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Comparative analysis of selected biomass cook stoves' efficiency in Minna Metropolis, Nigeria

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ABSTRACT

Background: Fuel use is a measure of how efficiently the stove is able to transfer heat into the pot, which is expected to vary among the cook stoves because heat transfer efficiency seems to be predominantly dependent on the geometry of the stove and how closely the hot gases pass around the bottom and sides of the pot.
Objectives: The aim of this study is to assess the efficiency of biomass energy cook stoves.
Methods: This study carried out a Comparative Analysis of Fuel wood efficiency of four biomass cook stoves in Minna Metropolis. The Save80, the single-hole improved, the local Metal charcoal, and the Three Stone Open Fire (TSF) cook stoves. Copies of Questionnaire were administered to households, and efficiency test was carried out using the Water Boiling Test (WBT). The metrics determined were Time to boil, Thermal efficiency, Burn Rate, Specific Fuel Consumption and the Percentage fuel savings.
Results: Household's size and income were found to be significant factors that influence the type of cook stoves, whereas occupation and educational attainment played no significant role. The Save 80 cook stove took the least time of 23 minutes, while in terms of Thermal Efficiency, it exhibited the highest efficiency of 34%. The Burn rate recorded for the cook stoves were 12g/min, 55g/min, 35g/min and 144g/min for the Save 80, single–hole improved cook stove, Local metal charcoal cook stove and the three stone fire respectively. Save 80 had the least Specific fuel consumption and highest percentage of fuel savings of 55g/liter and 65% respectively. It was observed that the Time to boil, Burn Rate and Specific Fuel consumption decreases with improved technology of the cook stoves.
Conclusions: The Fuel wood efficient cook stoves have the potentials of reducing deforestation thereby mitigating climate change since lesser trees will be cut down for fuel.

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Save 80;
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Fuel savings;
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1. INTRODUCTION

Majority of the global population live in developing countries and also account for depletion of around 3/4 of global biomass for domestic energy (Berrueta, Edwards, & Masera, 2008). It is estimated that, of the global population, 2.4 billion people (almost 35%), depends on biomass energy to meet their cooking and heating requirements (Ruiz-Mercado, Masera, Zamora, & Smith, 2011). Despite the availability of Kerosene, cooking gas, and Electricity, studies have shown that many households depend mainly on fuel wood for their energy needs (Sambo, 2009). It is estimated by International Center for Energy, Environment and Development (ICEED) that more than half of Nigeria's population relies on fuel wood for their domestic

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energy needs (Akinyele & Rayudu, 2013). In recent times the inadequate supply and exorbitant cost of kerosene and LPG further compounded the problem (Abasiryu, Ayuba, & Zira, 2016).

Deforestation is the main consequence of high demand for fuel wood however, the use of inefficient stoves with high rate of emission of smoke has been shown to be a major cause of indoor air pollution, especially in open fires without chimneys (Smith & Mehta, 2003). More efficient technologies for cooking are crucial in tackling adverse health and livelihood impacts of traditional biomass energy technologies. They lessen the quantity of wood needed, as well as both wood collecting and cooking periods. These advantages are capable of improving both health and household income (Sagar & Kartha, 2007). Similarly, these efficiencies can lower adverse effects of fuel wood use on the local environment and global climate due to lower rates of fuel wood consumption and particulate emissions (Sagar & Kartha, 2007). Not all stoves perform equally well. Therefore, unless measures are taken to check the performance of the stove there is a risk of introducing an inefficient product, providing marginal benefits at best over the original cooking technology. This research work seeks to look into fuel use efficiency of cook stoves in an urban area (Minna Metropolis) as against mostly the rural areas or laboratory-based analysis of previous studies.

Fuel use is a measure of how efficiently the stove is able to transfer heat into the pot. This is expected to vary among the cook stoves in the area because heat transfer efficiency seems to be predominantly dependent on the geometry of the stove and how closely the hot gases pass around the bottom and sides of the pot (MacCarty, Still, & Ogle, 2010). The aim of this study is to assess the efficiency of biomass energy cook stoves.

2. METHODS

2.1 Study design

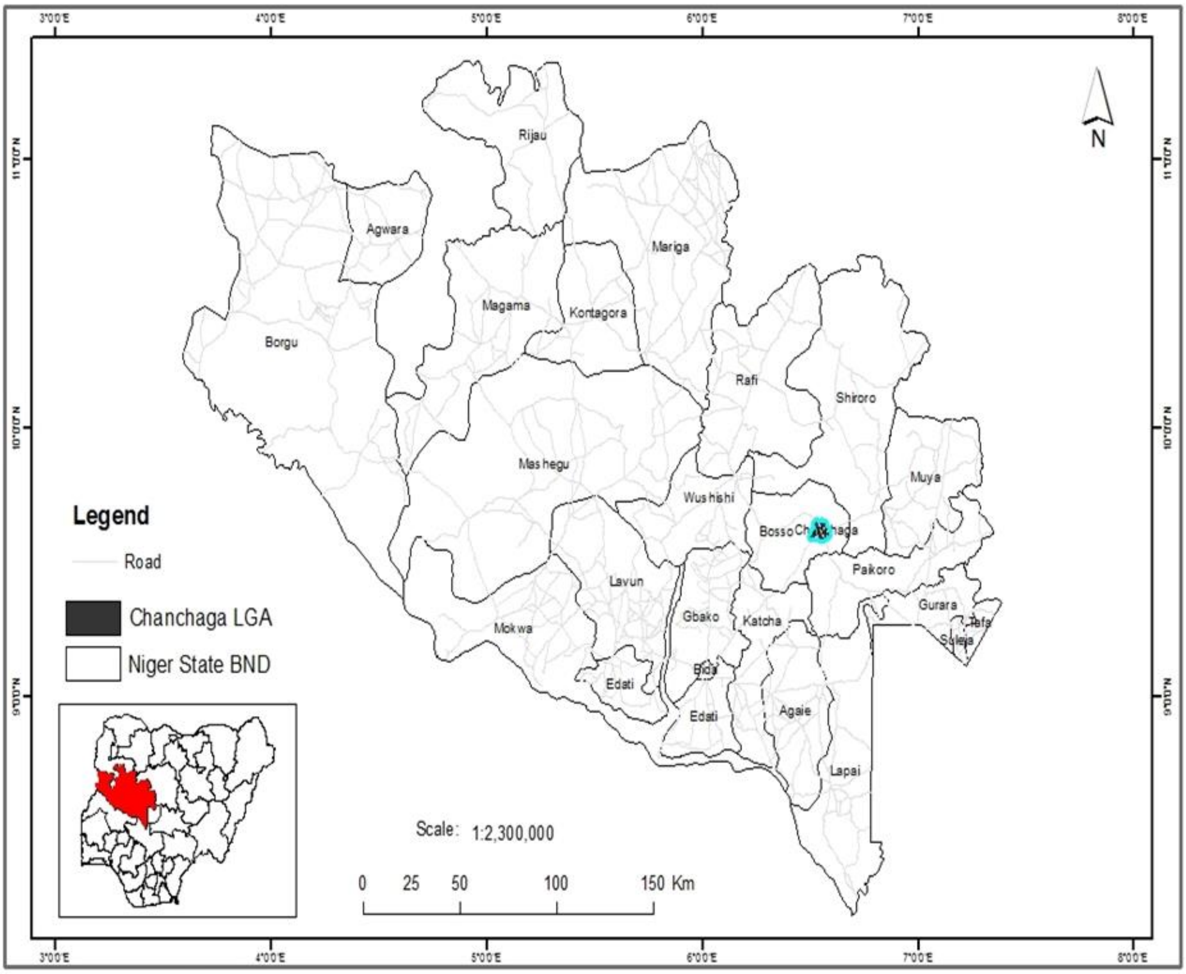
Cook stoves, fuel wood (Isoberlinia doka), Water Boiling Test (WBT) Kit, digital thermometer (GmH 3710 Greisinger)- with thermocouple probe, digital scale (MyWeigh KD-8000), charcoal, heat resistant pad, timer: to record the time it takes to bring the water to boiling point, standard pot (8 liter Save 80′ pot), wooden fixture, shovel/spatula, tongs, dust pan, metal tray, heat resistant gloves, tape, gas lighter.

