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Design, Fabrication and Performance Evaluation of a Nozzle Type Wood Cook Stove for Indoor Emissions Reduction

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Abstract
In this work, a nozzle type improved wood cook stove was designed, fabricated and tested using laboratory emissions monitoring system. Wood combustion principles and heat transfer mechanisms were explored in designing the stove. In this design, emissions was reduced by tangentially admitting preheated air into the combustion chamber with a baffle placed above the fuel bed to generate recirculation zones to improve combustion efficiency. The stove was insulated with 25 mm thick glass wool to minimize energy losses. Water boiling test was conducted using laboratory emissions monitoring system to compare its performance with the traditional three-stone open fire cooking, which it is designed to replace. The results showed that this stove performed better in terms cooking duration and specific fuel consumption. The tests also showed that nozzle type has lower burning rate, indicating that it handled fuel more efficiently and economically than the traditional open fire cooking. The cold start phase (high-power) thermal efficiency of the stove was 26.40%, while the traditional three-stone open fire cooking is within 5-17%. The annual thermal energy saving of the stove was estimated to be 44.5 TJ, while its emission reduction was 22.0 tCO_2equivalent per year.

Keywords: *Wood cook stove, performance evaluation, emission reduction*

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1. Introduction

About half of the world's population–up to 90% of rural households in developing countries - relies on biomass, such as wood, dung, and crop residue as their major source of energy for cooking and other heating purposes, and often on the open fires or inefficient cook stoves [1] and [2]. Similarly, IEA [3] reported that 2.4 billion people rely on traditional biomass, mainly for cooking and heating and that the users are low income earner in the rural areas in the developing countries. This was attributed to lack of access to alternative, modern fuels in place of the traditional energy supply [4]. In Nigeria, about 67% of the country's population depends on fuel wood for their daily cooking [5]. The demand for fuel wood in the country is currently more than the supply, thereby resulting in its rising prices. Current pattern of household cooking imposes heavy costs on the poor. Kerosene prices have increased six-fold over the past eight years. Household cooking demands an average of 3.5 hours in collecting wood especially in rural areas. With about 100 million m^3 of wood consumed annually, Nigeria's forests are under severe pressure from harvesting fuel wood for cooking [5].

Cooking with fuelwood in Nigeria is mostly through the traditional open fires method. This results in about 90% of energy losses, long hours spent in cooking and high costs for households dependent on the wood market [5]. An average rural household spends 20% or more of its income on the purchase of fuelwood or charcoal for cooking. The money a household spends on fuelwood or charcoal translates into less money available for food, education, and medical care. Besides the high expense, cooking over an open fire creates health problems from the smoke, particularly lung and eye ailments etc. It was estimated that 1.6 million people, mainly women and children, die every year as a result of the smoke from wood stoves [6]. In a study carried out by [7] in Delta State of Nigeria with a sample size of 500 rural dwellers noted that 14.60% suffered red eyes, 71.60% cough complications, and 6.80% suffered sneezing due to exposures to smoke in their cooking environment.

