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Adaptation and Performance Evaluation of Updraft Biomass Gasifier Stove with Sawdust as Fuel

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Abstract

This study aims to adapt and evaluate an updraft biomass gasifier stove using sawdust biomass. It was a cylindrical gasifier having a diameter of 32.5cm*40cm height and a rectangular box-like base that served as a set and had a primary air hole of 20cm*6cm sliding type door. Renewable biomass-derived fuels could readily replace fossil fuels in many energy utilization applications with environmental benefits. Gasification is a form of biomass energy conversion producing a fuel that could substitute for fossil fuels in high-efficiency power generation. The future of energy is looking promising for biomass energy as one of the most important renewable energy sources. This work has been carried out to adapt, construct, and test an applicable biomass gasifier stove. This is for producing producer gas from locally available biomass fuel. The gasifier was constructed and tested on Water Boiling Test (WBT). The test was run using sawdust as feeding fuel. Various parameters such as manufacturing materials and technique, operation, fuel type, and primary and secondary air inlets were provided and evaluated. The updraft gasifier stove was evaluated at a biomass feeding rate of 0.5kg per batch. The results obtained from this study show a combustion efficiency of 84.2% and a thermal efficiency of 30.6% respectively. Therefore, the output could provide modern energy services for basic needs and productive applications.

Keywords: Ash, Biomass fuels, Construction, Fuel efficiency, Gasification, Updraft gasifier,
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Introduction

In a technique known as micro gasification, solid fuels are converted into gas in gasifiers that are small enough to fit beneath a cooking pot at a comfortable height. Following the theory, the first commercial micro-gasifier cook burner became available in 2003 [1]. Thus, gasifiers are equipment that enables the thermochemical conversion of solid fuel to gaseous fuel. Drying at a temperature greater than 100 °C, Pyrolysis at a temperature greater than 300 °C, and combustion of wood gas are all steps in this process [2]. When fossil fuels were hard to come by in Europe during the Second World War, the concept of gasification became particularly important. However, when fuel availability became too commonplace, research and development drastically decreased[3].

The majority of advancements in biomass stoves have been centered on intuitive methods to look at factors of heat transport, pushing the combustion concerns to the sidelines[1]. In this instance, integrating simulation into the design phase offers a solution. A simulation-based design increases precision and reduces the expense of making numerous prototypes [4]. Without measurements, it is difficult to forecast how a cook stove will function. Testing is, therefore, a crucial tool for any designer to use when creating solutions and estimating any negative effects on the environment, human health, and the economy [5].

Utilizing a water boiling test (WBT), a stove's performance is assessed in terms of its thermal efficiency, emissions, specific fuel consumption, firepower, and safety[6]. Because they pose serious health risks, Carbon Monoxide and Particulate Matter are among the dangerous indoor air pollutants that should be minimized. [7]. A rough estimate of the percentage of the fuel's overall energy output that is used to heat the water pot is known as thermal efficiency. The majority of biomass-based stoves have extremely low usage efficiencies, ranging from 10 to 20% [8].

As previously mentioned, the developed experimental cook stove was evaluated using the Water Boiling Test.

However, it's crucial to remember that there are additional tests, such as controlled cooking tests and kitchen performance tests. Three phases make up WBT: a cold start high-power phase, a hot start high-power phase, and a simmering low-power phase. There are numerous measurements and calculations for each stage. [9].

For the numerous varieties of dishes served all over the world, various cooking techniques, such as simmering and heat levels, are required. Cooks modify the fuel or air supply to the fire to change how hot it gets [6]. One stove may be used to prepare a variety of dishes thanks to design characteristics that make air adjustment simple. The rate at which fuel burns, thermal efficiency, and the extent of combustion, however, can all be impacted by variations in air supply. As a result, performance and user advantages must be balanced. Depending on the location of the fire, a cook stove's air supply is commonly divided into two modes [10]. Primary air enters the combustion area immediately and interacts with the fuel there. The fuel aperture is where primary air enters rocket burners [11]. Some stoves include input ports on the bottom of the stove underneath the fuel, allowing oxygen to be supplied to the bed of burning charcoal residue while being prepared before entering the combustion zone. After the combustion zone, secondary air is pumped into the stove, delivering oxygen to the producing gas for the reaction [12].

