EVALUATION OF THE COOKING TIME FOR SOME FOOD SAMPLES USING A DESIGNED AND CONSRUCTED IMPROVED INVENTED MUD (IVM) STOVE IN GOMBE, GOMBE STATE.

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ABSTRACT

A study on testing the effectiveness of a designed and constructed fuelwood stove for domestic energy consumption has been carried out in Gombe State. Fuel wood and Cornstalk were used as the available energy sources. Three types of fuel wood namely mahogany (*Khaya senegalenses*), mark (*Annogeissus leoicarpus*) and Tifirmi (*Combretum nigricans*) and cornstalk were used as energy sources in comparative tests of the designed stove vis-à-vis the traditional stove. Three tests were carried out- KPT, WBT and CCT test. A 3-day KPT was conducted in a single household using fuel wood and cornstalk as sources of energy for both the designed stove and the traditional stove. The results indicated an average daily consumption of 231.47 MJ and a per capita consumption of 43.52 MJ with a standard deviation of 13.0 between the two energy sources for the traditional stove against the respective values of 194.67 MJ and 36.65 MJ and a standard deviation of 5.1 between the two energy sources for the improved stove. Thereafter, 20 households were randomly selected and the same procedure was repeated. The result obtained indicates great fuel wood saving using the improved stove because the per capita daily energy consumption of households varies from 14.4 to 25.60 MJ with an average daily consumption of 19.40 MJ giving a fuel wood savings of (44.60 %. The Analysis of Variance (ANOVA) and the two sample t-test shows significant difference between energy used in 20 households before and after intervention at 5 % level of significance. For WBT, the results indicated that it took less time, meaning less amount of wood, to boil water in the order (Mahogany, Mark and Tifirmi). The time taken for each are 7.10, 13.50 and 16.80 minutes respectively, thus indicating an energy equivalent of 2636.92 kJ (0.73 kWh), 6984.25 kJ (1.94 kWh) and 1825.56 kJ (0.51 kWh) respectively. Results for CCT, using rice and beans followed the same pattern. It took less time to cook both rice and beans using Mahogany than Mark and Tifirmi. The times for each were: 18.50, 30.50 and 34.50 minutes respectively for rice and for beans the order was: 24.50, 36.50 and 39.50 minutes respectively. The SC was found to be 0.002 of fuelwood per each kg of food cooked using Mark and 0.0031 of fuelwood per kg of food cooked, using Mahogany. The fuel burn rate per cycle was found to be 0.01 kg/min with a cycle time of 35 minutes. This designed and constructed stove is good, saves cooking time, wood used in cooking and can be made available to rural dwellers at affordable cost per unit. The stove efficiency using WBT was found to be 65.45 %. The cost implication for a unit of the designed stove was estimated as N3, 700.00; this cost may however be less under mass production. It is therefore recommended that government should encouragement massive production of this type of improved stove for use especially in the rural areas of Gombe State to reduce pressure on the already depleted forest resources in the State. It would also save time and energy used by women and children in gathering fuelwood in the rural areas.

Keywords: Fuelwood, Food, Effectiveness, Domestic, Energy and Consumption.

Introduction

Several scholars and energy experts are concerned with the growing dependence on finite and non-renewable energy sources have identified energy problems of the developing world and indeed Nigeria (NRCC, 1992). Nigeria is endowed with both conventional energy sources (like oil, natural gas and coal) and renewable energy sources (like wood, solar, hydropower and wind). Other domestic fuel types in Nigeria include fuel wood, charcoal, coal, sawdust, kerosene, liquefied petroleum gas (LPG), electricity, and solar energy. Other types such as biomass, biogas, coal briquette, sawdust briquette, and natural gas/liquefied petroleum gas and small hydro powers are readily available but these have not been commercialized for domestic use (NRCC, 1992).