A number of improved domestic cook stoves have been developed to address the environmental, health and social problems associated with the cooking on the traditional open fires and other inefficient cook stoves. One of such stoves is the "Rocket Stove" developed by the Aprovecho Research Center. The stove uses a grate for the fuelbed to increase air flow and combustion quality. The specifications of the stove height-to-volume ratio were such that an increased thermal efficiency is achieved and more of the energy produced actually reaches the stove [8]. However, the stove still has its limitations. There is no insulation in the stove design and therefore there is a tendency for the fire to smoke due to cooling near the walls of the stove. Again, the direct contact of the flame with the walls allows heat to be conducted out of the system thereby decreasing the thermal efficiency. Another improved wood cook stove that has been developed is the Save80 stove imported into Nigeria from Germany. This stove has a nominal effective thermal power of 1.5 kW and needs only 250 g of small pieces of wood to bring 6 L of water to the boil, 80% less than traditional fire places [9].The design ensures preheating of the air and complete combustion with no visible smoke and only small amounts of ash. Smoke is only seen immediately after the fire is started. Cooking with this stove is completed in a retained heat cooking device known as wonderbox. This box allows for more energy savings in addition to the savings made by the stove. The limitation of this stove is that it is very expensive and unaffordable by the rural and semi-urban populations in Nigeria that depend on the 3-stone fires or on inefficient cook stoves. This stove is also made of stainless steel which gets too hot to be touched during use, which can cause burn injuries and loss of useful energy through its wall. Other improved domestic cook stoves include the Kilakala mud stove built with locally available materials. It has a fuel saving capacity of 30%, but one major disadvantage of this stove is that it did not provide sufficient illumination [10]. The improved vented mud stove, a two-pot stove with chimney developed in India has the average thermal efficiency values across fuels that vary from 10 to 23.5%. The Angethi stove used for charcoal and char briquettes, fabricated with galvanized iron bucket, mud/concrete, and grate has a thermal efficiency of 17.5% [10]. The traditional mud stove, which is a simple U-shaped heavy stove for a single pot made with clay and coated with cow-dung clay mixture has an average thermal efficiency of 17.9% [11].

The present work is focused on designing and developing an improved domestic wood cook stove based on the concept of accelerating the volatiles from combusting fuelwood through a converging-nozzle mounted above the fuelbed zone. In this design emissions are reduced by tangentially admitting preheated air into the combustion chamber, with a baffle mounted above the fuelbed zone to generate recirculation zones to improve combustion efficiency. Heat energy losses through walls of the stove into the cooking environment are minimized by insulating the stove with 25 mm thick glass wool. The insulation also helps to increase the combustion chamber temperature by drastically reducing heat losses through stove wall.

2. 0 Design Criteria for the Improved Nozzle Type Cook Stove

The stove was designed based on four main criteria: (i) Cost – simple design and fabricated with locally sourced materials to make it affordable by low-income earners.
(ii) Functionality- it was also designed to be durable, easy to operate and replicated by road-side artisans. (iii) Emissions- for the stove to be useful it must reduce drastically the emissions such as particulates and carbon monoxide due to incomplete combustion of fuelwood.
(iv) Efficiency- it was also designed to increase efficiency by lowering cooking time and reducing wood fuel consumption.

2.1 Design considerations for the nozzle type stove

Cook stoves are basically used to generate the heat energy required for cooking and other heating purposes. The required heat energy is generated by burning fuelwood in the combustion chamber of the stoves. The main obstacle to reaching complete wood combustion in cook stoves is the difficulty in creating good mixing between the fuel and air in their combustion chambers [12]. In designing the combustion chamber, the effect of the competing factors such as heat transfer and combustion quality must be taken into consideration. However, efforts to maximize the heat transfer to the pot deteriorate the quality of combustion and vice versa, so there must be a balance between thermal efficiency and combustion quality. One way to increase thermal efficiency is to bring the pot closer to the fuel bed, but lowering the height of the combustion chamber reduces air flow and decreases combustion quality [12]. If the combustion chamber is too high it will result in a greater entrainment of air, resulting in quenching of the flame, thus reducing the radiation and convective input to the cooking pot. Based on studies conducted on open fires and wood pyrolysis, the combustion chamber is assumed to be composed of two sections - the charcoal combustion section and the volatiles combustion section [13]. The correlation given by [13] considered in determining the height of the charcoal section is expressed in Equations (1) and (2):

$$H_{cc} = \frac{\Delta M_f}{X \times P_f \times A_{cc}} \tag{1}$$

$$A_{cc} = \frac{P_{design}[kg]}{P_{density}[kg/m^2]} \tag{2}$$

$P_{density}$ is the power density which depends on the type of grate. For non-grate, fire power density appears to be 20W/cm^2.