Four cook stoves were tested namely the traditional stove, save 80′ woodstove, the single hole improved woodstove, and the local metal charcoal stove. These were used to conduct the stove efficiency tests at the Postgraduate School, Nigeria Defence Academy (NDA) old site in Kaduna, Nigeria. The reasons behind the choice of stoves are: the three stone fire is the most predominant stove in Minna Metropolis including Nigeria and used as baseline for comparison in Water Boiling Test. The Save 80′ woodstove is one of the highly recommended improved cook stoves by the Climate Change Department of Niger State Ministry of Environment because of its high performance and low emission. The Single Hole improved woodstove was one of the prototypes cook stoves developed by the Sokoto Energy Research Center of the Energy Commission of Nigeria. An Institutional prototype of the Single-hole improved cook stove is currently being developed and promoted in boarding schools by the Niger State Ministry of Environment. The Local Metal Charcoal stove is one of the widely used cook stoves in Minna metropolis because it is readily available and affordable.

2.2 Setting

The study area is Minna Metropolis. Minna city which is the State capital of Niger State and the administrative headquarters of Chanchaga Local Government Area (LGA) is shown on figure 1. The city has a land area of about 6,789 square kilometers and is the emirate council headquarters (Ishiaku, Emigilati, Kuta, Usman, & Hassan, 2014). Minna lies between latitudes 9°37ˈN- 9°79ˈN and longitude 6°16ˈE - 6°65ˈE. It is bordered in the Northeast by Shiroro, to the West by Bosso and Southwest by Paikoro LGAs respectively as shown in figure 1. The study area is accessible by air – the Minna Domestic Airport and by land such as the Minna-Bida, Minna-Suleja, Minna - Sarkin Pawa, and Minna – Zungeru - Kontagora roads. Minna is also connected by rail line running from Lagos through it to Kano.

This study was carried out in Minna Metropolis over a period of six months in 2018. It involved the administration of structured questionnaire to obtain socio-economic information and the use of water boiling test to determine the advantages of the use of improved cook stoves in terms of efficiency and fuel saving capacity.



Source: Space Metric Solutions, 2017

Figure 1 Niger State showing Minna Metropolis

2.3 Participants

The interview focused on staff from the Renewable Energy Department of the Energy Commission of Nigeria (ECN), who provided an insight into the National Energy Policy and activities of the Energy Research Centers. The Climate Change Department of Niger State Ministry of Environment also availed this research with information about Biomass Energy cook stoves being encouraged by the State. The interviews were used to generate factual information about the National Renewable Energy Policy and biomass cook stoves developed by the Energy centers. Low, middle, and high-income households were incorporated in the study.

2.4 Variables

These included socio-economic data such as educational attainment, household size and income level, as well as occupation. The water boiling test evaluated the efficiency of the improved cook stoves by determining fuel saving rate, burn rate, fuel consumption rate, boiling time, and thermal efficiency.

2.5 Data sources and data collection

This study made use of both primary and documented data. Primary data collected by the researcher included; thermal efficiency, burn rate, specific fuel consumption, time to boil, and percentage fuel savings. All these data were derived from the Water Boiling Test for each of the cook stoves under investigation. Other aspects of data were those collected from the households by use of structured questionnaire, interview schedules and observation.

Data were obtained through the administration of structured questionnaire and Water Boiling Test (WBT). Structured questionnaire was distributed to individual respondents as a participated approach to allow for enquiries and clarification (Kothari, 2004). This participated approach enabled respondents to both select options relevant to them, and also give their own views on the issues covered by the questionnaire. The questionnaire was used to collect data on socioeconomic variables such as educational attainment, gender, income level, types of efficient cook stoves used, source of fuel, and other relevant information. Oral interviews were preferred in this study for high level of response. The documented data were obtained from appropriate institutions as well as other published materials relevant to the area of research. These included climatic and population information from Maps and other statistical sources.

2.6 Sample design

The Minna urban area was divided into three (3) neighbourhood strata. The stratification was done to reflect areas that are considered as habitation for high income, middle class, and low-income earners. Thereafter, systematic random sampling was used to select households for administering the questionnaire. This approach was favoured because the streets in these neighbourhoods were arranged such that the boundaries between them are well defined. The selected neighbourhoods are: GRA, Minna Central, and Tunga Farm centre. The use of Systematic random sampling guarantees that the units can only be sampled once. The households were ranged on the street and a starting point was chosen randomly. Thereafter, households were selected at regular interval where the questionnaire to one after every 10 households, which is every 11th house.

Table 1: Sample Size Table

Neighbourhood	No. of households
GRA	581
Minna Central	4,495
Tunga Lowcost	726
Total	5,802

The Yamane (1967) formula for determining sample size was applied to determine the sample size, i.e., number of households to be selected.

$$n = \frac{N}{1+N(e)2} \text{ n .... } \textbf{(1)}$$

Where n = sample

N = population

e = 0.05 (significance level 95%)

= 5802/(1+5802(0.05)2) =5802/(1+5802(0.0025))

= 5802/(1+14.505) =5802/15.505 = 374

The sample size was 374, out of this number, 13 questionnaires were not returned by the respondents.