The precarious state of the environment manifesting in desertification, forest degradation, soil erosion, caused by over-exploitation for fuel wood and timber, agricultural expansion, over-grazing as well as bush burning culminated to the setting up of an inter- ministerial committee on combating desertification and deforestation (IMCA, 2000). Forest resources information resulting from several recent studies further underscores the rate of these degradation processes (IMCA, 2000). The current demand for fuelwood, which is the major energy source, for the rural dwellers has outstripped its supplies. The demand for the year 2000 was 139.7 million metric tones as against a supply of 76.6 million metric tones (IMCA, 2000). The rapid rate of deforestation of 3.5% per annum translates into 350,000 - 400,000 ha loss of productive land (IMCA, 2000). These trends further push the country away from attaining the Food and

Agricultural Organization (FAO) minimum requirement of having 25% of a country's land area under forest cover (FAO, 1995). Presently less than 10% of the country is under forest cover (IMCA, 2000).

It is important to note that more efforts has to be geared towards the development of an efficient and reliable energy saving stoves especially for our rural communities that constitute over 70 % of the Nigerian population (World Bank/UNDP, 1983).

The indiscriminate felling of trees for energy use has contributed greatly to the rate of deforestation and subsequent environmental degradation such as soil erosion and desertification. Moreover, over 90 % of households in Gombe State rely on fuelwood to meet their domestic energy needs (Langa and Ododo, 2011). Gombe State is one of the frontline States bedeviled by desertification and land degradation. This, coupled with agricultural activities and population pressure on the fragile available forest resources, informed the dire need for this study. This will translate to a reduction in the quantum of fuelwood used in households, thereby saving our forest reserves from destruction.

Fuelwood is the most readily available and utilized cooking fuel for the majority of Nigerians (Danshehu and Atiku, 2003). However, the un-coordinated felling of trees to supply the required quantities of wood without systematic replacement has encouraged desert encroachment and soil erosion. The traditional open fire method of cooking which have been used for centuries has some advantage, in that the devices are simple and cheap (Danshehu and Sambo, 1990). However, the methods leave considerable room for improvements, because they are very inefficient as only 7 % to 15 % of the potential energy in the fuel wood is utilized in the cooking process.

Globally, biomass fuels are the principal source of cooking energy for most developing countries. Additionally, they provide energy for household needs such as heating bath water, ironing, and other uses. However, perhaps a typical, 60 % of domestic wood consumption in Bangalore, India, is used to heat bath water (Reddy and Reddy, 1982).

In view of the above, the study proposes the use of improved wood-burning stove with higher efficiency for use in Gombe State. This improved stove encouraged increased efficiency in the use of energy, forest conservation and the expanded use of alternative energy sources as essential goals for effective future energy plans.

In addition, women and children spent several hours gathering fuelwood for domestic cooking (Langa and Ododo, 2011). This present study is designed to investigate the cooking time of some food samples using a designed and constructed improved stove for domestic use in Gombe State, Nigeria. The objective of this study is to investigate the cooking time of some food samples in Gombe State.

2.0 Materials and Methods

Area of Study

Gombe State, which was created on October 1, 1996, is located in the Northeast sub-region of Nigeria. It is bounded in the north by Yobe State, in the south by Taraba and Adamawa States, in the East by Borno State and in the west by Bauchi State. It has a population of about 2.4 million people (NPC, 2006) and occupies a total landmass of 36,542.14 km^2. Although Gombe State is in Northern Nigeria and is one of the states in the northeast region, no such studies have been conducted so far. In view of the fast rate of small and medium scale industry development in the young state, there is the dire need to have a study such as the one being undertaken by the researcher. Moreover, exhaustive literature searches did not indicate the existence of any detailed domestic energy consumption survey of Gombe State; this has obviously created a need for this study.