$$P_{design} = 0.7P_{\max} \tag{3}$$

$P_{\max}$ is the maximum power a stove can deliver without any restriction on the quality of combustion [9]. The correlation considered in determining the height of the volatiles section was based on the experimental studies on flame heights in open fires and this is expressed as:

$$H_{fl} = C_2 P^{0.4} \tag{4}$$

where, P is the power output and C_2 is a constant, which depends on the type of grate.
C_2= 75 mm/kW$^{0.4}$ for a fire with a grate and 110 mm/kW $^{0.4}$ for fires without grate [13].
The combustion chamber is also provided with two side openings which serve the purpose of admitting preheated air tangentially into the combustion chamber and another one which serve as fuel inlet. The side opening for air is determined on the basis of volumetric flow rate (V) of air using the correlation by [13]:

$$V = 29.7h^{0.5}(1 - \frac{T_a}{T_i}) \tag{5}$$

The design power of the stove is based on the time required for cooking. But data on the time required for different cooking operations on cook stoves, as a function of quantity of food at maximum power has not been reported. The correlation by [12] based on testing of gas cooking range was therefore used for the design, which is expressed as:

$$T_c = 550M_f^{0.38} \tag{6}$$

Based on this, the correlation [13] considered in determining the maximum power of the stove is:

$$P_{\max} = \frac{M_f C_p (T_b - T_i)}{\eta T_c} \tag{7}$$

Another important consideration in designing the combustion chamber of the stove was the reduction of heat losses from the side walls. The combustion chamber of the stove is made of metal sheet which has high thermal conductivity. Without proper insulation there would be higher outer surface heat losses and this could cause burn injuries. Therefore, the stove is designed with double walls separated with the insulator- glass wool (25 mm thickness). This would substantially reduce the heat losses from the combustion chamber. A baffle was also introduced in this design to improve the combustion efficiency. The baffle increased the residence time of the flue gases in the combustion chamber and directs the hot gases towards the pot to improve convective heat transfer and the radiation to the pot, since part of the energy it absorbed radiates back to the pot. An increase in the velocity of the burnt gas, as a result of reduction in the flow passage gap between the top surface of the baffle and the bottom of the pot, increases the convective heat transfer an hence the heat transfer to the pot [13].

Table 1: Design specifications of the Nozzle type stove

Description	**Specification**
Maximum power of the stove (P_{max})	5.53kW
Design power of the stove (P_{design})	3.87kW
Time to boil 5 liters of water (T_C)	50 minutes
Stove designed efficiency (η)	45%
Fuel consumption rate	5.26×10^{-6}kg/sec
Air flow rate (Q)	1.496×10^{-4} m^3/sec.
Air inlet area	80mm x 12mm
Net air suction pressure (Pnet)	0.143kg/m^2
Combustion chamber dimensions: (i) Height of volatile combustion section (H_{fl}) (ii) Height of charcoal bed combustion section (Hcc) (iii) Area of the charcoal bed (Acc)	 100mm 130mm 258cm^2
Converging Nozzle (i) Inlet area of the nozzle (i) Outlet area of the nozzle	 $25.78 \times 10^3 mm^2$ $4.13 \times 10^3 mm^2$
Temperature (T) of the hot gas from the combustion chamber impinging on the pot	706°C
Insulation material- glass wool	25 mm

Figure 1 Nozzle type wood cook stove developed at NCERD UNN under test

g Standard

A number of standard methods have developed for evaluating the performance of cook stoves. Such methods are the constant heat output, constant temperature rise, constant time and water boiling test [14] and [15]. However, water boiling test method is mostly used as it is short and provides a simple simulation of standard cooking procedures. It measures the quantity of fuel consumed and time required for the simulated cooking and usually employed in investigating the performance of cook stoves under different operating conditions [16]. It also provides a quick method of comparing the performance of cook stoves. This method is therefore employed in evaluating the performance of the stove using a laboratory emissions monitoring system domicile at the National Stove Eligibility Laboratory (NSEL), National Centre for Energy Research and Development, Universirty of Nigeria, Nsukka. The water boiling test (WBT) protocol is fully described in www.community.cleancookstoves.org/files. The WBT consists of three phases: high-power (cold start) phase, high power (hot start) phase, and low power (simmer) phase. These tests offered very important indicators in evaluating the ability of cook stoves to conserve fuel. The materials/apparatus used in conducting the WBT in this study are as follows: (i) A cooking pot with 28cm bottom diameter and stop watch (timer),

(ii) A digital thermocouple for measuring the ambient and initial temperature of the water,
(iii) A digital balance for measuring the weight of the fuelwood, charcoal, water and pots,
(iv) Metal tray to hold charcoal for weighing,
(v) Two bundles of air-dried fuelwood each weighing 5 kg for each test.

