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Performance Of Energy Efficient Stoves Using Selected Wood Species In North Eastern Nigeria

H. B. Biri[1] Ibrahim[2], A.Q. Sabo[3], A.

1. *Department of PreND and Remedial Studies, Federal Polytechnic Bauchi, Bauchi State, Nigeria.*
2. Department of Chemistry, Police Academy, Wudil, Kano State, Nigeria
3. Department of Environmental Management Technology, Abubakar Tafawa Balewa Univeristy, PMB. 024,Bauchi State, Nigeria

Abstract: *The study examined the calorific values of Five Nigerian wood species in North Eastern Nigeria. In order to evaluate the performance and effectiveness of Energy Efficient Stoves with the five wood species. Water Boiling test (WBT) and specific fuel wood consumption were conducted. The results of the Bomb calorimeter reading revealed that the calorific values of the wood species are as follows: Anogeisus loecarpus (65031J/g, 15532Kcal/Kg), Balanite aegyptiaca(63207J/g, 15096Kcal/Kg)Pericopsis laxiflora(62650J/g, 14963Kcal/Kg), Presopis africana (61154J/g, 14606Kcal/Kg) and Danellia Oliveris (49428J/g, 11805Kcal/Kg) respectively. With regards to time spent in cooking a meal, the study revealed about 30 - 50% reduction in the times spent. The study established that the five indigenous wood species are of high calorific values, the calorific values have positive correlation with the efficiency of the Energy Efficient Stoves, thus the need for more research into only their cultivation, but their utilization in an environmentally friendly and sustainable manner cannot be over emphasized.*
Keywords: *Calorific Value, Efficiency, Wood Fuel, environment*

I. Introduction

About half of the world's population cook most of their meals with the aid of biomass (Scurlock and Hall, 1989). In most rural parts of Nigeria, for instance, the traditional three – stone stove has been the most common medium of heating water and cooking meals amongst rural dwellers. Most traditional bios-mass stoves are very inefficient. About 3 billion people are without clean cooking facilities, according to the International Energy Agency (IEA) and they rely on the traditional use of biomass for cooking (IEA 2011). The number of households using traditional biomass fuels is estimated to rise even further by an additional 100 million people by 2030. Reliance on these traditional fuels is higher with over 90% dependence on such energy sources in rural areas. (Bruce et al. 2000, Schlag & Zuzarte 2008).

The major environmental problems related to energy production, distribution and consumption in Nigeria are mainly deforestation, pollution and climate change. From available statistics, the nation's 15 million hectares of forest and woodland reserves could be depleted within the next fifty years. These would result in negative impacts on the environment, such as soil erosion, desertification, loss of biodiversity, micro-climatic change and flooding. Most of these impacts are already evident in different ecological zones in the country, amounting to huge economic losses.

Some of the major consequences of the climate change around the globe are increases in rainfall, melting of ice in the Arctic and Antarctic circles; this has increased the volume of water in the oceans and rivers leading to flooding that coastal cities and towns around the globe with thousands of lives and property destroyed (Gomper & Olaolu, 2013).

Nigeria had in 2012 witnessed flooding that overwhelmed the country with twenty six states affected. This is attributed that flooding to the global warming phenomenon caused by the careless misuse of the environment particularly in the area of widespread deforestation. (Farukanmi, 2006)

According to Butler (2012), Nigeria currently has less than 10% of her total land area under constituted forest reserves and that the implication of this high rate of deforestation of her primary forests is that the country is more prone to desert encroachment, destruction of soil structure, extinction of wild life, drought and of course global warming which leads to climate change.

