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Evaluation of thermal Efficiency of Double-hole Sawdust Stove using Different Biomass Residues in Sokoto, Nigeria

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Abstract: *A cooking energy crisis exists today in Nigeria. The cooking energy demand far surpasses the supply. Many households have been forced by prevailing circumstances to switch from one source/type of cooking energy to the other This study evaluated the thermal efficiency of a double hole sawdust stove in Sokoto, Nigeria. Different biomass residues that includes; sawdust, rice husk and millet husk were used as fuel separately in evaluating the efficiencies of the stove and a comparison was made to ascertain the best fuel for the stove used. In the analysis, control cooking test, water boiling test and burning of the three fuels completely was carried out using the common food items namely; water, rice and beans. Mass of each fuel required in cooking half kilogram of rice and beans were determined. Moreover, mass of each waste material required for boiling two liters of water and the time taken to burn the three fuels completely using the stove were also recorded. The burning test results were 0.0983kg/min, 0.0473kg/min and 0.0664kg/min for sawdust, rice husk and millet husk respectively. The results indicate that rice husk waste material is averagely the best because it has the lowest burning rate. It requires lesser amount of fuel per mass of cooked rice and beans and using it as fuel, the stove had the highest thermal efficiency of 46% and 47%for cooking rice and beans respectively.*

Keywords: *Biomass residues, double-hole stove, cooking test, efficiency, and common food*

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I. Introduction

The need for energy resources management has long been felt in Nigeria. This gave rise to the establishment of the National Centres for Energy Research and Development in three of the nation's Universities in 1976 and a fourth centre was later opened in 1980. The Energy Commission of Nigeria was established in 1987 and was charged with the responsibility for overall energy sector planning; the formulation and monitoring of plans and policies to ensure that the nation's energy needs in the short, medium and long-term can be met. Researchers at the National Centres for Energy Research and Development and individual researchers have been working to develop renewable energy technologies and better energy efficient cooking appliances (Anozie, et al.,2004).

Energy availability in the rural as well as urban areas of Nigeria is fast becoming a great challenge with the high cost of cooking gas and kerosene and environmental problems associated with firewood (Oladeji, 2011). In many part of the world especially in Africa, it is mostly the women and children that are responsible for fuel collection. Often a times, they travel for hours to find and fetch fuel wood, wasting most of their times and energy. Many times, the children are kept out of school due to this process. Lately, much attention has been focused on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuel energy sources. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required (McKendry, 2002).

In response, a growing number of governmental and non-governmental organizations have participated in initiatives to improve indoor air quality and reduce biofuel consumption. Intervention includes improved ventilation, cleaner and more efficient fuel sources, and improved stoves that increases fuel economy, reduce health risk and exposure to danger on the field where these fuel woods are collected (Mehta and Shahpar, 2004). The use of sawdust stove for cooking can cut down the fuel expense by more than 60% and can help to overcome the harmful effect arising from combustion of fossil fuels. Over the last three decades, a number of sawdust stove have been designed and developed yet, there is need for improvement in the thermal performance of sawdust stoves which are subjected to the selected materials for its components and design improvement (Bryden et al., 2002). Therefore the paper intends to evaluate the performance of biomass materials, sawdust, rice husk and millet husk with respect to their burning rate, comparatively analyze the performance of double hole improved sawdust stove and to recommend solutions for the improvement of stove.

II. Materials and Experimental procedures

2.7 2.1 Materials

The materials used for the test includes the biomass material used as fuel (rice husk, sawdust, and millet dusk), water, cooking pot, liquid in glass thermometers, watt meter, fuel/food calorimeter, measuring cylinder, weighing balance, meter rule, matches and double hole ICS. The specimens used during the cooking test were Rice (Oryza Sativa) and beans (phaseolusvulgaris).

2.2 Description of the improved sawdust stove.

The improved sawdust cooking stove is made up of galvanized iron sheets designed inform of a cylinder with a central hole and side opening at the bottom. The central hole is meant to serve as the flame outlet while the side opening is for the supply of air into the stove. Appropriate biomass (rice husk, sawdust, and millet dusk) which are in the form of loose briquettes are usually compacted into the stove by means of a piece of metal mold. The pot is mounted on top of the stand provided on the stove. The fuel is usually ignited and continues to burn around the periphery of the central hole. Figure 1.0 is a systematic diagram of the improved sawdust cooking stove. **.**