(vi) 5 liters of clean water for each test.

3.1 WBT with the Laboratory Emissions Monitoring System

The WBT is conducted in this study using a laboratory emissions monitoring system (LEMS) developed by Aprovecho Research Center [17]. It quantifies the emissions from cookstoves by collecting, measuring and analyzing the emissions: CO_2, CO and particulate matter (PM) emitted from the stove. It also determines the thermal efficiency performance of a cookstove. Figure 1 shows the nozzle type biomass energy efficient cookstove mounted inside the metal hood of the LEMS during testing at the National Stove Eligibility Laboratory, National Center for Energy Research and Development, University of Nigeria Nsukka. The LEMS consists of carbon monoxide (CO) sensor which is an electrochemical cell with two electrodes.

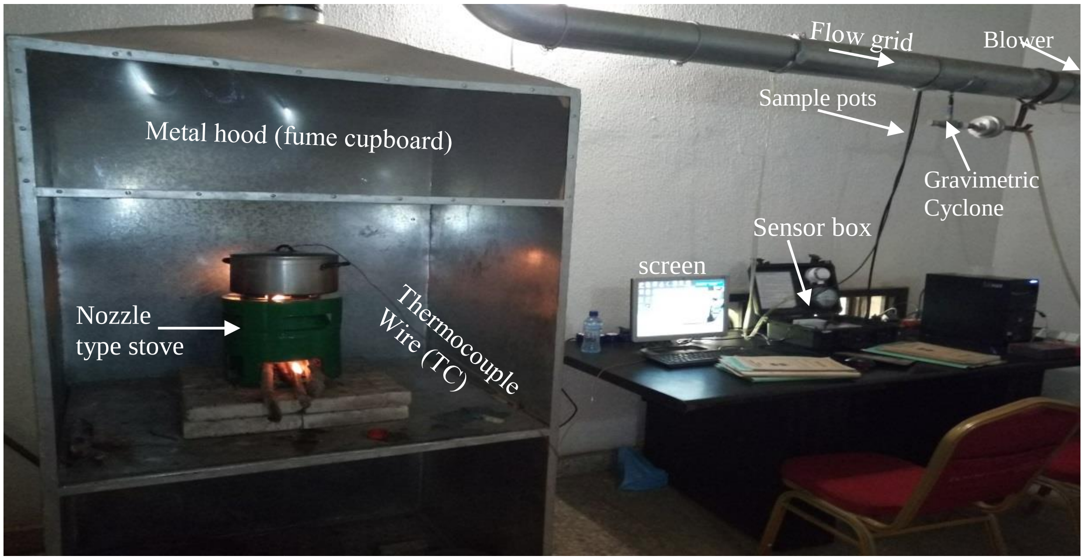

Figure 2 Laboratory emissions monitoring system with the nozzle type energy efficient cookstove mounted inside the metal hood

The conductivity between the two electrodes gives the proportional concentration of the CO produced by the stove under testing. The carbon dioxide (CO_2) sensor uses non-dispersive infrared to measure CO_2 concentration and outputs voltage. The LEMS has two particulate matter (PM) sensors – the gravimetric system and light scattering photometer. The gravimetric system gives a direct measurement of total PM using filter-based sampling. The light scattering photometer has both a laser and a light receiver. When smoke enters the sensing chamber, particles of smoke scatter the laser light into the receiver and more light reaching the receiver indicates more smoke in the chamber. The flow grid is an amplified pitot tube that provides a low pressure drop through the system and a strong differential pressure signal, averaged across the entire duct cross-section. The exhaust gas velocity, volume, and mass flow rate within the duct, are calculated based on pressure drop recorded using the Magnesense pressure transducer. The thermocouple (TC) temperature sensor is used to record the water temperature of the pot. The thermocouple temperature output is linear and the thermocouple probe provided with the LEMS is rated for temperatures up to 250°C [17].