Deforestation has a significant impact on the environment. It affects hydrological cycle, leaching and compacting of the soil, acceleration of erosion processes, loss of species diversity, change of water quality and change in water life habitant (Mercado, 1990). According to Yahaya (2002), there exists a direct relationship between human population and fuel wood demand. For instance, the quantity of fuel wood consumed in Kano State of Nigeria was ratherhigh despite the growing urbanization. This has led to what may be termed rural-urban energy crisis where large quantities of fuel wood are supplied to the city from the rural areas. Improvement in the transport infrastructure has made it possible to export the fuel wood crisis from Kano to other part of the country. Cline-Cole *et al* (1988) have reported that fuel wood was transported to Kano in lorry loads from distances of up to 400 kilometers. Momoh and Soaga (1999), in their study; however, handed a word of caution to the use of existing data on fuel wood production and consumption. In their opinion, fuel wood consumption in the country is as disparate as the number of sources of such estimates. This is because fuel wood is usually obtained by self-collection by households in some places, and only relatively small quantities enter the market. Nevertheless, available data show that fuel wood consumption has increased rapidly in recent decades. According to Sanda *et at* (1991), consumption of fuel wood in Nigeria rose from 44 million cubic meters in 1984 to 80 million cubic meters in 1992. "The average annual per capita consumption of fuel wood was estimated to be 0.72 m^3 or 171kg oil equivalent (KOE) 1985. This per capita annual consumption increased to 0.80m^3 or 190 KOE in 1995. In his work, however, McNamara (l990), estimated 12m^3or 267 KOE for 1984/86. Momah and Saoga, (1999) also reported increase in fuelwood consumption in the country. Annual average rate of increase in per capita consumption of fuel wood in KOE between 1984/86 production of fuel wood and increase in industrial demand for wood. The Nigerian population increased from about 63 million in 1960 to about 85.5 million in 1991 and to over 170 million in 2010. The rate of population growth is not commensurate with the rate of increase in essential facilities including energy supply, thus the problem of deficit in energy supply.

The aim of this research is to assess the performance of Energy Efficient Stove using the wood species in North Eastern Nigeria.

II. Materials And Methods

2.1 Study Area

Map of Nigeria showing the Northeastern state with the Study areas highlighted

2.2 Equipment

1. Energy Efficient Stoves (metals and clay brand of stoves)
   - 1-hole clay stove (15cm by 13 cm & 27cm by 13.5cm)
   - 2-hole clay stove (22cm by 14cm)
   - 4-hole clay stove (45cm by 11 cm)
   - Metal Stove (33 cm by 19 cm & 37 cm by 18 cm)
2. Thermometer
3. Stop watch
4. Metal pots
5. Firewood
6. Weighing balance
7. Oxygen Bomb Calorimeter XRY-1C model

2.3 Consumables

1. Water
2. Firewood:
   - *Prosopis africana* (Kirya)
   - *Danielia oliveri*(Maje)
   - *Anugeisus leiocarpus* (Marke)
   - *Balanites aegyptiaca* (Aduwa)
   - *Pericopsis laxiflora*(Karya Gatari)
3. Beans, Thailand Rice, Yam and Meat (Beef)

2.4 Methods

The woodstoves were assembled in an open space to match the condition in which cooking is generally done in the rural areas. Metal pots were used; two types of test were conducted.

Water Boiling Test (WBT)

Controlled Cooking Test

Water boiling test was conducted to determine the efficiency of the stoves which can be expressed by the percentage of heat utilized which is given as

Phu = (Total heat Utilized x 100) / Net heat supplied

The test includes "HIGH POWER" and "LOW POWER" phases. The higher power phase involves heating of water from ambient temperature to boiling as rapidly as possible and keeping it boiling at the same high power for 15 minutes. The lower phase follows when the power is reduced to the lowest level needed to keep the water within 200C of boiling over a one-hour period.

The water boiling test uses percentage heat utilized to evaluate the stoves' performance.

$$P.H.U = M_w S(t-Q) + M_p Sp (Pt-t) + MvLvX^* \text{ X } 100$$

WmCw - WeCc

Where Mw = initial mass of water
t = final mass of water
at = ambient temp
Cp = specific capacity of material of the pot
M = mass of water evaporated
L = latent heat of vaporization of water
Wm = mass of the wood
Cw = calorific value of wood
We = mass of charcoal remaining after test
Cc = calorific value of charcoal

2.5 Controlled Cooking Test

The agreed provisional international standard, with the primary objectives of comparing the fuel wood consumed and time spent in cooking a meal with different stoves were followed. The controlled cooking test also determines the fuel wood required to cook a kilogram of well cooked food termed as specific consumption.