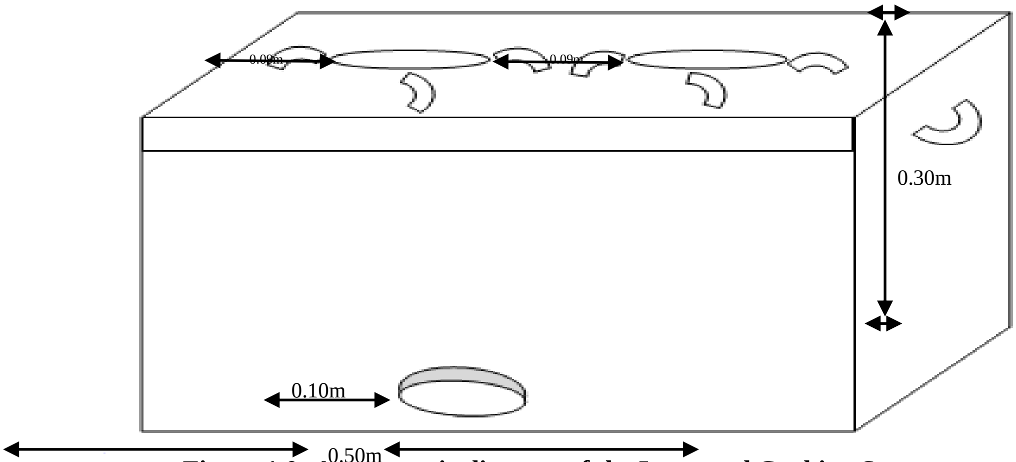

Figure 1.0: A systematic diagram of the Improved Cooking Stoves.

2.3 **Determination of Calorific Value**

This is the heat liberated when a unit quantity of fuel completely burnt; it is determined using fuel/food calorimeter mode L04 -340 by Griffin and George Ltd.

2.4 Experimental Set Up

All tests were conducted at the Sokoto Energy Research Centre. The biomass materials used as fuel were bought in the market that is the sawdust and the rice husk while the millet husk was bought in the nearby village and all were assembled in the laboratory for the water boiling cooking tests and burning of the fuel completely. For each test, the stove was filled with waste specimen (rice husk, sawdust, and millet dusk), with the help of a metal mold which was inserted through the hole to the bottom of the stove and the shaft was held straight up while pouring each of the biomass materials (rice husk, sawdust, and millet dusk) around it. As the chamber was being filled, the fuel was compressed making it very compact for a better combustion process. When the stove was full, the top was completely covered with the stove cover. Then the mold was twisted back and forth and carefully pulled out of the packed fuel to avoid scattering of the fuel Akinbode (1996).

2.5 Water boiling test

The water boiling test is a simplified simulation of the cooking process. It intends to measure how efficiently a stove uses fuel to heat up water in a cooking pot and the quantity of emission produced while cooking in a controlled environment (Makonese et al., 2006). A simple laboratory tests was conducted to compare the performance of the three different biomass materials using an improved sawdut syove, a known quantity of fuel was fed into the stove and piece of paper was used to ignite it, while a metallic pot with known volume of water was placed on the stove. 1 and 2 litres of water were used to evaluate the performance on both single and double hole stove respectively. A thermometer was inserted in the pot to measure the initial temperature and subsequent rise in every 2 minutes, until the water boiled to a steady boiling temperature i.e. boiling point. The percentage heat utilization of the three samples materials used as fuel was also measured.

2.6 Controlled Cooking test

This is based on the agreed provisional international standard, with primary objectives of comparing the amount of fuel consumed and the time spent in cooking meal with different stoves. It can also effectively determine whether the stoves can cook varieties of meal normally prepared in particular locality or not. The controlled cooking test enables the investigator to fine out the amount of fuel required to cook a kilogram of well cooked food termed as specific consumption figure. (Danshehu et all., 1996).

2.8 Total Burning Test

The total burning test was carried out in order to determine the time it would take each of the biomass materials used as biofuel to burn off completely. Each of them were loaded into the stove and allowed to burn while observing the time it takes for each to burn completely and the results recorded in Table 3.3

2.8 Specific Fuel Consumption

This is defined as the amount of solid fuel equivalent used in achieving a defined task divided by the weight of the task. The specific fuel consumptions of the fuels (appendix A) were determined using equation 2, expressed by (Onuegbu et al., 2011) as:

$$\text{Specific fuel consumption} = \frac{m_f}{m_{cf}} \ldots\ldots (1)$$

Where $m_{f=}$ mass of fuel used

$m_{cf}=$ mass of cooked food

2.9 Determination of the stove efficiency.

In order to get at least some degree of scientific exactness, the Eindhoven formula (F.O Akinbode 1996) was used for measuring the degree of efficiency of the stove.

The Eindhoven formula below was used to calculate the stoves efficiencies as:

$$E_{ff} = \frac{M_w \times C_w\ (T_f - T_i) + MvR}{M_b \times H_c} \times 100\% \ldots\ldots 2$$

Where E_{ff} =fuel efficiency, M_w = initial mass of water in the pot (kg), C_w= specific heat capacity of water (4.2kJ/kg), T_f= final temperature of water (^oC), T_i= initial temperature of water (^oC), Mv=amount of water evaporated during the experiment (kg), $M_{b=}$mass of burnt fuel (kg), H_c= combustion value of fuel used (kJ/kg), R= Heat of evaporation of water at atmospheric pressure and 100^{o}C (2256.9Kj/kg)

III. Results and Discussion.

Table 1.0: Results of Cooking Test of rice using the biomass residues as fuel.