3.2 Thermal performance characteristics of the stove

The thermal performance characteristics of the nozzle type cookstove developed in this study is determined from the WBT with the Laboratory Emissions Monitoring System code are based on the parameters described in Equations (8) to (13).

(i) Burning rate of the stove

The burning rate R (g/min) which measures how economically the stove burns the fuel wood in its combustion chamber is determined using Equation (8) [16]:

$$R = \left[\frac{100(W_i - W_f)}{(100+M)} - \frac{M_c H_c}{H_w} \right] \frac{1}{t} \tag{8}$$

W_i is the initial weight of fuelwood at start of test (g), W_f is the final weight of fuelwood at end of test (g), M is the moisture content of fuelwood (%), H_c is the Calorific value of charcoal (28.8MJ/kg), M_c is the weight of charcoal (g), H_w is the Calorific value of fuel wood (15.5MJ/kg) and t is the total time taken for boiling the water.

(ii)Thermal efficiency of the stove

The thermal efficiency measures how the heat generated by the stove is utilized in boiling the water or in cooking the food. The thermal efficiency (η_{th}) of the stove can be determined using the Equation (9) [10].

$$\eta_{th} = \eta_h \times \eta_c \tag{9}$$

It is also related to the percentage heat utilized (PHU) by the stove which is given as:

$$\eta_{th} = \text{Burning Rate x } PHU \tag{10}$$

The percentage heat utilized (PHU) is determined by Equation (4).

$$PHU = \frac{M_w C_p (T_b - T_{o)} + M_{ev} L}{M_f H_f} \tag{11}$$

(iii) Specific fuel consumption (SFC)

The specific fuel consumption is expressed in Equation (12).

$$SFC = \frac{\lfloor W_f (1 - M) - 1.5 M_C \rfloor}{M_w} \tag{12}$$

(iv) Power consumption for boiling or simmering:
This measures the wood energy consumed by the stove per unit time. It indicates the average power output of the stove (in Watts) during the high-power test. The power consumed (PC) for boiling water is expressed in Equation (13).

$$PC = \frac{\lfloor W_f (1 - X) - 1.5 M_C \rfloor \times H_w}{60t} \tag{13}$$

4.0 Thermal and Emissions Performance Tests Results and Data Analysis

The measured and calculated data obtained from the high-power (cold start), high-power (hot Start) and low-power (simmering) phases of the WBT are presented in Tables 1, 2 and 3 and Figures 1 and 2 with the Laboratory Emissions Monitoring System code [17].

4.1 Thermal performance analysis

Table 1 indicates the basic operation performance of the stove which includes the burning rate, thermal efficiency, specific fuel consumption and firepower. The values in Table 1 are calculated from the WBT data implemented in the LEMS software code. Table 2 indicates the energy consumption performance evaluation of the stove for the cold start, hot start and simmering phases of the tests. The results indicate that the 3-stone open fire has a higher burning rate than that of nozzle type stove. The higher the burning rate the faster the fuel is used up and this is a disadvantage for a stove to have very high burning rate. The lower burning rate achieved by the nozzle stove indicates that this stove handles fuel more economically than the traditional open fire cooking.