Specific consumption = Mass of Fuel Wood Consumed
Mass of cooked food
(SFC) = W (1 – M) – 1.5C / WF
Where
W = mass of fuel wood burned
M = moisture content of wood
C = mass of charcoal remaining after the test
WF = mass of cooked food
The time spent in cooking a kg of cooked has been defined by the expression

$$T = \frac{T}{WF}$$

Where;
T = total time spent in cooking
Wf = total weight cooked food
Calorific Values of Indigenous Wood Species

III. RESULT AND DISCUSSION

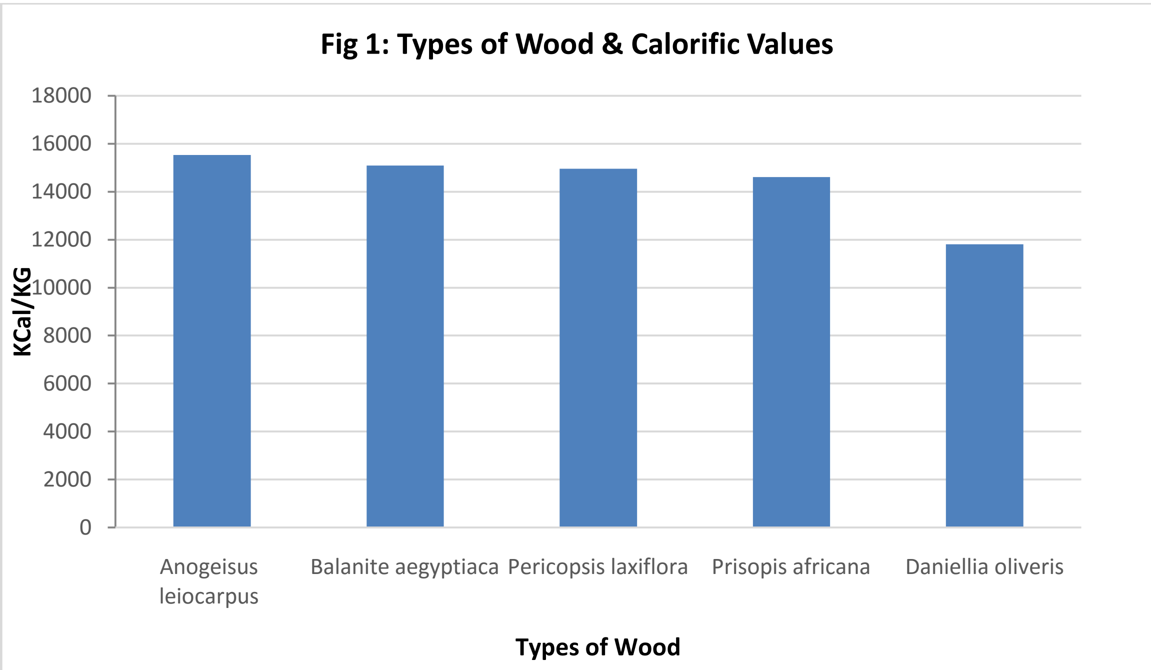


Fig. 1: The average gross heat of combustion (calorific value) for each species studied and measured with oxygen bomb was given in fig 1. The results showed that calorific value of the five (5) tested wood species is as follows: Anogeisus Leiocarpus was found to have the highest calorific value of 65631 J/g, Balanite Aegypticica (63207 J/g), Pericopsis laxiflora (62650 J/g), Prisopis Africana (61154 J/g) and the least was Daniellia Oliveris (49428 J/g). The moisture content of the tested samples are Anogeisus Leiocarpus (4.1%), Balanite Aegypticica (2.7%), Pericopsis laxiflora (6.5%), Prisopis Africana (2.6%) and Daniellia Oliveris (3.5%). In a similar study by Ogunsawo et al (2007) it was established that

Anogeisus leiocarpus is the most preferred woods species for charcoal production in their study area. Adekiigbe (2012) accerted that Terminalia superb wood species is very efficient and would be of good use as fuel. Khider and Fisaki (2012) reported that Acacia, Mellifera, Aecia Senegal and Eucalyptus Tereticornis wood species were found to have high calorific values and indicated that they could be utilized as fuelwood of charcoal. (Abubakar et al. 2011) in their studies established that Adonsonia Digitata fuelwood exhibited a high calorific value and high combustion rate.
Percentage Heat utilized of Traditional three-stone Stove and the Energy efficient stove using the five selected wood species.