2.1 Materials

The materials used for the construction of the improved wood-burning stove were purchased locally in Gombe, the capital of Gombe state. These include: the design mould, a special local clay, a wire mesh, binding material (Millet/Rice husk), separator (millet ash), a 3 inch metal pipe, a granulated powder of broken pots (Grog), a wooden spatula, scissors, and a ½ inch metal flat bar. These materials are discussed as follows:

i. Clay: Is the main ingredient of the construction,
ii. Millet/Rice husk: Serves as binding materials in the clay,
iii. Ash: This is a separator between the clay, hand and mould,

iv. Grog: This serves as an anti-cracking agent in the clay mixture,

v. Moulds: Two (2) moulds required for this design. The first Mould is the top of the stove which is a flat rectangular wood (or metal). The base is 80 cm in length and 36 cm in breath. It has three (3) openings of diameter, 28, 24 and 6 cm respectively. The first and second holes stands for the two (2) pots, while the last one is an opening for the chimney. The second mould is called the chimney mould which is hollow and cylindrical in shape. Results for the three (3) energy sources: mahogany (*Khaya senegalenses*), mark (Annogeissus leoicarpus) and Tifirmi (*Combretum nigricans*) were collated as indicated on Tables 1 – 6.

2.2 Methods

i. The clay with rice and millet husk in the ratio of 2:1, were mixed very well to ensure an even distribution of binding material in the clay. Water was added to make the clay pastry and soft enough to be cut and molded in different shapes without the clay sticking to the hand after touching the separator.

ii. Small quantity of ash was sprinkled on the mould and thereafter placed on the mould flat form clay.

iii. Three (3) sides walls of the stove were erected, with length of 18 cm, leaving the side of the bigger pot

iv. A fire box by measuring 16 cm x 16 cm was erected to serve as the fire box opening (or inlet).

v. A cover was constructed with a sheet of metal inserted between the chimney hole and the chimney collar at the end side.

vi. The chimney was constructed by casting the prepared clay around the cylindrical mould that was sprinkled with ash. The mould is then removed leaving the cast chimney; about 3-4 numbers of such was constructed for one stove.

vii. The hole covers were constructed to fit the pot holes.

viii. The casted stove was allowed to dry over night and was turn upside down to allow for further drying..

ix. A chimney cover and damper were constructed separately using an iron sheet.

The constructed two-hole Improved Vented Mud Stove (IVM) was then dried and fired in a locally made kiln and thereafter used in the Water Boiling Test (WBT) using three varieties of wood source viz: Mark, Mahogany and Tifirmi. The data so obtained from these tests was used to determine the stove efficiecy, stove deleivery power, burning rate and Annual Saving Potential (AES). Controlled cooking test (CCT) was performed using three varieties of available wood sources, namely; Mark (marke local name), Tifirmi (local name), and mahogany (madachi local name).

Stove performance is usually evaluated through the use of three standard tests in wood stove designs, the test tests are Kitchen Performance Test (KPT), Water Boiling Test (WBT) and Controlled Cooking Test (CCT).

The controlled cooking test (CCT)

The Controlled Cooking Test (CCT) is a laboratory or field test that measures stove performance in comparison to traditional cooking methods when a cook prepares a local meal. The CCT is designed to assess stove performance in a controlled setting using a standard task chosen to emulate local practices. It reveals what is possible in households under ideal conditions but not necessarily what is actually achieved by households during daily use. It should be done by a person who is familiar with the meal being cooked, the traditional cooking methods, and the operation of the stove being tested (The Partnnership for Clean Indoor Air, 2010).

The strengths of the CCT among others are; its relative simplicity, replicability, speed, and cost to conduct. It can provide preliminary understanding of stove performance for local cooking and therefore can be helpful through the design and dissemination process.

Some weaknesses of the CCT are that; controlled conditions (including fuel, food procurement and training) still do not reflect uncontrolled usage that is sensitive to operator behavior, differences or fuels that vary in composition, moisture, and size (Smith *et al.*, 1996). However, this test was used to determime the cooking of some food samples, such as rice, and beans.