2.7 Water boiling test (WBT)

Water Boiling Test (WBT) is a test that involves the investigation of the cook stoves in a controlled environment in order to evaluate or reveal their technical performance. The Test Protocol version 2.0 by Atmosphere was used for the WBT. This method focused on simulation of cooking practices by water boiling hence does not present the actual cooking conditions.

The weight of the empty pot was recorded (912g). The pot was filled with clean water at room temperature. The amount of water was determined by placing the pot on the scale and adding water until the total weight of pot and water together was 5300g. Air temperature (°C) was measured and recorded, and the wind condition was also noted. 700g of fuel wood and kindling material were weighed. The kindling material used was old newspaper and nylons. The pot was placed on the stove, using the wooden fixtures, the thermometer with the thermocouple was placed in the pot so that water temperature may be measured in the center, 5 cm from the bottom. The initial water temperature in the pot was measured. It was confirmed that the initial water temperature does not vary substantially from the ambient temperature.

Once the fire was lit, the timer was started and the starting time recorded. The pot was quickly brought to a boil without being too wasteful of fuel using wood from the pre-weighed bundle.

The time at which the water in the pot reached the local boiling temperature was recorded. The remaining fuel wood was removed from the cook stoves and the flames extinguished. The flame was extinguished by blowing on the ends of the burnt fuel wood and placing them in a sand because using water to extinguish the flame will affect the weight of the wood by increasing its weight. All loose charcoal from the ends of the wood were knocked into the container for weighing charcoal.

The unburnt wood removed from the cook stove together with the remaining unused wood from the pre-weighed bundle were weighed. The remaining charcoal from the cook stove was removed and weighed with the charcoal that was knocked off the burnt fuel wood. Finally, the pot together with the boiled water are weighed and recorded.

2.8 Data analysis methods

Descriptive statistics was used to evaluate the characteristics of the cook stoves studied. Results were presented as graphs and tables. The WBT parameters were analysed using the GACC WBT 4.2.4 Spreadsheet. The spreadsheet software was used to calculate efficiency metrics. Chi square was used to express the fuel wood use variations among the cook stoves tested. The Analysis of Variance (ANOVA) was used to determine the relationship between socio-economics status of the respondents and the type of cook stoves.

3. RESULTS

3.1 Respondents' gender

The gender of the respondent played a significant role in the nature of their responses. Women accounted for majority of the respondents in the study area because they are directly responsible for the household chores (Table 2).

Table 2 Gender of the respondent

Gender	Frequency (f)	Percentage (%)
Male	116	32
Female	245	68
Total	361	100

Source: Field survey, 2018

3.2 Age of the respondents

Findings of the study indicated that most of the respondents were aged between 42-49 years, this class of respondents represents economically active segment of the population of the Minna Metropolis (Table 3).

Table 3 Age of the Respondents

Age	Frequency (f)	Percentage (%)
18-25	7	2
26-33	36	10
34-41	47	13
42-49	87	24
50-57	83	23
58-65	76	21
66 and above	25	7
Total	361	100

Source: Field survey, 2018

3.3 Awareness about cook stove types

The survey on the awareness and use of the various fuel wood cook stove as shown in Figure 2 indicated that nearly all the respondents are aware of the three stone fire stove (TSF), metal/ceramic charcoal stove, followed by Single Hole improved stove and Environ fit stove than the rest of the cook stove in the study area.

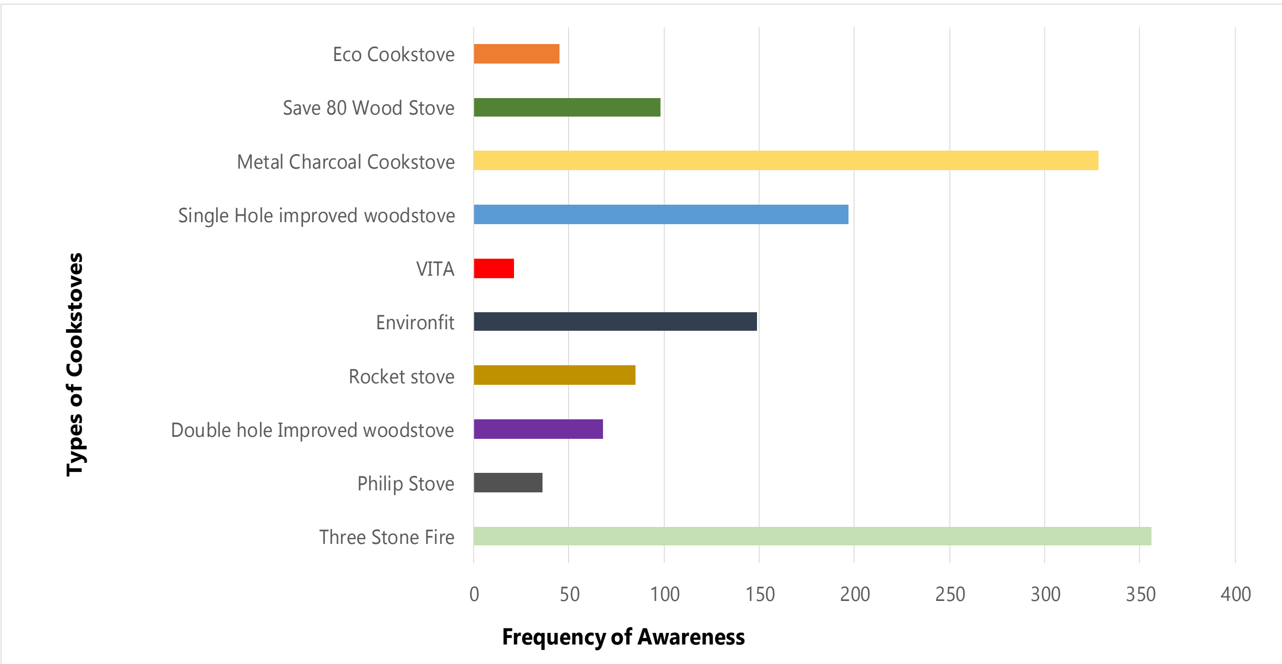


Figure 2 Cook stove type awareness in the study area

Source: Field survey, 2018

3.4 Willingness to switch to various improved technologies

This study shows that majority of the respondents are willing to switch from their current cook stove to a more improved cook stove technology. Households reported that they are facing problems with their current fuels especially firewood because it is becoming scarce and therefore, they are willing to diversify to a more improved biomass cook stoves and other biomass fuels.