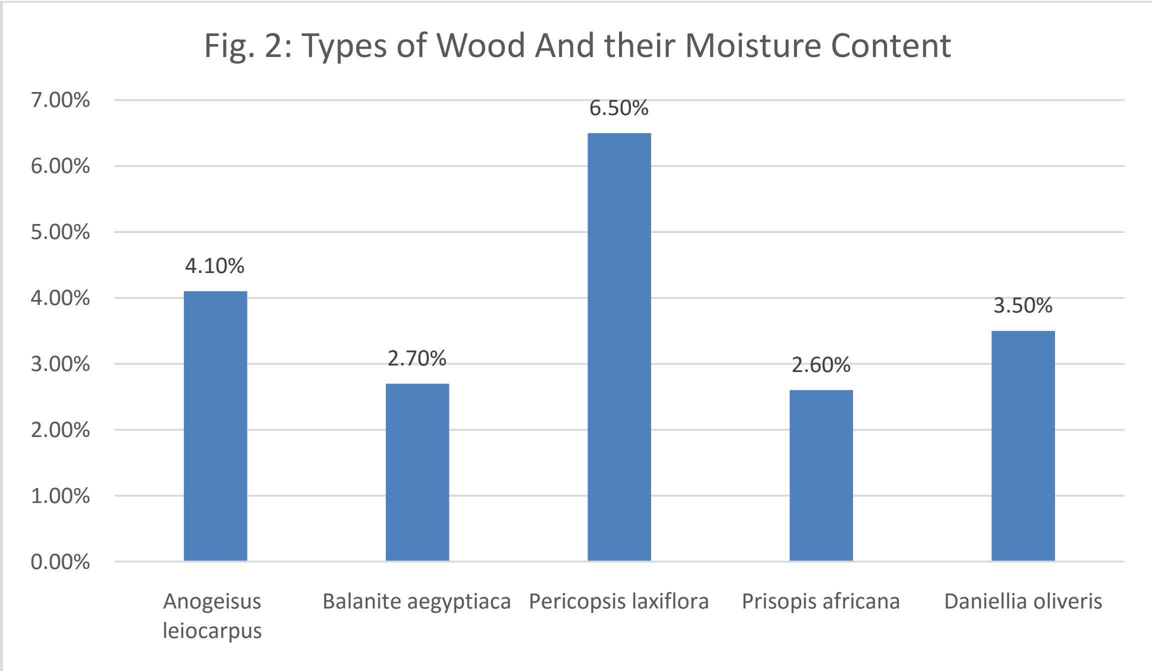
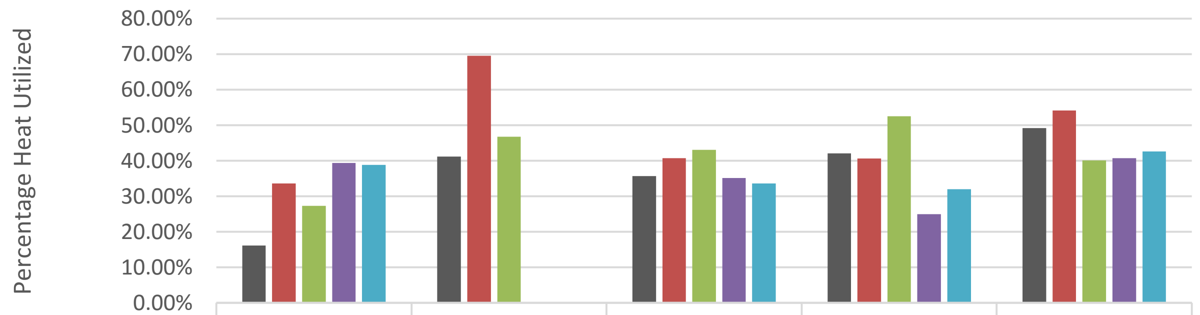


Fig. 2: On the basis of the moisture content, all the samples showed a low moisture content. According to Lucas and Fawepe (1984), low moisture content in a fuel is usually preferable.