3.0 Some Stove Parameters so Determined were:

a) Annual saving potential of the stove (AES) can be computed as:

$$AES = B_{ysaving} \times NCV_{fuelwood} \quad (1)$$

$$AES = B_y \times \left(1 - \frac{\eta_{old}}{\eta_{new}}\right) \times NCV_{fuelwood} \quad (2)$$

where,

B_y is the quantity of fuelwood used by a household that rely on the traditional 3-stone open fire,

η_{old} is the efficiency of the traditional 3-stone stove,

η_{new} is the efficiency of the new stove, (IVM) stove, and

NCV is the net caloric value of fuelwood = 0,015 TJ/ton (or 4,167 kWh/ton.

b) The Fuel burn rate per cycle, *F*, may be determined by:

$$F = \frac{Amt}{t_{cycle}} \quad (3)$$

where:

F = Fuel burn rate per cycle,

t_{cycle} = Duration of fuel burn cycle,

c) The firepower (the ratio of the energy content of the fuel consumed during a test or phase to the duration of the test or phase) is calculated as follows:

$$P = \frac{m_f h_f^o - m_c h_c^o}{T} \quad (4)$$

where

P is the average fire power (kJ),

m_f is the mass of fuel (kg),

h_f^o is the enthalpy of combustion of the fuel (kJ/kg),

m_c is the mass of the charcoal remaining (kg),

h_c^o is the enthalpy of combustion of charcoal (kJ/kg), and

T is the test duration.

The equivalent mass of fuel burned, on an energy basis (with reference to the unburned wood), can then be calculated in the following manner:

(http://www.cookstove.net/others/fuel-economy.html)

Efficiency,

$$\eta = \frac{M_{wo}C_{pw}(T_W - T_{amb}) + (M_{wo} - M_w)H_{vw} + m\Delta T}{(M_c - M_{co})H_{vc}} \tag{5}$$

where

M_{wo} is the initial weights of water,

M_w, is the final weights of water,

m, is the mass of water in the second pot,

T_w is the water temperature,

T_{amb} is the water ambient temperature,

C_{pw} is the specific heat of water,

H_{vw} is the latent heat vaporization of water;

M_{co} is the initial weights of charcoal,

M_c is the final weight of charcoal,

H_{vc} is the heat value of charcoal, and

ΔT is the temperature rise in the second pot.

The specific fuel consumption for CCT can be expressed as:

$$SFC = \frac{Mass\,of\ \ fuel\,consumed}{Total\,mass\,of\ cooked\ \ food} \tag{6}$$

Specific fuel consumption can also be expressed as:

$$SFC = \frac{\lfloor W_f(1-m) - 1.5M_c \rfloor}{M_w} \tag{7}$$

where

W_f is the final mass of fuel wood at the end of the test,

m is the moisture content of the fuel wood in (%),

M_c is the mass of charcoal and

M_w is the mass of water.

4.0 Results and Discussion

Tables 1 to 3 indicates the Water Boiling Test (WBT) carried out using a variety of locally available wood sources namely: Mark, Tifirmi and Mahogany. The results shows that the time taken to heat 2.25 liters (2250 cm^3) of water from 32.50 °C to 98.00 °C varies between 7.10 minutes and 16.80 minutes, and the energy required also varies from 1825.56 to 6984.25 kJ as shown. It indicates that we consume more wood in raising the temperature of water to its boiling point using Tifirmi and Mark and less wood when mahogany is used. This is because mahogany has high calorific value than both mark and tifirmi.

Moreover, Tables 1 to 3 indicates that an energy equivalent of 0.51 to 1.94 kWh is required to raise the temperature of water from ambient temperature to its boiling point. This amount of energy is more than enough for a day's use by an individual household. This creates a dire need for a continuous search for increase in the efficiency of the wood burning stove in thus making it more efficient.

Tables 4 - 5 is a controlled cooking test (CCT) conducted using the modified improved stove that has been designed and constructed. A variety of available wood sources are used viz: Mark, Tifirmi and Mahogany. Some quantity of raw rice (0.5 kg) was used in each case. The results indicate that the duration varies between 18.50 minutes to 34.50 minutes to cook rice. The energy required or the quantity of wood used varies from 0.65 kg (13666.25 J) for mahogany to 1.20 kg (23946.00 J). This shows it requires more amount of wood to cook rice when using tifirmi than mahogany. The Tables 4 to 6 shows that we require 3.80 to 6.65 kWh of electricity to cook rice and 4.96 to 8.04 kWh of energy to cook beans. This quantum of electrical energy is enough for a 2 day's use for a family of 5 members. This also stresses the need for an efficient way of using wood burning stove to bring to the barest minimum energy wastages.