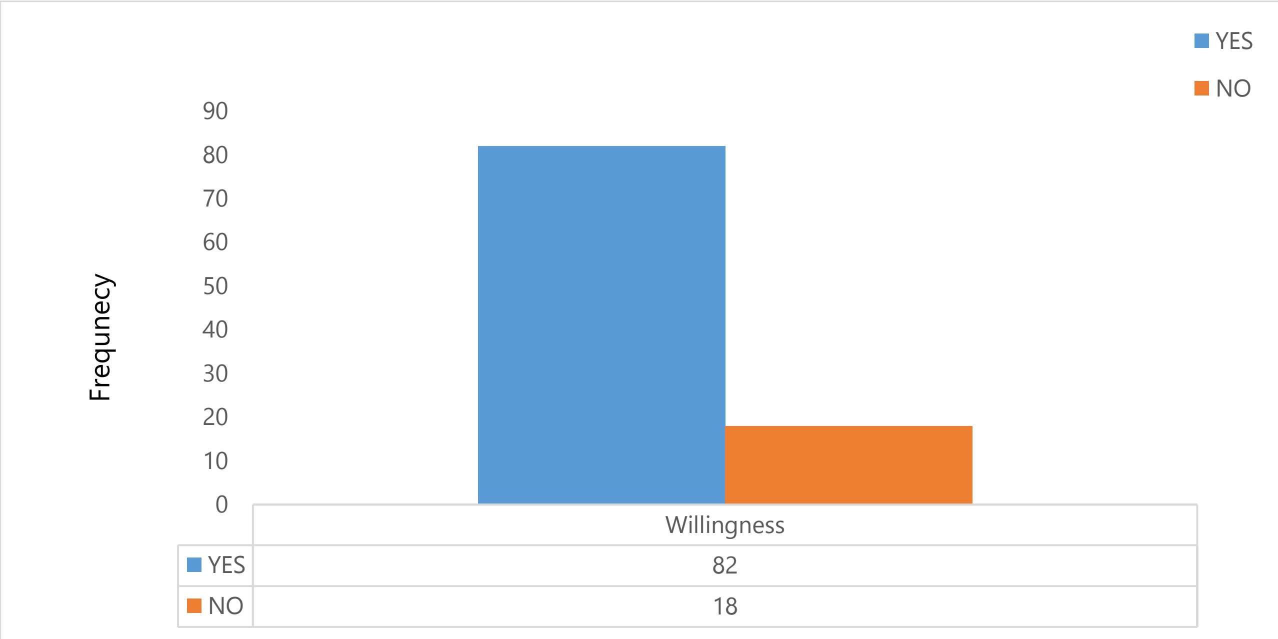


Figure 3. Willingness to change to improve cook stove technology

Source: Field survey, 2018

3.5 Socio-economic characteristics of the respondents

The socio-economic parameters of the respondents that were used for the purpose of this study are the major occupation of the respondent, their educational status, household income, and household size.

3.5.1 Major occupation of the respondent and use of cook stoves

The major occupation of the respondents from this survey indicates that a significant number of the respondents are civil servants, are into business activities, (Table 4). Generally, occupation of the respondents significantly affects predisposition to accepting new efficient cook stove. No statistically significant relationship was observed between occupation/employment status and the type of cook stove used. The implication of this is that, despite some of the respondents being in paid employments with access to credit facilities to enable them afford the fuel wood efficient cook stoves, it still did not necessarily translate to adoption of fuel wood efficient cook stoves.

Table 4 Major occupations of the respondent and types of cook stoves

Types of cook stove	Main Occupation of respondents				Total
	Farming	Business	Civil Servant	Casual worker	
	f (%)	f (%)	f (%)	f (%)	
Save 80	5 (15)	11(29)	19(52)	1 (3)	36
Single Hole Improved cook	16 (37)	11(26)	12 (28)	4 (9)	43
Metal Charcoal Stove	43 (28)	35 (23)	53 (35)	49(14)	21
Three Stone Fire	48 (37)	25(19)	27(21)	30 (23)	130
Total	268(31)	196(23)	267(31)	131(15)	361(100)

Source: Field survey, 2018

3.5.2 Household size and use of cook stoves

Household size is part of the socio-economic factors that were expected to encourage the use of Fuel wood efficient cook stoves at the beginning of this study. Majority of the households found to be using the Save 80 cook stoves have between 6-9 persons living it. Similarly, the same category (6-9) of household account for majority of users of the other cook stove types (Table 5). This finding indicates a significant relationship between the household size and the type of cook stoves.

Table 5 Household size and the type of cook stove used

Types of cook stove	Household Size (family members)			Total
	2 – 5	6 – 9	10 and above	
	f (%)	f (%)	f (%)	
Save 80	11(19)	26(74)	3(7)	36
Single hole Improved Cook Stove	4(10)	34(78)	5(12)	43
Metal Charcoal Stove	11(7)	132(87)	9(6)	152
Three Stone Fire	5(4)	100(77)	25(19)	130
Total	27(7)	292(82)	42(11)	361(100)

Source: Field survey, 2018

3.5.3 Educational status and types of cook stoves used

Respondents who have attained Tertiary Education constitute the larger percentage of those found to be using Save 80 fuel wood efficient cook stove (Table 6). At the onset of the research, educational attainment was assumed to be a key factor in influencing the adoption and use of improved cook stove, because being educated the respondents are aware of the immense benefit derivable from the use of fuel wood efficient cook stoves and the dangers associated with the use of traditional cook stoves. This however, runs contrary to the research findings, that showed no significant relationship between educational attainment and the type of biomass cook stove used.

Table 6 Educational Status and type of cook stove

Types of cook stove	Educational Status				Total
	No education	Primary	Secondary	Tertiary	
	f (%)	f (%)	f (%)	f (%)	
Save 80	0 (0)	2(5)	12(34)	22(62)	36
Single Hole Improved Cook	3(7)	8(21)	20(47)	12(25)	43
Metal Charcoal Stove	12(8)	42(12)	225(62)	64(18)	152
Three Stone Fire	29(22)	23(18)	53(41)	25(19)	130
Total	104	123	432	203	361

Source: Field survey, 2018

3.6 Efficiency of the biomass cook stoves tested

The air/ambient temperature and initial water temperature varied progressively as the atmospheric temperature increased during the test. Final water temperature, initial weight of the water, and average moisture content of the fuel wood were the same for all the cook stoves (Table 7).

