Washington DC; 1975.

Bhattacharya, S.C., and Salam, P.A. (2002). Low greenhouse gas biomass option for cooking in the developing countries, *Biomass and Bio-Energy*, 2002: Vol 22, pp305-317.

Chukwueyem, S.R., Adeniyi, O.A., Williams, J.K., Magnus, O.A., Peter, D.G., Margaret, J.H., Ibrahim, A.U., and Emeka, R.O., (2015). Analysis of energy market conditions in Nigeria. Central Bank of Nigeria (Occasional Paper No. 55), 2015.

Deepak, K.B., Jnanesh, N.A.(2015).Biomass Briquettes-A renewable source of clean energy. *The International reviewer* 2015; Vol 2,2 pp 27-30

Husain, Z.,Zainac, Z., Abdullah, Z. (2002). Briquetting of palm fiber and shell from the processing of palm nuts to palm oil. *Biomass and Bioenergy*, 2002; Vol22: pp505-509

International Workshop Agreement (IWA) (2012). ISO Standard Specification for stove testing 2012

Oladeji, J.T. (2011). Comparative fuel characterization of Briquettes produced from two species of corncob, *Researcher*; 2011,Vol3,4.

Siti-Farhana,B. (2011).To study the production viability of Bio-Briquette from oil palm decanter cake, Faculty of Chemical and Natural Resources University Malaysia Pahang, 2011.

UNEP. (2007). Converting Waste Agricultural Biomass into a Resource.Compendium of Technologies.United Nations Environmental Programme.Division of Technology, Industry, and Economics International Environmental Technology Center Osaka/Shiga, Japan, 2007.

World Health Organisation.(2006) .Fuel for life, household Energy and Health. 20 Avenue Appia, 1211 Geneva 27 Switzerland, 2006