The Specific Fuel Consumption was calculated using equation (6) as:

For mark (20284 kJ) as the wood source, we have, SC = 0.0031

This is value of SC for rice using mahogany as fuel source and for beans, the value of SC = 0.002 was obtained.

This implies that 0.0031 kg of wood is required to cook 1 kg of food (rice) and 0.002 kg of wood is needed to cook a kg of beans. Available data indicate that for traditional stove we require 0.95 kg of wood to cook a kg of rice, 1.07 kg of wood to cook a kg of beans and an average of 2.52 kg of wood to cook all kinds of food (Wang *et al.*, 2009). It could be observed that this design works better.

Table 1: Water Boiling Test (Wood Type- Mark, 20,284 kJ/kg)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
Mass of Pot B	1.78		
M_A+M_W	4.30		
M_B +M_W	4.00		
Stove Temp T_S	34.50 °C		
Stove Temp T_F	36.7 °C		
$\Delta t = t_f - t_i$	13.5 mins		
Temp of Water T_{wi}	34.00 °C		
Temp of Water T_{wf}	98.00 °C		
Temp of Water PotB	65.80 °C		
Mass of $Wood_i$	2.25	45,639.00	12.68
Mass of $Wood_f$	2.12	43,002.08	11.95
Mass of Wood used M_u	0.13	2,636.92	0.73
Initial mass of Charcoal M_{co}	0.00		
Final Mass of Charcoal M_c	0.046		

Source: Langa, H.B. (PhD Thesis)

In our design, a Multipot massive wood stove with chimney was used. It was highlighted much earlier what was done especially to improved upon heat losses notably the one through the flue gas, a baffle was placed between the first and second pots to get more heat to the second cooking pot. For heat loss by convection and radiation from the stove body, a paste of ash was used to paint (2 cm thickness) the outside of the stove to reduce radiation loss. Tables 5 - 6 indicate that it reduces the temperature difference to less than 1 °C between the commencements of the cooking process to the final stage. Good air draft provided by the use of chimney height of 65 cm and appropriate opening for wood inlet complete combustion was achieved.

Table 2: Water Boiling Test (Wood Type- Tifirmi, 19,955 kJ/kg)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
Mass of Pot B	1.78		
M_A+M_W	4.30		
M_B +M_W	4.00		
Stove Temp T_S	34.40 °C		
Stove Temp T_F	36.20 °C		
$\Delta t = t_f - t_i$	16.80 mins		
Temp of Water T_{wi}	33.00 °C		
Temp of Water T_{wf}	98.00 °C		
Temp of Water Pot B	58.50 °C		
Mass of $Wood_i$	2.25	44898.75	12.47
Mass of $Wood_f$	1.90	37,914.50	10.53
Mass of Wood used M_u	0.35	6,984.25	1.94
Final Mass of Charcoal M_c	0.034		

Source: Langa, H.B. (PhD Thesis)

Table 3: Water Boiling Test (Wood Type- Red Wood- Mahogany**,** 21,025 kJ/kg)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
Mass of Pot B			
M_A+M_W	4.30		

$M_B + M_W$	4.00		
Stove Temp T_S	35.00 °C		
Stove Temp T_F	36.40 °C		
$\Delta t = t_f - t_i$	7 mins 10 s		
Temp of Water T_{wi}	32.50 °C		
Temp of Water T_{wf}	98.00 °C		
Temp of Water PotB	72.00 °C		
Mass of $Wood_i$	4.60	96,715.00	26.87
Mass of $Wood_f$	4.35	91,458.75	25.41
Mass of Wood used M_u	0.25	5,256.25	0.51
Final Mass of Charcoal M_c	0.042		