Ethiopia is one of the developing country with limited access to clean energy sources, but biomass gasifier stove technology could be a part of the solution because of the benefits it offers both users and the wider public. It is a good substitute for an LPG stove, especially in terms of fuel savings and flame quality[13]. will also aid in reducing environmental pollution, particularly that caused by waste dumped along river banks and burned on roadsides. [14], Additionally, it will aid in reducing airborne emissions of carbon dioxide, carbon monoxide, and particulate matter caused by the excessive burning of wood and other biomass fuel in traditional cookstoves, which causes the ozone layer to be destroyed and subsequently causes the "GHG effect" in the atmosphere [15], Lastly, by eliminating issues with drought during the summer and flood during the rainy season, it will assist maintain the forest by lowering the chopping of trees for the manufacture of wood fuel and wood charcoal.

In the US, China, India, and other developing nations in Asia, gasifier stoves that use wood as fuel have been developed. These gasifier stoves, such as the Teri gasifiers and Philips Wood stoves, create a flammable gas by burning the fuel with little or no air[16].

For forced draft cook stoves to work effectively, design factors such as airflow rates, reactor diameter, and reactor height are critical. The diameter of the reactor has a significant impact on the power output of the stove; hence, the larger the reactor's diameter, the more energy the stove can produce. Additionally, since gas production is a function of the gasification rate (measured in kilograms of fuel burned per unit of time) and reactor area, more fuel should be burned per unit of time [11]. Additionally, the height of the reactor has an impact on the overall operating time to produce gas. Finally, the size of the reactor affects the size of the air inlet. More airflow is required as the larger the reactor's diameter. More pressure is required to overcome the fuel's resistance the higher the reactor is [17].

In an experimental setting or a lab, nearly any carbonaceous or biomass fuel can be gasified. To ascertain the fuel's moisture content, carbon content, volatile material, heat energy calorific value, and ash content, an evaluation of the fuel is required. For this study, the homogeneity criteria were accomplished by using sawdust pellets with a diameter of 2 to 10 mm and a length of less than 40 mm. The goal of this work was to develop and evaluate a gasifier stove that uses sawdust biomass as a feedstock instead of softwood as a potential alternative fuel source for home fuel consumption

Materials and Method

Description of the Study Area:

The experiment was conducted at the Bako Agricultural Engineering Research Center (BAERC), which is found 250 km west of Addis Ababa, the capital of Ethiopia. Its precise location is at 9°06' N latitude, 37°09' E longitude, and 1650 m above mean sea level. According to Ethiopia's central statistical office (CSA), the city had a total population of roughly 184,925 in 2017 G C.

Materials

Materials and apparatus used for this experiment are:

- ✓ Wood Gas Stove- fabricated in BAERC workshop and type mild steel metal
- ✓ Three-stone cooking stove (TSCS)-locally prepared
- ✓ aluminum cooking vessel-purchased from a local market
- ✓ Stopwatch
- ✓ infrared thermometer,
- ✓ Digital thermometer (+_0.5)
- ✓ k-type thermocouple
- ✓ Digital balance (5kg, accuracy +-1gram)
- ✓ Hygrometer (air relative humidity 10-90%)

✓ Fuel sawdust

Description of Sawdust Gasifier Stoves

The up-draft type of sawdust Gasifier stove was fabricated by BAERC workshop *(figure 1).* The gasifier stove had a single combustion chamber and a double-cylinder construction. Both ends of the outer cylinder are open, and the cylinder set box includes one sliding-open door and ring ventilation holes at the bottom of the cylinder. Both ends of the inner cylinder open to create a combustion chamber. The outer cylinder nestles inside this one. It is supported by the bottom air box and rests on the perforated sheet or grate. The upper end of this cylinder has a ring of ventilation holes punched into it. To create a cap for the inner and outer cylinders, the upper cylinder, which is just slightly smaller than the outer cylinder, is reduced in size. The upper end of this cylinder has a ring of ventilation holes punched into it. To create a cap for the inner and outer cylinders, the upper cylinder, which is just slightly smaller than the outer cylinder, is reduced in size. The cap has a riser (to improve producer gas combustion efficiency) and a circular hole that is only slightly smaller in diameter than the inner cylinder. The opening was big enough not to block the flow of heat up through the top of the combustion chamber despite being supported by the upper lip of the combustion chamber. The hat served as a support for the pot seat.