Table 7 Weight of materials and instruments used

Materials/Parameters	Cook stoves			
	Save 80	Single Hole Improved Cook stove	Metal Charcoal Cook stove	Three Stone Open Fire
Ambience Air Temp (oC)	28.86	30.59	30.02	25.64
Initial water Temp (oC)	27.68	28.97	29.39	28.97
Final water Temp (oC)	96	96	96	96
Initial Weight of water (g)	5300	5300	5300	5300
Weight of water (g) evaporated	611	761	681	898
Initial Weight of fuel wood (g)	700	700	700	700
Weight of fuel wood (g) consumed	245	326	412	568
Weight of charcoal (g) produced	35	70	89	262
Average Moisture content	13.76	13.76	13.76	13.76
Time/Duration (Min)	23	35	49	57

Source: Field survey, 2018

3.7 Boiling time effective coverage

The time taken to bring water to boiling point reduces with advancement in the technology of the cook stove design. The Save 80 cook stove took the least time to bring 5300g of water to boil at 960C and produced little amount of charcoal because the cook stove has enclosed combustion chamber that facilitate the complete burning of the fuel wood (Figure 4).

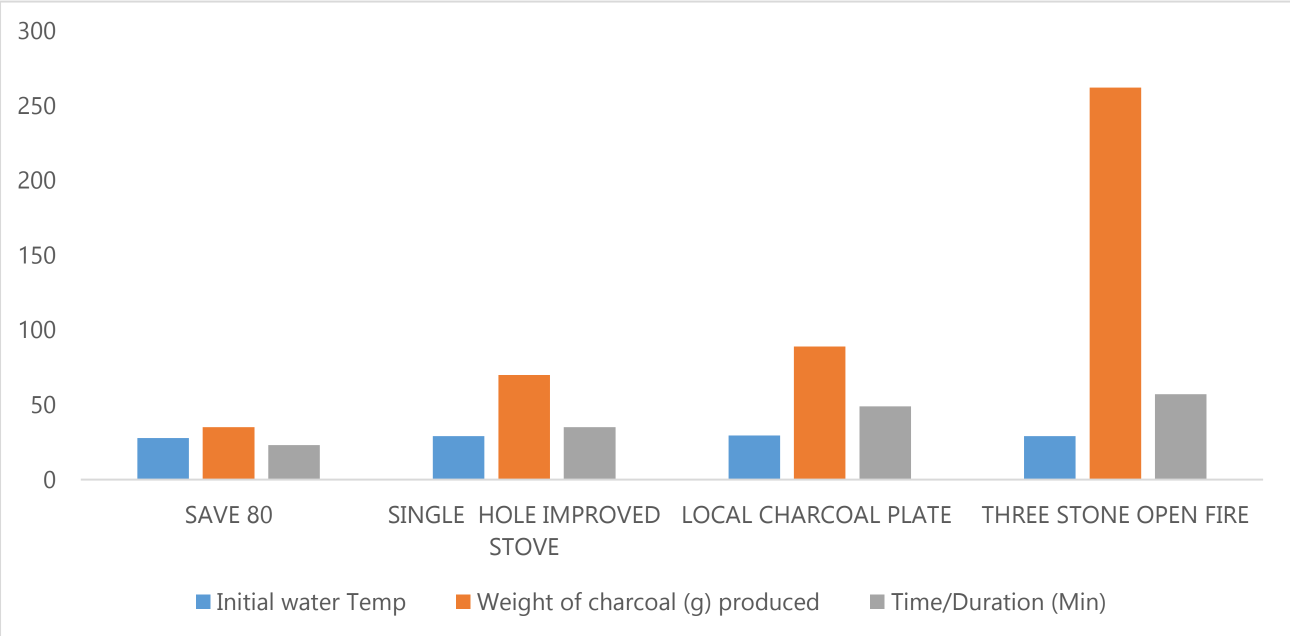


Figure 4 Water Boiling Test

Source: Field survey, 2018

3.8 Weight of water and fuel wood

The weight of water evaporated and the weight of fuel wood used to bring the water to boil are presented in Figure 5. The initial weight of fuel wood is same for all of cook stoves tested, weight of the fuel wood consumed by the cook stoves decreases relatively with improving technology from the three stone open fire to Save 80.