Table 1 Basic operation performance of the nozzle type stove and open fire cooking

Basic Operation Performance	**Units**	**Cold Start Phase**		**Hot Start Phase**		**Simmering Phase**	
		Traditional 3-stone open fire	**Nozzle Type Stove**	**Traditional 3-stone open fire**	**Nozzle Type Stove**	**Traditional 3-stone open fire**	**Nozzle Type Stove**
Time to boil 5 liters of water	min	73	62	56	47	45	45
Thermal Efficiency η_{th}	(%)	9.7	26.4	10.6	28.6	13.8	36.4
Specific fuel consumption	g/liter	327.5	268.2	283.7	179.0	198.6	126.7

Fire power	watts	4,563.0	3732.0	5830.0	4296.0	438.0	187.0
Equivalent dry fuel consumed	g	1356.8	1089.2	1013.6	794.4	823.5	441.3

Table 2 Indicates the energy consumption performance evaluation of the stove

Energy Consumption	**Units**	Value		
Net calorific value (dry firewood)	kJ/kg	14,800		
Moisture content	%	10%		
		Cold Start	Hot Start	Simmer
Temp-corrected time to boil	min	61.2	42.0	45
Energy consumption rate	kJ/min	224	318	145
Dry fuel consumed	g	1,012	711	1,875
Total energy consumed	kJ	14,972	10,523	4,440
Energy delivered to the cooking pot	MJ	3.512	2.631	2.136
Average cooking power	kW	0.721	1.043	0.791

4.2 Emission performance analysis

Figure 1 indicates the real-time PM, pot temperature, and relative humidity profiles and Figure 2 indicates the real-time CO_2 and CO emissions profiles during the cold start (high-power), hot start (high-power) and simmer (low-power) phases of the WBT respectively with the LEMS software code.

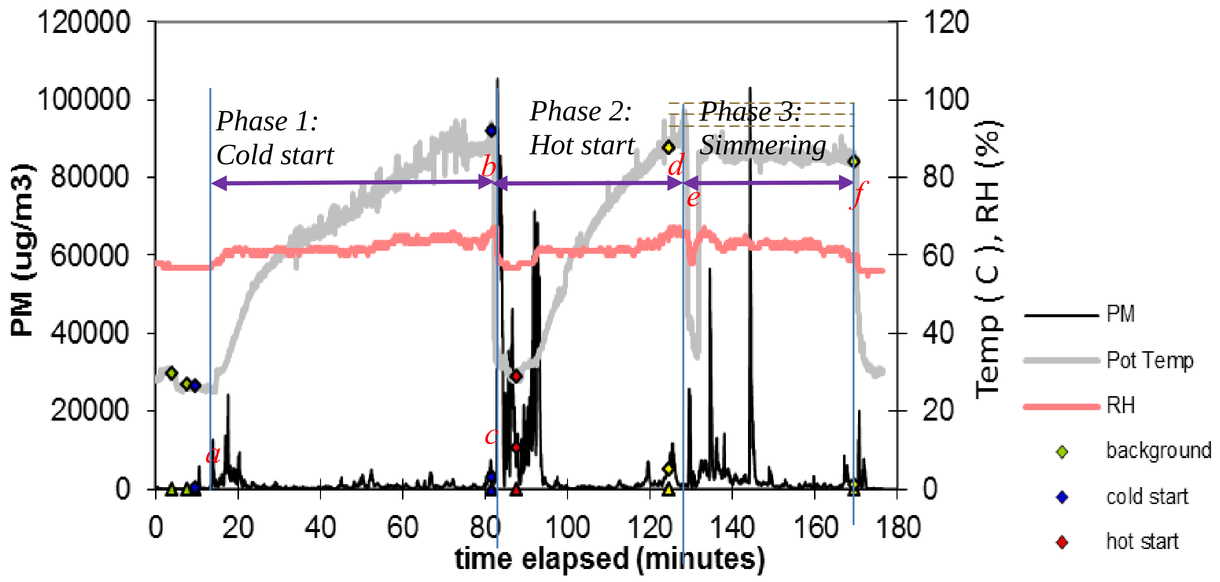

Figure 1 Particulate matter (PM), pot temperature, and relative humidity during WBT