Figure 1 Main components of a stove

Sawdust the unburned fuel is at the bottom of the grate. The fuel charge was fired on top, generating a layer of charcoal. The blazing pyrolysis was above the layer of charcoal. Through holes drilled at the bottom of the outer cylinder, the primary air for the pyrolysis process entered the bottom and moved up, forming gases in the blazing pyrolysis zone. Secondary air was used to ignite the pyrolysis gas, along with some primary air that passed through both the inner and outer cylinders of the combustion chamber and holes punched into the top of the combustion chamber above the charcoal zone.

Design calculation

The BAERC's workshop served as the design and manufacturing location for the updraft biomass gasifier stove. If necessary, we have created a cylinder-shaped biomass gasifier with a ring-shaped combustion chamber. The formula was used to calculate the size of the combustion chamber, which permeated the entire stove.

$$A_c = \pi r_c h \qquad \text{……………………} (1)$$

Where A_c was the area of the combustion chamber, r_c was the radius of the combustion chamber, and h= height of the cylindrical combustion chamber. Therefore, the area of the combustion chamber was 0.4082m^2. The combustion chamber gap needed at the edge was determined from the circumference of the area that the hot gasses pass through. To do this measurement was taken from the center of the combustion chamber outlet to the farthest edge(r_c). To determine the circumference associated with this distance using the formula.

$$C_c = 2 * \pi * r_c \qquad \text{……………………} (2)$$

Where, C_c=the circumferences of the combustion chambers. Therefore, the circumference of the combustion chamber was, C_c=1.021m.

The gap between the bottom of the pot and the top edge of the combustion chamber next, divide the cross-sectional area, Ac, determined in equation (1) by the C_c determined in equation (2). This was

$G_c = \frac{A_c}{C_c}$ Where G_c is the needed gap between the bottom of the pot and the top edge of the combustion chamber and the circumference of our pot in the case was

$$C_p = 2 * \pi * r_p \text{ and } G_p = {}^{A_c}\!/_{C_p} \quad \text{........ (3)}$$

where Cp and Gp were the circumferences of our pot and the needed gap at the edge of the pot from the combustion chamber. Therefore C_p=41.762cm and G_p=13.2cm and the gap between the top of the fire chamber and the bottom of the pot from our design was 15.5cm-13.2cm=2.3cm which was very safe for better firepower capturing

Biomass fuel characteristics

The sawdust used for the experiments was average softwood (conifer) obtained from the center as a leftover of different activities, split and air-dried. Semi-cylindrical pieces of wood (0.5-3 cm in length) were used during each experiment. The moisture content (13.5%) and the calorific value were determined at the end of the entire series of experiments by using the water boiling test version 4.2.3 software.

Performance evaluation experimental setup

The Water Boiling Test (WBT) is an abbreviated model of the cooking process. It aims to gauge how well a stove uses fuel to heat water in a cooking pot as well as the extent of pollutants created during cooking[10]. It is typically used to examine cookstove performance under various operating settings and evaluates the amount of fuel consumed and the amount of time needed for the simulated cooking.

Three phases that immediately follow one another make up the conventional WBT. We started the test for the cold-start high-power phase with the stove at room temperature and used fuel from a pre-weighed bundle of fuel (2kg) to boil a specific amount of water (3 liters) in a vessel with a diameter of 13.3 cm made of stainless steel. Then we replaced the boiled water with fresh water of ambient temperature to perform the second phase. The *hot-start high-power phase* was conducted after the first phase while the stove and cooking vessel was still hot. Again, we used fuel from a pre-weighed bundle of fuel to boil a measured quantity of water (2 Kg) 0.5kg in the vessel. Repeating the test with a hot stove helps to identify differences in performance between a stove when it is cold and when it is hot. The *simmer phase* provides the amount of fuel required to simmer a measured amount of water at just below boiling point for 45 minutes. This step simulates the long cooking of legumes or pulses commonly throughout much of the world. During this phase, a pre-weighed amount of fuel was used to simmer the boiled water for 45 minutes. As it was a quick method of comparing the performance of cookstoves[10], we employed it in evaluating the performance of the improved biomass cook stove and compared it with the performance of the 3-stone traditional cook stove, which it intends to replace. For each stove, the two phases were repeated three times.