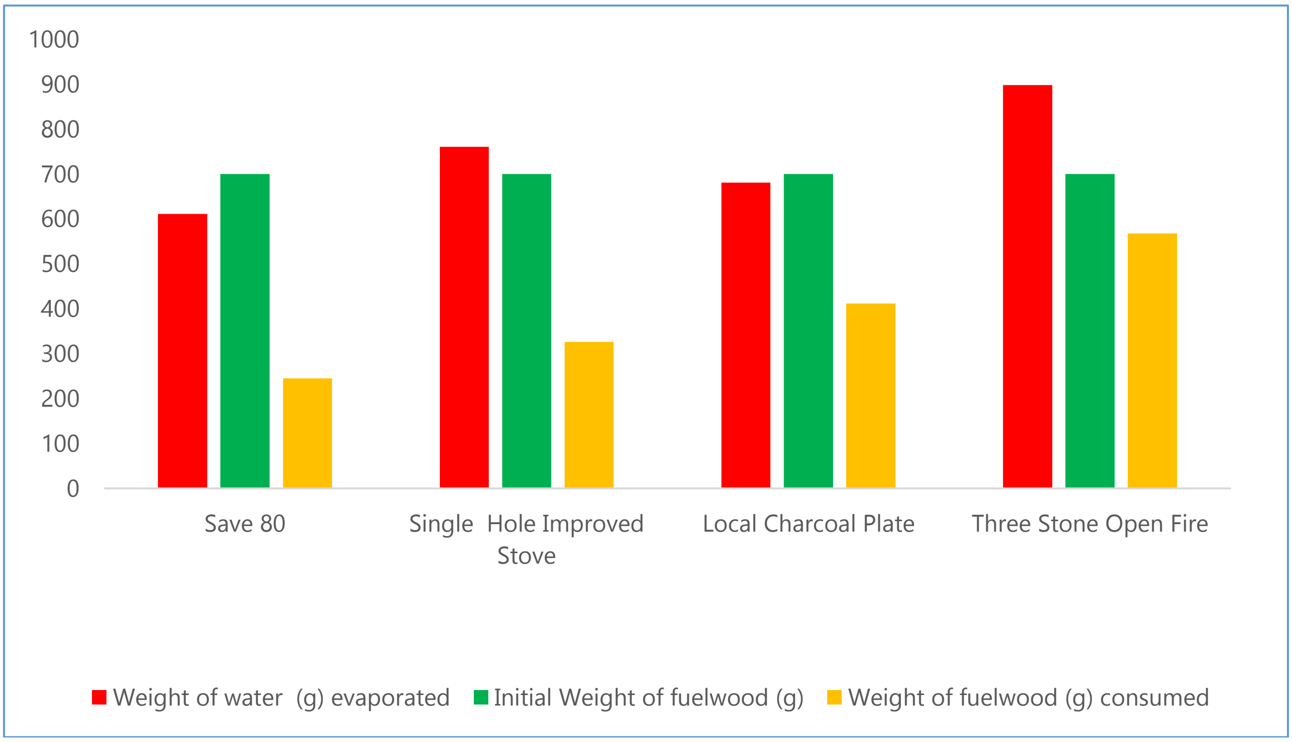


Figure 5 Weight Used from Water Boiling Test

Source: Field survey, 2018

3.9 Thermal efficiency

The test results depict a significantly high thermal efficiency for the Save 80 stove (Table 8), this is an indication that about 34% of the heat produced by the Save 80 cook stove was able to make it to the pot (Figure 6). The enhanced thermal efficiency of the Save 80 cook stove can be attributed to the insulation provided round the combustion chamber. This reduces the rate of heat loss across the combustion chamber by radiation and conduction and ensures that a good proportion of the heat is conserved within the chamber and directed towards the top of the chamber to the pot.

3.10 Fuel savings

The Save 80 cook stove originally designed to save at least 80% of fuel wood when compared to the Three Stone fire. However, our study reported 65% savings (Table 8), which may be attributed to operating conditions such as outdoor wind exposure and general handling of the cook stove. Energy Efficiency Landscape for cooking refers to opportunity for improvement of the cook stoves not only in terms of fuel saving rate, time, and greenhouse emission alone but also in terms of cost and ease rate of adoption. The landscape map for efficiencies of the cook stoves shows that additional reduction in greenhouse gasses (low burn rate) through combination of improved design and fuel switches may increase their efficiencies.

3.11 Burn rate

This is a measure of the average grams of wood per minute that was burnt during the test. When compared between the cook stoves, this measure indicates how rapidly the cook stove consumes fuel wood. Results from the test revealed that the Save 80 has the burn rate of 12g/minute (Table 8). This is an indication that Save 80 consumes fuel wood slowly. This can be attributed to its design framework which allows for near complete combustion of fuel wood.

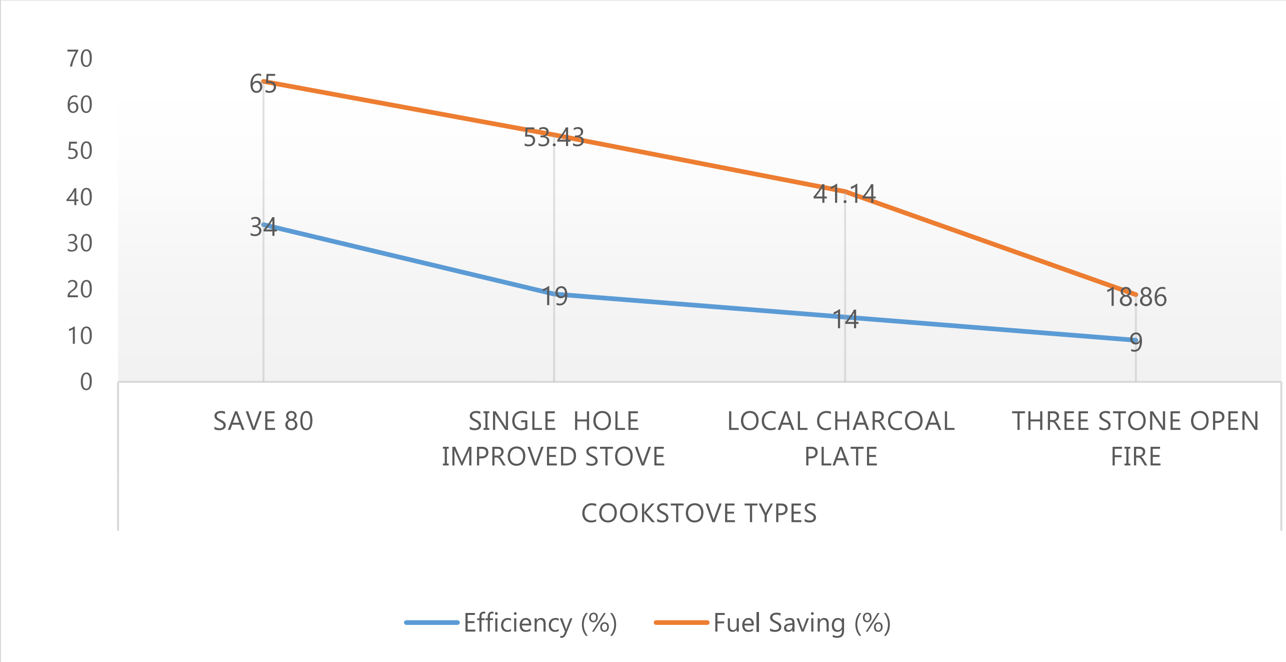


Figure 6 Efficiency of the cook stoves measured fuel saving (%)

Source: Field survey, 2018

Table 8 Fuel wood use efficiency performance of the cook stoves

Parameters determined from WBT	Cook stove Types			
	Save 80	Single Hole	Local Metal	Three Stone
Thermal efficiency (%)	34	19	14	9
Burn rate (g/min)	12	55	35	144
Specific Fuel consumption (g/litre)	55	378	336	1229
Fuel saving (%)	65	53.43	41.14	18.86
Time to boil (minutes)	23	35	49	57