Table 4: Controlled Cooking Test (Wood Type-Mark, 20,284 kJ/kg) (Rice)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
$M_A + M_W$	4.30		
Stove Temp T_S	34.50 °C		
Stove Temp T_F	35.6 °C		
$\Delta t = t_f - t_i$	30.50 mins		
Temp of Water T_{wi}	34.00 °C		
Mass of $Wood_i$	2.12	43002.08	11.95
Mass of $Wood_f$	1.22	24746.48	6.87
Mass of Wood used M_u	0.90	18255.60	5.07
Mass of Raw Rice M_r	0.50		
Mass of Cooked Rice M_{cr}	3.80		

Source: Langa, H.B. (PhD Thesis)

Table 5: Controlled Cooking Test (Wood Type - Tifirmi, 19,955 kJ/kg) (Rice)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
$M_A + M_W$	4.30		
Stove Temp T_S	35.4 °C		

Stove Temp T_F	36.6 °C		
$\Delta t = t_f - t_i$	34.5 mins		
Temp of Water T_{wi}	32.50 °C		
Mass of $Wood_i$	2.12	42304.60	11.75
Mass of $Wood_f$	0.92	18358.60	5.10
Mass of Wood used M_u	1.20	23946.00	6.65
Mass of Raw Rice M_r	0.50		
Mass of Cooked Rice M_{cr}	3.80		

Source: Langa, H.B. (PhD Thesis)

Table 6: Controlled Cooking Test (Wood Type - Mahogany, 21,025 kJ/kg) (Rice)

Items	Quantity (kg)	Energy (kJ)	Energy (kWh)
Mass of Pot A	2.50		
M_A+M_W	4.30		
Stove Temp T_S	35.00 °C		
Stove Temp T_F	36.20 °C		
$\Delta t = t_f - t_i$	18.50 mins		
Temp of Water T_{wi}	33.00 °C		
Mass of $Wood_i$	2.50	52562.50	14.60
Mass of $Wood_f$	1.85	38896.25	10.80
Mass of Wood used M_u	0.65	13666.25	3.80
Mass of Raw Rice M_r	0.50		
Mass of Cooked Rice M_{cr}	2.02		

Source: Langa, H.B. (PhD Thesis)

In our design, a Multipot massive wood stove with chimney was used. It was highlighted much earlier what was done especially to improved upon heat losses notably the one through the flue gas, a baffle was placed between the first and second pots to get more heat to the second cooking pot. For heat loss by convection and radiation from the stove body, a paste of ash was used to paint (2 cm thickness) the outside of the stove to reduce radiation loss. Table 1 - 6 indicate that it reduces the temperature difference to less than 1 °C between the commencements of the cooking process to the final stage. Good air draft provided by the use of chimney height of 65 cm and appropriate opening for wood inlet complete combustion was achieved.

4.1 The Result of the Stove Efficiency

The result of the stove efficiency (equation 5) were as follows

a. Data obtained from Water Boiling Test (WBT)

T_{amb} = 34.0 ^{o}C (307 K)

T_w = 98.0 ^{o}C (371 K)

M_{wo} = 1.80 kg

M_w = 1.74 kg

M_c = 0.046 kg

M_{co} = 0.00 kg

C_{pw} = 4200 J/kg K

H_{vw} = 2.26 MJ/kg

H_{vc} = 21.40 MJ/kg

M_{ws} = 1.78 kg

T_{ws} = 65.0 ^{o}C

Inserting the data into equation (5), we have;

η= 0.65446.

This formula has been used by many Researchers (VITA, 1982, Geller, 1981 and Bhatt, 1981)

Delivery Power

This quantity measures the amount of power delivered to the cooking pots, and in this case the first pot in the water boiling test. Here equation (4) is employed as:

b. Data

t = 430 seconds,

ΔT = (371 – 305.5) K = 65.5 K,

$V = 0.225\ m^3$

Inserting the given values P in kW was obtained as:

$P = 2.56$ kW.