Biomass materials	m_1 (kg)	m_2 (kg)	m_3 (kg)	m_4 (kg)	m_5 (kg)	m_6 (kg)	t (mins)
Rice husk	8.90	17.10	8.20	15.60	1.50	6.70	31.70
Millet husk	8.90	10.90	2.00	9.90	3.00	1.00	45.20
Sawdust	8.90	11.80	2.90	9.60	2.20	0.70	22.40

Table 2.0: Results of Cooking Test of beans using the biomass residues as fuel.

Biomass materials	t (min)	m_1 (kg)	m_2 (kg)	m_3 (kg)	m_4 (kg)	m_5 (kg)	m_6 (kg)
Rice husk	42.30	8.90	16.10	7.20	14.10	2.00	5.20
Millet husk	58.00	8.90	14.90	6.00	11.40	3.50	2.50
Sawdust	38.90	8.90	12.00	3.10	11.40	2.50	0.60

Table 3.0: Results of Thermal Efficiency and the burning rate during cooking test.

Type of fuel	Type of food cooked	Burning rate kg/min	Thermal efficiency %	Mass of fuel used kg
Sawdust	Rice	0.0983	32	2.2
Rice husk	Rice	0.0473	47	1.5
Millet husk	Rice	0.0664	40	3
Sawdust	Beans	0.0643	42	2.5
Rice hudk	Beans	0.0483	46	2
Millet husk	Beans	0.0583	45	3.5

IV. Discussion of results

Tables 1.0 and 2.0 showed the cooking test results of rice and beans; The results revealed a significant difference. Sawdust had the fastest cooking time of 22.4 min. followed by rice husk with 31.7 min. and millet husk had the longest cooking time of 45.2 min. The burning rates of these fuels were 0.0983kg/min, 0.0473kg/min and 0.0664kg/min for sawdust, rice husk and millet husk respectively.

Having tested the three different biomass waste materials in cooking of rice and beans the results are shown in Table 3.0. The burning rates of the samples materials in cooking beans were 0.0643kg/min, 0.0483kg/min, and 0.0583kg/min respectively for sawdust, rice husk and millet husk with rice husk having the lowest burning rate. Moreover the times taken to cook beans on that stove were 58.0min using millet husk, 38.9min with sawdust and 42.3min using rice husk. The results obtained reveals that the stove had the highest efficiency when using rice husk as fuel in cooking both rice and beans. Also the mass of fuel used and the burning rates were low in both tests using rice husk as fuel. Therefore rice husk was recommended the best because it had the lowest value of burning rate it can cook food in a shorter time using lesser amount. The difference in the tested parameters can be explained by their differences in heating value.

V. Conclusion

From the results of the test carried out on the Improved Cooking Stove; it was found that the development of this stove would lighten the burden of rural and urban dwellers in search for energy. It would also decrease the amount of solid waste found in our big cities and would lead to less dependence of rural and urban dwellers on kerosene and liquid petroleum gas that are very scars, expensive and not readily available all the time. It would also reduce deforestation rate. Thus, the Millet husk had the highest burning rate of 0.0983 kg/min while the rice husk had the lowest burning rate of 0.0473kg/min and sawdust had 0.0664 kg/min. Conclusively rice husk with the lowest burning rate would serve as a better fuel with longer time in cooking food compare to the others.

References

[1]. Anozie, A.N., Bakarea, A.R., Sonibarea, J.A., and Oyebisi, T.O. (2007), Evaluation of cooking energy cost, efficiency, impact on air pollution and policy in Nigeria. Elsevier, ScienceDirect, Energy 32 pp. 1283-129 www.elsevier.com/locate/energy

[2]. Bryden M., Still D., Scott P., Hoffa G., Ogle D,, Bailis R., and Goyer K., (2002). Danjuma M.N., Maiwada B., and Tukur R (2013). Disseminating Biomass Briquetting Technology in Nigeria: A case for Briquettes Production Initiatives in Katsina State. International Journal of Emerging Technology and Advanced Engineering 3(10), 12-20.

[3]. Danshehu B.G., Atiku A.T. and Tambuwal A.D. (1996). Effect of Glazing on the Performance of Improved Wood-Burning Stoves. Nigerian Journal of Renewable Energy , 4(1), 15-18

[4]. F.O. Akinbode (1996). The Development of a sawdust stove, Nig. J. Renewable Energy, 4,

[5]. 53-57.

[6]. Makonese T., Robinson J., Pemberton-Pigott C. and Annegarn H. (2006). A Preliminary Comparison of Stove Testing Methods between the Water Boiling Test and The Heterogeneous Testing Protocol. 1-8.

[7]. Mckendry P. (2002). Energy production from biomass (part 2): conversion technologies. Bioresource Technology 83, 47–54

[8]. Mehta S. and Shahpar C., (2004). The health benefits of interventions to reduce indoor air ollution from solid fuel use: a cost-effectiveness analysis Energy for Sustainable Development 8(3) 53-59.

[9]. Oladeji J.T. (2011). Pyrolytic Conversion of Cow Dung into Medium-Grade Biomass Fuels. International Journal of Pure and Applied Sciences, 4(2), 173-178.

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