Source Field survey, 2018

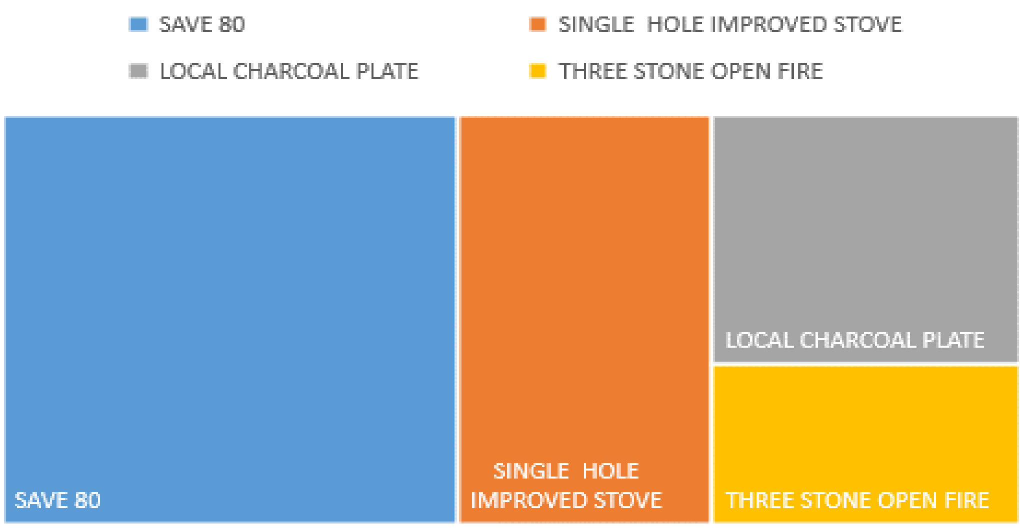


Figure 7 Cook stove Energy Landscape

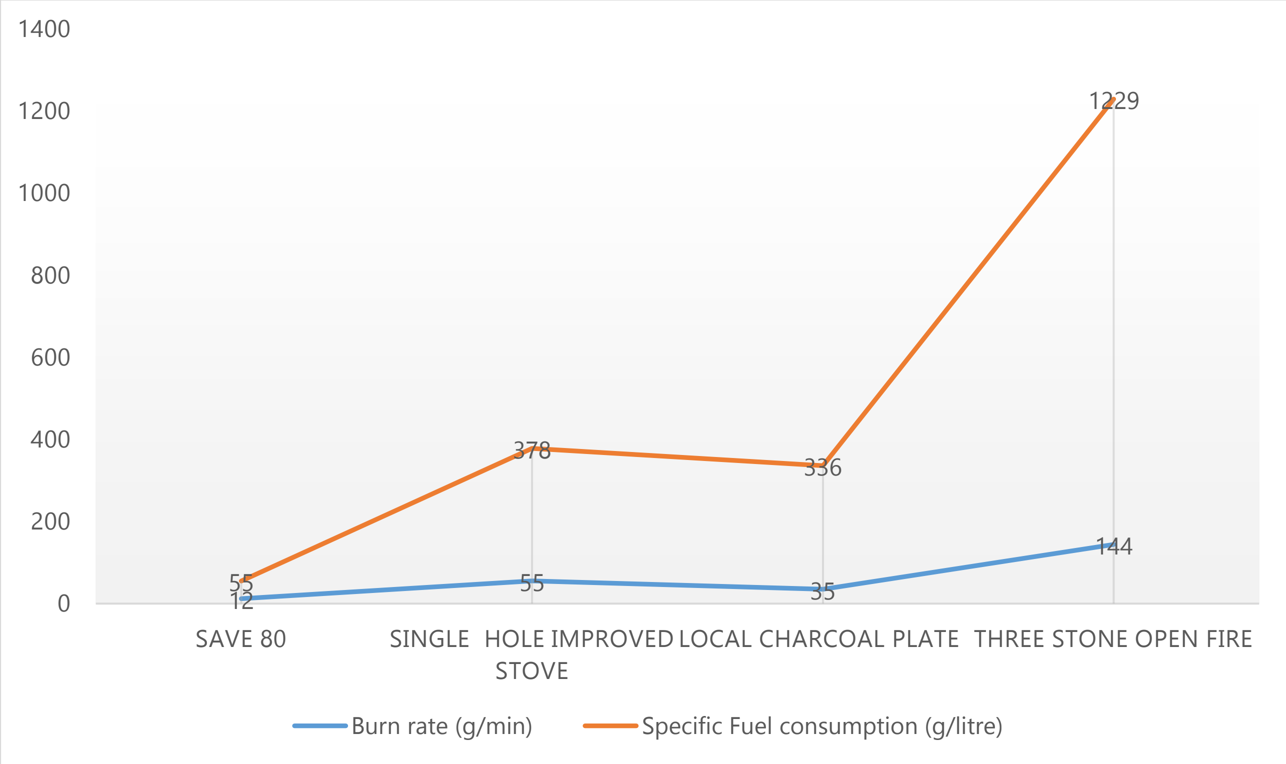


Figure 8 Burn rate (g/min) of the cook stoves measured with specific fuel consumption (g/liter)

3.12 Specific fuel consumption

This is a measure of the amount of fuel wood required to boil (or simmer) 1 litre of water. The Save 80 cook stove showed the least Specific Fuel Consumption of 55g/litre. This showed an indication of high fuel wood-use efficiency of the Save 80 cook stove (Figure 8). Significant variations in fuel wood use efficiency among the biomass cook stoves were observed in the study area. The more improved biomass fuel wood cook stoves have higher fuel wood use efficiency.

4. DISCUSSION

Fuel Efficient Biomass Cook stove have the capability of reducing cooking time which will enable the housewife with more free time for activities other than cooking. Women prefer to adopt efficient fuel wood cook stoves because of the cumulative benefits inherent in its use such as reduction in workload and faster cooking time. It has been reported in the study conducted by Rao and Reddy (2007) affirmed that female-headed households prefer modern fuel cooking technologies as compared to man-headed households. Age also play an important role to choosing the type of cook stove to be used in a household. Majority of the respondents in our study were aged between 42 – 49, and they happen to be the decision makers in their respective households and as such more dynamic to changes with regards to use and adoption of fuel-efficient biomass cook stoves such as Save 80 Cook stove.

Three stone fire (TSF) has long been in use since ancient times and still in use up till today because it is readily available at no cost. The Single and double-hole improved cook stoves are institutional cook stoves that has been built in some government-owned boarding secondary schools in Niger State to reduce the amount spent on fuel wood and also conserve the environment. The Environ-fit cook stove was introduced into the study area by Atmosphere, which is a German Organization. Not much of the respondents seemed to be aware of the Save 80 Woodstove despite efforts by the Niger State Ministry of Environment to promote its use. Not much is known about the Volunteer in Technical Assistance Cook stove (VITA) cook stove because it is not easily available, although prototype can be manufactured locally. It is believed that awareness of various improved biomass energy technologies plays a very great role in influencing adoption.

Willingness in this perspective refers to the state of being ready to switch from the currently used biomass cooking technologies to a better technology. The first step towards willingness to change is the consciousness of the shortcomings of the current technology and also the solution being proffered by the new technology. Households being rational, have their own priority of problems they want to solve for their development and they may not be ready to invest their time and resources in what they do not perceive to be a problem. Thus, acknowledging the harmful effects of Indoor Air Pollution and climate change caused by the use of inefficient cook stoves will aid in determining the willingness to adopt improved biomass cook stoves.