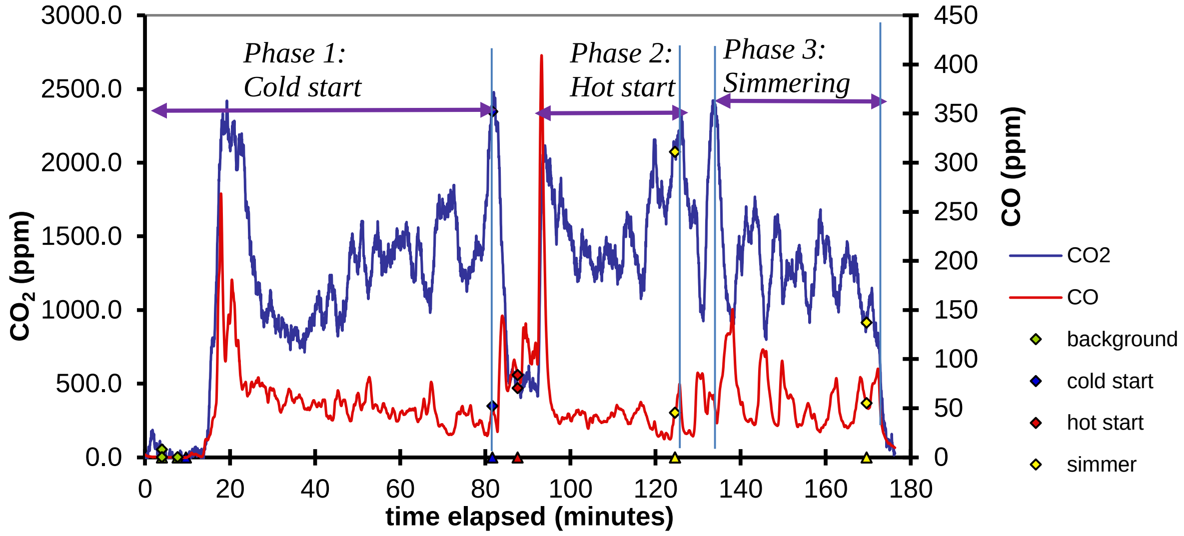

Figure 3 CO_2 and CO emissions during WBT

Tables 3 International Workshop Agreement (IWA) Performance Metrics

IWA Performance Metrics		Nozzle type cookstove performance	Traditional open fire performance Value (Tier 0)*	Minimum standard (Tier 2)*
High Power Thermal Efficiency	%	26.4	< 15.0	> 25.0
Low Power Specific Consumption Rate	MJ/min/L	0.036	> 0.05	<0.039
High Power CO	g/MJd	10.97	> 16.0	<11
Low Power CO	g/min/L	0.18	> 0.2	<0.13
High Power PM	mg/MJd	352.0	> 979	<386
Low Power PM	mg/min/L	3.76	> 8	<4
Indoor Emissions CO	g/min	0.61	> 0.97	<0.62
Indoor Emissions PM	mg/min	15.9	> 40	<17

*__Source: Nigerian Industrial Standard, FDNIS 1000: 2017__

Table 3 compares the performance of the nozzle type stove with the traditional open fire cooking and the minimum performance standard (Tier 2) for biomass cookstoves established by Standard Organization of Nigeria (SON). It can be observed in Table 3 that the thermal and emission performance values of the stove are in line with the minimum performance standard of Tier 2 acceptable by IWA [18]. These results indicate that the traditional open fire cooking (Tier 0) has a lower thermal efficiency than the nozzle stove due its higher burning rate, since both parameters are inversely proportional to each other. The higher thermal efficiency of the nozzle stove is due to its proper insulation to reduce heat losses by conduction, increase in radiation heat transfer by increasing flame temperature and increase in convective heat transfer achieved by accelerating the burning hot gas up the converging nozzle of the volatile combustion section before impinging on the pot. The nozzle stove has thermal efficiency higher than of the improved vented mud stove, a two-pot stove with chimney developed in India, Kilakala mud stove reported by Otiti [19], Angethi stove by [10], traditional mud stove, which is a simple U-shaped heavy stove reported by George [11].