	Aduwa	Karya Gatari	Kirya	Maje	Marke
2-Holes Stove	16.16%	41.18%	35.68%	42.05%	49.23%
1-Hole Stove	33.61%	69.57%	40.68%	40.67%	54.10%
4-Holes Stove	27.29%	46.78%	43.03%	52.55%	40.13%
33 x 19 cm Stove	39.40%	0	35.14%	24.93%	40.76%
37 x 18 cm Stove	38.87%	0	33.60%	32.01%	42.65%

Type of Stoves

Fig 3 presents the percentage heat utilized for clay and metal stoves with the selected wood species. It can observed that the wood species that exhibited the highest calorific values (pericopsis laxiflora and anugeisus leocarpus) gave the highest percentage heat utilized. The indicates that there is a positive correlation between calorific value and performance the stoves. A comparison of the amount of fuel-wood consumed and time spent in cooking four popular meals (Rice, Beans, Yam and Meat) was carried out. Figure 3, 4, 5, and 6 displayed the fuelwood consumption for wood species (Prisopis Africana, Anogeisus Leiocarpus, Pericopsis laxiflora and Danielia Oliveris) with both the traditional three stone and improved wood stoves. The result showed that those wood species that exhibited the high calorific values gave the highest percentage heat utilized. On the other hand, the charts on exhibits 7, 8, 9, and 10 present the time sent in cooking the four different dishes with the improved stoves.