Variables that are constant throughout all phases

HHV	Gross calorific value (dry wood) (kJ/kg)
LHV	Net calorific value (dry wood) (kJ/kg)
MC	Wood moisture content (% - wet basis)
EHV	Effective calorific value (accounting for moisture content of wood)
P	Dry mass of empty pot (grams)
K	Weight of empty container for char (grams)
Ta	Ambient Temperature (°C)
Tb	Local boiling point of water (°C)

Determination of performance parameters

a) Fuel consumed (dry base): The amount of fuel wood used to bring water temperature from room temperature to boil (Teka.T and Ancha V, 2017). And it **a**ccounts for two factors: (1) the energy that was needed to remove the moisture in the fuel and (2) the amount of char remaining unburned, given by:

Mass of dry fuel = Fuel mass (wet)(1-M) ... (4)*

b) Specific fuel consumption (SFC): This is a measure of the amount of fuel required to boil (or simmer) 1 liter of water. It is calculated by the equivalent dry fuel used minus the energy in the remaining charcoal, divided by the liters of water remaining at the end of the test. In this way, the fuel used to produce a useful liter of "food" and essentially the time taken to do so is accounted for and given by an equation (Sabrina Chan, 2016)).

$$SFC \frac{mass of fuel consumed (kg)}{total mass of boiling water (lit)} \quad \text{.. (5)}$$

c)Burning rate: the Burning rate is the ratio of the mass of the fuel burnt (in grams) to the total time taken (in a minute). It was calculated by using the equation

$$Br = \frac{\mathrm{fcb}(gm)}{\mathrm{dtc}(\mathrm{min})} \quad \text{……………………………………………………………} (6)$$

Where, Br= Burning rate (g/min,
fcb = Equivalent dry fuel consumed,
dtc =Time to boil (min)

d) Firepower (Fp): This is the ratio of the wood energy consumed by the stove per unit of time. It is a useful measure of the stove's heat output and an indicator of how consistently the operator ran the stove over multiple tests. And the firepower (Fp) is given by (Roth Bails et al, 2014)

$$Fp = \frac{fcd * LHV}{change\ \ T * 60} \quad \text{……………………………………………………………} (7)$$

Where LHV- is the lower heating value of the fuel, fcd=Equivalent specific fuel consumption.

e) Turn-down ratio: The turndown ratio of the average high firepower to the average low firepower. it serves as a representation of the degree to which the user can adjust the firepower of the stove. The equation for the turn-down ratio is shown in the equation below.

$$TDR = \frac{FPC}{FPS} \quad \text{……………………………………………………………} (8)$$

Where, TDR=Turn-down ratio, FPC =Fire power during cold start (W) and FPS =Fire power during simmering (W)

f) Thermal efficiency (η_{th}): Thermal efficiency is a measure of the fraction of heat produced by the fuel that made it directly to the water in the pot. The remaining energy is lost to the environment. So, a higher thermal efficiency indicates a greater ability to transfer the heat produced into the pot. While thermal efficiency is a well-known measure of stove performance, a better indicator may be specific consumption, especially during the low-power phase of the WBT. This is because a stove that is very slow to boil may have a very good-looking TE. After all, a great deal of water was evaporated. However, the fuel used per water remaining may be too high since so much water was evaporated and so much time was taken while bringing the pot to boil [10] and determined using an equation (M.S Islam et al, 2014).

$$\eta th = \frac{4.186 * mwb * \Delta T + LHW * Vmass}{fuelconsumeddrybase * LHV} \quad \text{……………………………………………………} (9)$$

Where, LHV=lower heating value of the fuel wood, LHW=is latent heat of vaporization of
Water and mwb=mass of water boiled Therefore; the thermal efficiency of the fabricated sawdust updraft biomass gasifier stove efficiency was 30.6%

i) Temp-Corrected Specific Fuel Consumption (*SCTc)* – This corrects specific consumption to account for differences in initial water temperatures. This facilitates the comparison of stoves tested on different days or in different environmental conditions. The correction is a simple factor that "normalizes" the temperature change observed in test conditions to a "standard" temperature change of 75 ºC [4]. It is calculated in the following way:

$$\mathrm{SCtc} = SCc\ \frac{75}{Tfcf - T1c1} \quad \text{……………………………………………………} (10)$$

j) Temp-Corrected Specific Energy Consumption (*SETc*) – Similar to temperature-corrected specific fuel consumption, this metric is a measure of the amount of fuel energy required to produce one liter (or kilo) of boiling water starting with a cold stove. It is the temperature-corrected specific fuel consumption multiplied by the energy content of the fuel[10] .