5.0 Annual energy savings (ES) potential of the nozzle type stove

Energy efficient cookstove are basically designed to improve efficiency thereby reducing wood fuel consumption and lowering the cooking time. The annual energy saving of the nozzle type stove is estimated using the Equations (14) and (15) [20].

$$ES = FW_{A-Savings} \times NCV_{Fuelwood} \tag{14}$$

$$ES = FW_A \times (1 - \frac{\eta_{old}}{\eta_{new}}) \times NCV_{fuelwood} \tag{15}$$

FW_A = Quantity of fuelwood used by a household that rely on the traditional three-stone open fire cooking. This is estimated to be 4.9561 t per annum [20].
η_{old} = Efficiency of the traditional three-stone open fire cooking, which the nozzle type cookstove is designed to replace has been determined to be within 5 to 17 % or less by WBT [21]. η_{new} = Efficiency of the nozzle stove designed to replace the traditional open fire cooking. This was determined to be 26.4% by WBT using Laboratory Emissions Monitoring System.
$NCV_{fuelwood}$ = Net calorific value of fuelwood = 0.015 TJ/tonne, or 4,167 kWh/t
From equation (14), Energy Saving (ES) = 12359.95kWh or 44.5 TJ. Thus the annual energy savings of this stove by a household that depends on traditional open fire for their daily cooking activities and other heating purposes is estimated to be 44.5 TJ.

6.0 Annual emission reduction of the nozzle stove

Energy efficient cookstove are also designed to improve combustion efficiency in order to reduce harmful emissions such as CO, PM and NOx associated with incomplete combustion of biomass fuels into the kitchen cooking environment. The energy required in the household energy sector in Nigeria is dominated by fuelwood, meeting up to 80% of the demand, followed by kerosene (10%), LPG (4%), charcoal (3%), and other biomass (3%) [20]. It follows that kerosene is the fossil fuel likely to be used by a similar household. The emission reduction is estimated on the basis of the emission of a fossil fuel with the same energy content as the non-renewable biomass displaced. The annual emission reduction by this stove is estimated using the Equation (16) [20].

$$AER = FW_{A-Savings} \times F_A \times NCV_{fuelwood} \times EF_{fossil-fuel} \tag{16}$$

Where, AER = Annual emission reduction in tCO$_2$equivalent. FW_A = Quantity of fuelwood used by a household that rely on the traditional open fire cooking. F_A = Fraction of the fuelwood to be saved by using the nozzle type stove in a year. $NCV_{fuelwood}$ = Net calorific value of fuelwood used for the calculation, which equal to 15.5x10^6 MJ/kg = 0.015 TJ/tonne, or 4,167 kWh/t. EF is the fossil fuel emission factor for the substitution of fuelwood by similar households.

$$FW_{A-Savings} = FW_A \times (1 - \frac{\eta_{old}}{\eta_{new}}) \tag{17}$$

FW_A is the quantity of fuelwood used by a household that rely on the traditional open fire cooking (tonnes/annum). This is estimated to be 4.9561t per annum [20].

From Equation (16), AER is determined to be 22.0 t CO_2/year. Thus, the annual emissions reduction of the nozzle type stove by a household using traditional open fire for cooking and other heating purposes is estimated to be 22.0 t CO_2 equivalent /year. This is achieved by admitting preheated air tangentially through the annular channels into the combustion chamber, which improved the combustion efficiency of the stove.

7.0 Conclusions

This work has designed and fabricated a nozzle type improved wood cook stove and conducted WBTs with LEMS to compare its thermal and emissions performances with the traditional open fire cooking mostly used in the rural areas in the developing countries. The results show that this stove performed better in terms cooking duration, specific fuel consumption and drastic emissions reduction. Its burning rate was lower than that of the traditional open fire cooking, indicating that it burnt fuel more efficiently than the traditional open fire cooking. The annual thermal energy saving by this stove was estimated to be 44.5 TJ, while its emission reduction was 22.0 tCO_2 equivalent per year. The benefits of using an improved wood cook stoves include reduce the sufferings of mostly women and children involved in cooking and fetching fuel wood, reduced risk of burns and money spent by households on fuel wood, indoor air pollution from fuel wood smoke, thereby minimizing its harmful effects on human health and reduce demand for fuel wood.

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