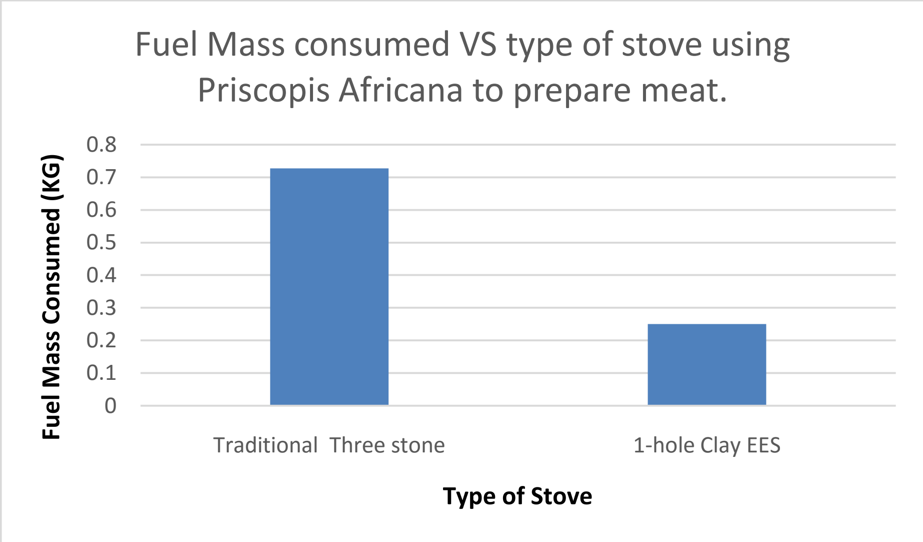


Fig. 4: Prosopis africana with, Meat Fuel Mass Consumed

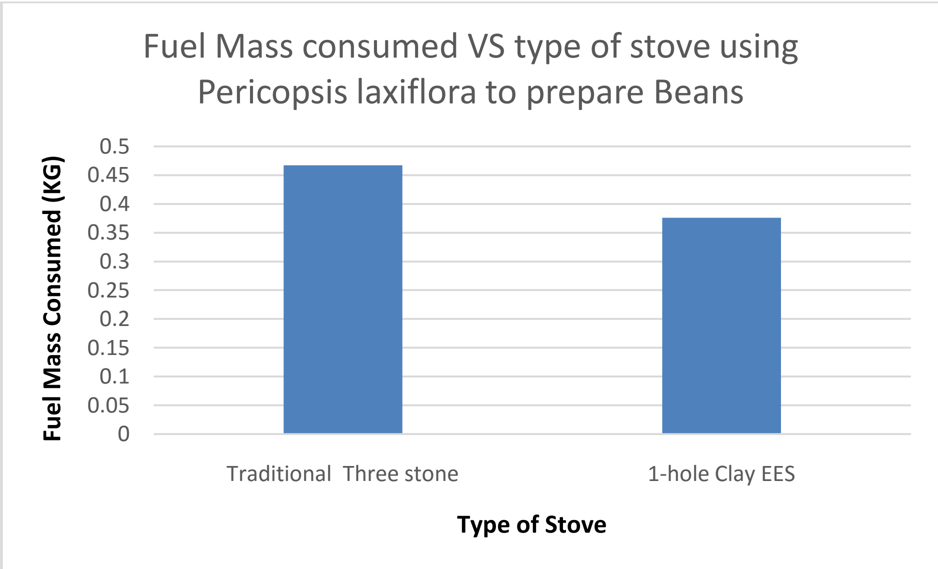


Fig. 5: Pericopsis laxiflora with Beans, Fuel Mass consumed

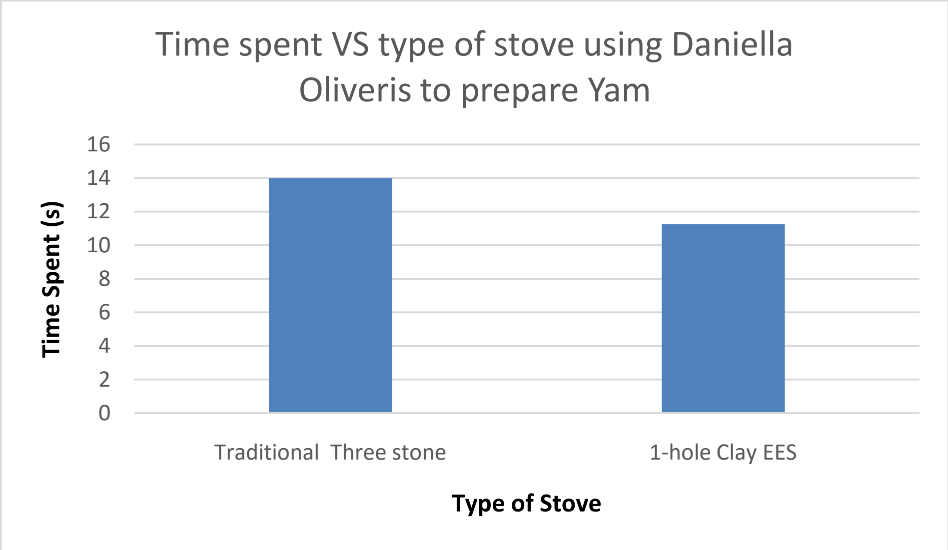


Fig. 6: Daniella Oliveris with Yam, Fuel Mass consumed

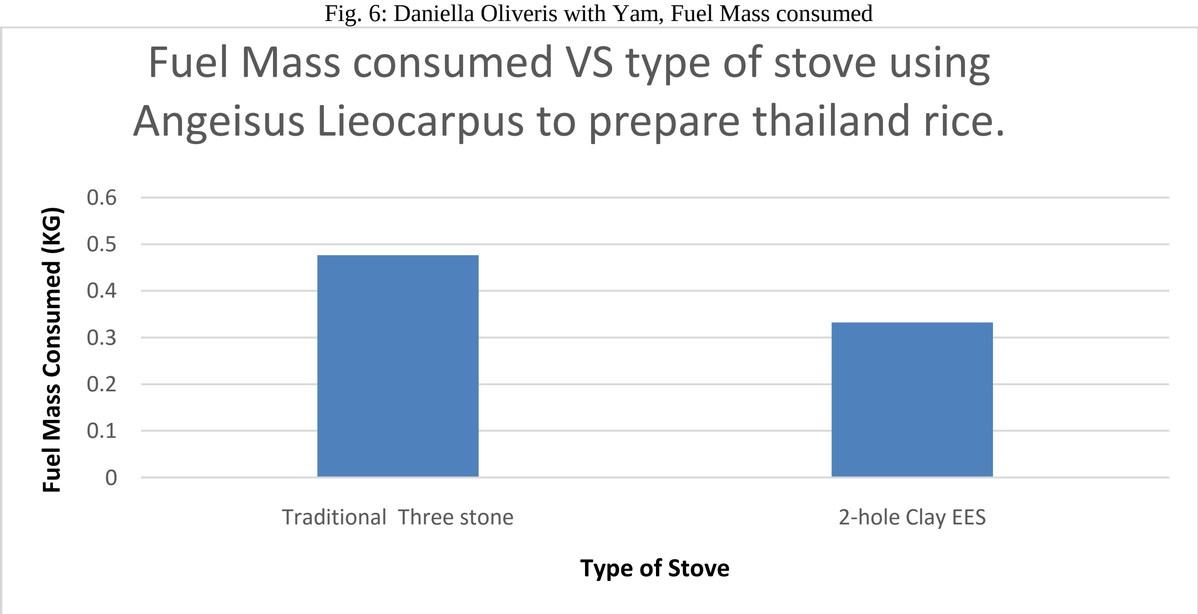


Fig. 7: Anogeisus Lieocarpus with Thailand Rice, Fuel Mass Consumed

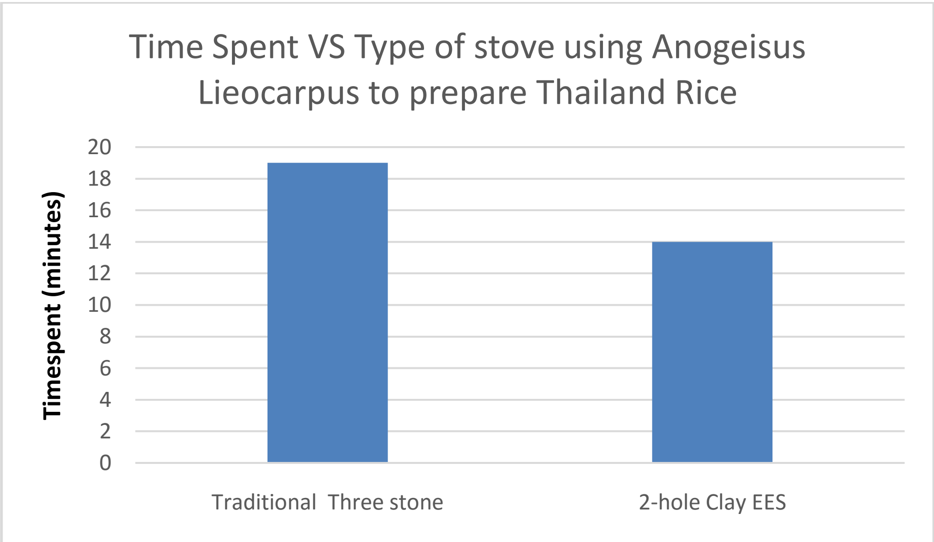


Fig. 8: Anogeisus Lieocarpus with Thailand Rice, Time Spent

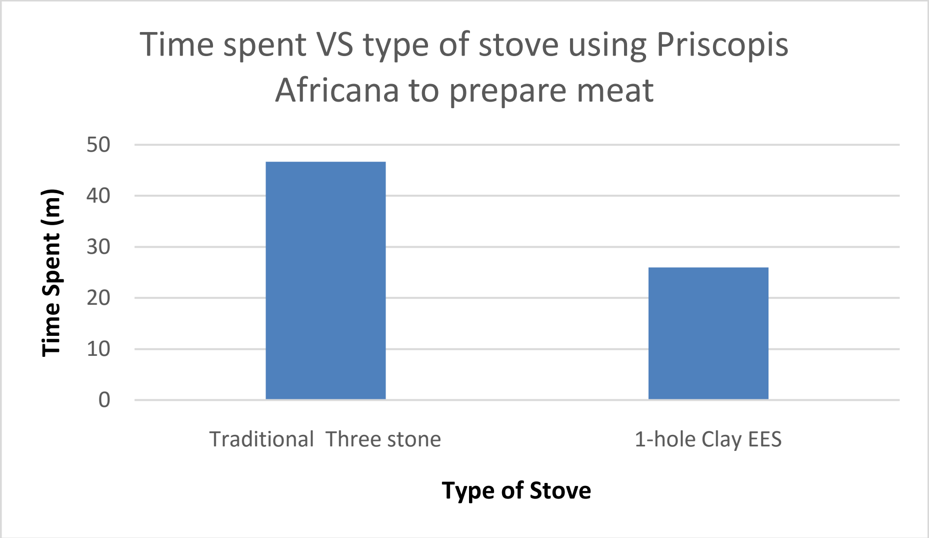


Fig. 9: Priscopis Africana with Meat, Time Spent

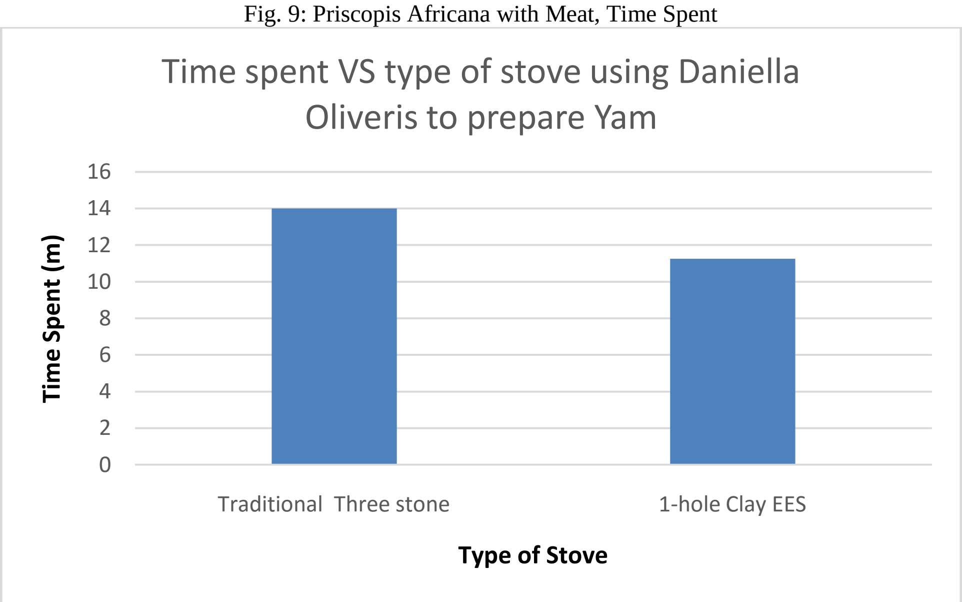


Fig. 10: Daniella Oliveris with Yam, Time Spent