$$\mathrm{SEtc} = SCt * \frac{HLV}{1000} \quad \text{……………………………………………………} (11)$$

k) The local boiling point (**Tb**) of water is the point at which the temperature no longer rises, no matter how much heat is applied. The local boiling temperature is influenced by several factors including altitude, minor inaccuracies in the thermometer, and weather conditions. For these reasons, the local boiling temperature cannot be assumed to be 1000 C. For a given altitude h (in meters), the boiling point of water may be estimated by the following formula [10]:

$$\mathrm{Tb} = (100 - \frac{h}{300})oC \quad \text{……………………………………………………} 12)$$

i) Temperature Corrected Time to Boil (ΔT_C) – The time it took for the vessel to reach boiling temperature, corrected to reflect a temperature rise of 75 deg C from start to boil. This measure can be compared across tests and stoves to determine the “speed” of the stove at high power, often an important factor to cooks [4]

$$\Delta \mathrm{Tct} = \Delta tc * \frac{75}{T1cf - T1ci} \qquad \text{……………………………………………………… (13)}$$

Where, $\Delta Tc\ t$=Temperature-correlated time to boil (min)
$\Delta c\ t$ =Time to boil (min), $T1ci$= Water temperature at start of test (°c)
$T1cf$ =Water temperature at end of the test (°c)

Data Analysis

All the collected data were analyzed using R-Software (Rx64 4.1.0) and Micro Soft Excel 2010 for preparing their graph. The data obtained from the experiment were subjected to graphical and statistical analysis of variance (ANOVA) at a 5 % level of significance.

Results and Discussion

Observation result

At first, the flames emerge from the stove's top through orifice holes, but after a few minutes, the combustion changes, and a fire vortex with unexpected flame is produced. The sawdust is gradually turned into charcoal, and the gas that is generated as a result of this conversion burns for a considerably longer time and at a higher flame height than would be possible with wood. After some time, the flames start to emerge from the base of the outer cylinder rather than the stove's top. The heat that is escaping is redirected around the combustion chamber's exterior, flows upward, is captured by the cap, and is then sent back into the chamber through a ring of holes at the top. The outcome obtained was almost identical to that of [18].

Performance indicator parameters determined by the above equations

Both thermal and stove characteristics indicators discussed above under the determination of performance parameter part of this paper were summarized and statically discussed below

Table 1: Calculation result summary

parameters	**Updraft SDGS**		**TSCS**				
	Cold phase	Hot phase	Cold phase	Hot phase	**mean**	**LSD**	**CV**
Boiling Time, BT (min)	15.66^{b}	12.66^{b}	33.00^{a}	30.00^{a}	22.83	4.66	10.57
Tcore- time to boil TCBT (min)	16.00^{b}	13.00^{b}	34.66^{a}	33.66^{a}	24.33	5.09	10.85
Burning Rate, BR (gm/min)	25.03^{a}	28.83^{a}	12.00^{b}	12.33^{b}	19.55	10.04	26.60
Fuel consumed, FC (gm)	480.00^{b}	471.66^{b}	500.00^{a}	500.00^{a}	487.91	9.06	0.96
Firepower, FP (watts)	7684.00^{a}	8865.33^{a}	3735.66^{b}	3814.00^{b}	6024.75	3055.50	26.26
Specific fuel consumption, SFC(g/liter)	137.00^{a}	129.70^{a}	127.33^{a}	118.33^{a}	128.09	22.31	9.02
Temp corrected, TCSFC (g/lite	137.50^{a}	136.03^{a}	133.67^{a}	132.33^{a}	134.88	20.97	8.05
Temp-corrected, TCSEC (kj/lit)	2536.00^{a}	2448.33^{a}	2329.33^{a}	2435.00^{a}	2437.16	311.72	6.62
Thermal Efficiency, TE, Ƞ (%)	20.33^{ab}	24.66^{a}	15.66^{bc}	14.333^{c}	18.75	5.72	15.81

Where, TSCS indicates a three-stone cook stove and SDGS sawdust Gasifier stove, LSD=list significant difference and CV= critical value for comparison.

Means with the same letters for the same parameters that have the same level of significance for both cold and hot phases are none significant for updraft SDGS and TSCS whereas the others are highly significant in terms of comparing the performances and efficiencies of updraft SDGS and TSCS at 5% level of probability. The effects of burning rate for both updraft SDGS and TSCS are not significant in terms of time taken to boil a given volume of water for both phases Whereas it is highly significant in comparison of updraft SDGS with the TSCS for both phases respectively.