The civil servants in this study were found to account for larger percentage of those using the Save 80 fuel wood efficient cook stove. The reason for this may not be unconnected to the effort of the Niger State Ministry of Environment to discourage the use of charcoal because of the harmful effects of charcoal production on the environment. The ministry through its Climate change department, encouraged the use of Save 80 by subsidizing it for the civil servants that were interested. The low percentages recorded for Save 80 among other classes of occupation can be attributed to non-availability and high cost of acquisition. Another reason adduced for low percentage or use is the time consumed to break the fuel wood into tiny pieces before it can be fed into the Save 80 cook stove.

Majority of the Households found to be using the Save 80 cook stoves have between 6-9 persons living it. This is in agreement with earlier literature sources (Puzzolo, Stanistreet, Pope, Bruce, & Rehfuess, 2013). where it was assumed that household with higher number of people are more likely to adopt efficient cooking technologies because of the need to economize the amount spent regularly on fuel wood supply. Respondents who have attained tertiary education constitute are more modern and have access to information on alternative cleaner cooking energy sources compared to their educationally disadvantaged counterparts. Cost implication and inadequate awareness may be the reason for the low number of users of the Save 80 cook stove and the other fuel wood efficient cook stoves. The level of educational attainment of the household wife plays a pivotal role in increasing the likelihood of changing from traditional cooking devices to the new and more efficient cook stoves (Pundo & Fraser, 2006). It can be reasoned that educated biomass cook stove users are probably aware of the rewards and advantages derivable from the use of fuel wood efficient cook stoves over the uneducated or less educated users (Jan, 2012).

In this study, the least weight of water evaporated is reported for Save 80 cook stove because the water was able to boil in a shorter period of time hence making very little time available for the water molecules to evaporate away, unlike its three stone open fire and single hole improved stove counterparts. This is in agreement with the study conducted by Akpootu et al (2014) that carried out a Comparative Analysis of Performance of four selected wood stoves (Save 80, Single Hole Improved (SHI) wood Stove, locally fabricated Metal (LFM) Stove and the Traditional Open Fire (TOF) using the Water Boiling Test. The results indicated that the Save 80 and SHI took less time to bring 2 litres of water to boiling point using least amount of wood (Akpootu et al., 2014). The water boiling test (WBT) was also used to determine the thermal efficiency, fire power, the specific fuel consumption, and the burn rate of some locally fabricated cook stoves in Mubi, Adamawa State, Nigeria, revealed that the Metal Charcoal Stove has the highest Thermal Efficiency and lowest Specific Fuel Consumption, whereas the 3-Stone Fire has the least Thermal Efficiency and highest Specific Fuel Consumption (Abasiryu et al., 2016).

Results from our study also revealed that the Save 80 has the least burn rate of 12g/minute and least Specific Fuel Consumption of 55g/liter., which indicated that Save 80 consumes fuel wood slowly. This can be attributed to its design framework which allows for near complete combustion of fuelwood. The Performance Evaluation of Save 80 was compared against the Locally Fabricated Wood Stove, Single Hole Improved wood Stove and the 3-Stone using the Controlled Cooking Test (CCT) in a study conducted showed that the Save 80 Stove took the least time to cook and has lowest Specific Fuel Consumption and highest percentage of Fuel Saving (Muhammad, Kaisan, Cyprian, Sani, & Abdulkadir, 2014).

5. CONCLUSION

Households' income and size are significant factors in choosing cook stove type, while occupation and education status are not. Save 80 cook stove has the highest thermal efficiency and is the most efficient. The three stone open fire had the highest specific fuel consumption, an indication that it consumes the most fuel; it also had high noticeable smoke emissions with high burn rate and fire power. Efficient fuel wood cook stoves have the potential to reduce the quantity of fuel wood use, reduce the deforestation, and also harmful effects observed with the use of inefficient traditional cook stoves. This pose public health concerns such as indoor air pollution (IAP) and lung infections which can result from the smoke emitted by such cook stoves.

DECLARATIONS

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APPENDIX

Questionnaire

Department of Geography, Nigerian Defence Academy, Kaduna.

This research is aimed at investigating the efficiency of Biomass Energy of selected cookstoves in Minna Metropolis, Nigeria.

The information you give will be strictly used for this research and treated with utmost confidentiality.

Demographic Characteristics

1. Position in the household

    (a) Household head

    (b) Spouse

    (c) Son

    (d) Daughter

    (e) Parent

2. Gender of the respondent

    (a) Male

    (b) Female

3. What is your age in years?

    (a) 18 – 25 (b) 26 – 33 (c) 34 – 41 (d) 42 – 49

    (e) 50 – 57 (f) 58 – 65 (g) 66 and above

4. Marital status

    (a) Married

    (b) Single

    (c) Separated/divorced

5. What is the headship of your household?

(a) Male headed

(b) Female headed

(c) Child headed

Socio-economic Indicators

6. What is your highest level of education?

(a) No formal Education

(b) Primary School

(c) Secondary School Cert

(d) Tertiary

7. What is your main occupation?

(a) Farming

(b) Business

(c) Civil Servant

(d) Casual work

8. What is the average monthly income of the household?

(a) Below ₦ 18,000

(b) ₦ 18,000 - ₦ 100,000

(c) Above ₦ 100,000

9. What is the size of your Household?

(a) 2- 5 persons

(b) 6 – 9 persons

(c) 10 persons and above

10. House construction materials

No	Section of House	Construction Material
1	Walls	_______________
2	Roof	_______________
3	Floor	_______________
4	Doors	_______________
5	Windows	_______________

11. Have heard of any of the following cookstoves?

12. Have heard of any improved cookstoves?

(a) Yes (b) No

13. If Yes, from whom did you get the information from?

(a) Government extension workers

(b) NGOs

(c) Traders

(d) Women groups

(e) Friends/neighbours/relatives

(f) Others (specify)

14. Do you know of any promoters of improved biomass energy stoves in this area?

(a)Yes (b) No

15. Which fuelwood stove do you use for cooking?

16. Why do you like using the cook stove?

(a) Readily available (b) Affordable (c) Easy to use (d) No other alternative

(e) Others (specify)

17. Is this the only stove available for firewood?

(a) Yes (b) No

18. If No, which one (s) are available?

……

……

19. Why don't you use them?

……

……

20. Please indicate the level of acceptance of the following improved biomass energy technologies and biomass fuel for cooking.

Acceptance levels:

1=Highly accepted,2=Accepted, 3=Moderately accepted,4=Least accepted, 5= Not accepted

No	Stove	Level of Acceptance
1	Save '80' wood stove	________________
2	Metal charcoal stove	________________
3	Single hole improved woodstove	________________
4	Three stone fire	________________

21. Would you be willing to switch from the current technology using the same biomass- based fuel to another?

(a) Yes

(b) No

22. If Yes, to which technology

………

23. What modifications can you recommend for any of the stove if any?

Thank you.