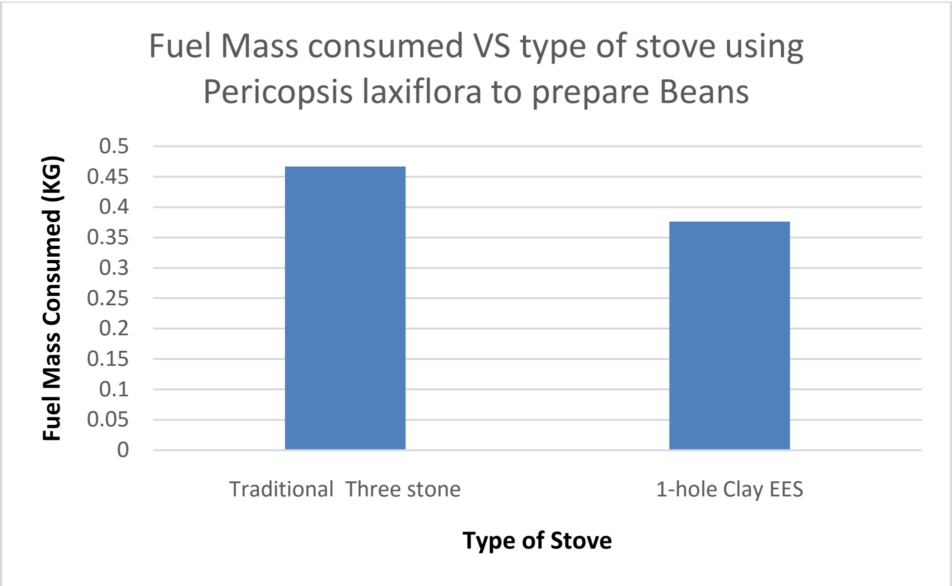


Fig. 11: Pericopsis laxiflora with beans, Time Spent

Figures 4 – 11 presents the results of fuelwood consumed and timespent in cooking a meal. It can be deduced from the results that in terms of time spent, the three stone stove spent more time in cooking the dishes compared to the improved cooking stove. The decrease in fuelwood consumption and time spent in cooking a meal agrees with the studies of Holmes, 2012; Ibrahim 2014, Haider 2002, B.G. Danshehu 2002, TECA, 2006 and Gill ,1985). B.G. Danshehu & A.S Sambo 1993).

IV. Conclusion & Recommendation

The result of the water boiling test and fuelwood consumption rate has indicated the Energy Efficient Stove is better than the Traditional Three Stone Stove with the tested wood species. The percentage heat utilized was found to be very high especially 1-pot based clay stove with Angeious leocarpus and Periscopis Lexiflora. Furthermore, a decrease in fuel consumption was also observed.

The study has shown that there is a positive relationship between calorific values of firewood and efficiency of energy efficient stoves. Wood species of high calorific values will enhance the efficiency of Energy Efficient Stoves. The result will help in fine-tuning government policies regarding the use of EES.

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