This is the amount of power delivered to the first pot during the water boiling test (WBT).

The burning rate of the fuelwood can be expressed as in equation (3) as

c. Data

X is the moisture content of the fuelwood (assumed to 20 % of fuelwood used)

$X = 0.026$ kg,

$H_C = 21{,}400$ kJ,

$H_W = 20284$ kJ,

$M_w = 0.13$ kg,

$M_C = 0.046$ kg, and

$t = 7.0$ minutes.

Inserting these values into equation (2.12), we obtain the burning rate as:

$F = 1.326$ kg/min.

Thermal Efficiency

Recall equations (2.13) and (2.14), thermal efficiency was computed thus:

d. Data

where ,

$C_w = 4{,}200$ J/kg

$C_p = 910$ J/kg/K

$L_v = 2{,}256{,}000$ J/kg

$M_V = 1.78$ Kg

$C_F = 20{,}284{,}000$ J/kg/K

$M_W = 2.25$ kg

$M_F = 0.0252$ kg

$M_C = 0.046$ kg

$M_p = 2.50$ kg

$C_C = 21{,}400{,}000$J/kg/K.

$T_f = 98.0$ °C

$T_i = 34.5$ °C

Inserting these values into equation (3), we obtain the percentage heat utilized (PHU) as:

PHU = 49.337 %.

The thermal efficiency, therefore becomes,

$$\eta_{th} = Burningrate \times PHU$$

$$= 65.42\ \%$$

Annual saving potential of the stove (AES) can be computed using equation (1) as:

e. Data

NCV is the net caloric value of fuelwood = 0,015 TJ/ton (or 4,167 kWh/ton).

Now, with an average daily consumption of 10.03 kg of fuelwood for households who depends solely fuelwood,

B_y = 3610.8 kg

η_{old} = 0.25

η_{new} = 0.6545

Inserting these values into equation (1), we obtain AES as:

AES = 33.33 x 10^9 J

This implies that the new stove has a potential of saving 33.33 x 10^9 J of energy per annum for a household that rely solely on the traditional 3-stone stove for domestic cooking. In other words, the Improved Vented Mud (IVM) stove saves 33.33 x 10^9 J of energy per annum for a household.

Cooking Time for Some Food Samples

The study indicates the cooking time for the following food samples and their energy sources used:

a) Rice: Performed Controlled Cooking Test (CCT) using three wood samples Mark, (30.50 mins),Tifirmi (34.50 mins) and Mahogany (18.50mins)thus it takes between 18.50 – 34.50 minutes to cook 0.5 kg of rice, and the energy required also varies from 13666.25 to 23946.00 kJ,

b) Beans: Performed Controled Cooking Test (CCT) using three wood samples Mark, (30.50 mins),Tifirmi (34.50 mins) and Mahogany (18.50mins)thus it takes between 18.50 – 34.50 minutes to cook 0.5 kg of rice.

c). Water: Performed Water Boiling Test (WBT) using three wood samples Mark, (13.50 mins) Tifirmi (16.80 mins) and Mahogany(7.10 mins), thus it takes between 7.00-16.8 minutes to boil (2250 cm^3) of water from 32.50 °C to 98.00 °C, and the energy required also varies from 1825.56 to 6984.25 kJ.

5.0 Conclusions

We have been able to achieve the following in this research work:

i. Designed and constructed a modified improved Multipot cook stove of two (2) holes,

ii. Determined the efficiency of the modified improved cook stove, which was found to be 65.45 %,

iii. Performed Water Boiling Test (WBT) using three wood samples Mark, Tifirmi and Mahogany and found that it takes between 7.00-16.8 minutes to boil (2250 cm^3) of water from 32.50 °C to 98.00 °C, and the energy required also varies from 1825.56 to 6984.25 kJ,

iv. The specific fuel consumption was found to be 0.0031 for mark and 0.002 for mahogany using rice as food sample,

v. Determined the cooking time of some food samples like rice and beans, predominantly used food samples.

vi. Achieved an energy savings of about 24.12 MJ in a household,

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