Table 2. Mean comparison of cold start phase for Updraft SDGS and TSCS

Parameters	Units	Updraft SDGS			TSCS		
		Mean	STD	COV	Mean	STD	COV
time to boil	Min	13.67	1.53	0.11	33	1.00	0.03
Tcore- time to boil	Min	13.74	1.71	0.12	34.69	1.39	0.04
fuel consumed (dry)	Gm	486.67	0.96	0.002	500	-	-
Burning rate	Gm/min	26.95	4.56	0.23	12.16	0.61	0.05
Thermal Efficiency,	ɳ (%)	0.23	0.01	0.06	0.14	0.01	0.10
Specific fuel consumption, SFC	g/liter	133.11	7.66	0.06	127.26	13.62	0.11
Temp corrected SFC	g/liter	133.58	5.11	0.04	133.63	12.34	0.09
Temp-corrected SEC	kJ/liter	2461.677	94.23	0.04	2462.78	227.40	0.09
Firepower	Watts	8277.67	1399.72	0.17	3735.74	188.15	0.05

I, Boiling Time-Cold phases and its Tcore- time to boil

From the above table of Mean comparison of the cold start phase for Updraft SDGS and TSCS, the Boiling Time for Cold phases and its Tcore- time to boil the mean boiling times were 13.67, 13.74, and 33, 34.69 for both stoves which shows that the fabricated stove uses less boiling with less biomass consumption and fast boiling time than the three stone cooking stoves.

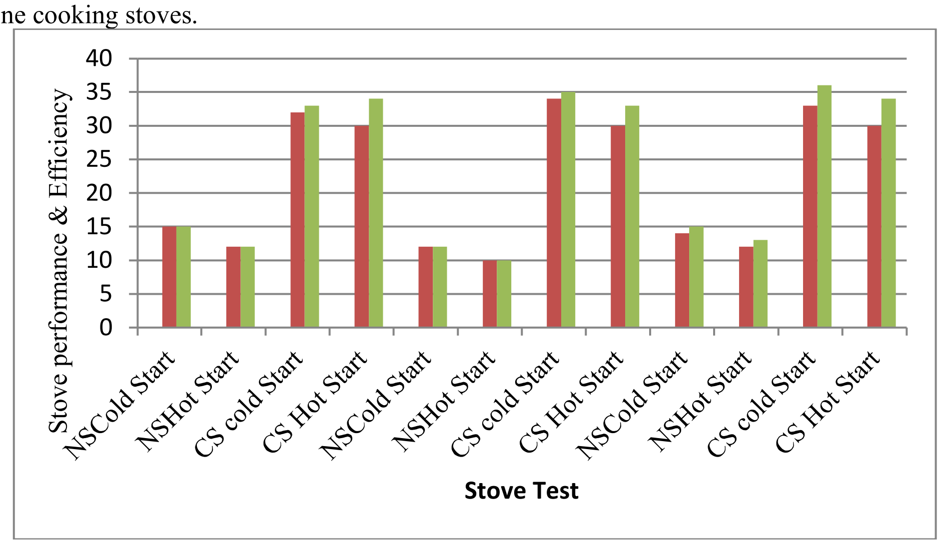

Fig 1. Graph of boiling time (BT) and its TCBT

Where BT=boiling time and TCBT=T Corrected time to boiling

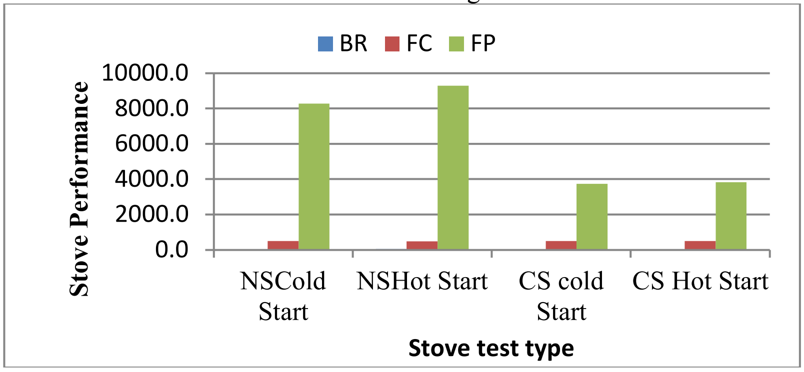

Fig 2. The graph of Fuel Consumed, Burning Rate, and its Fire Power

Improving heat transfer efficiency to the pot can make a large difference, saving significant amounts of firewood. The updraft SDG stoves fabricated tend to display better heat transfer efficiency at high power than the TSCS. It was observed that the updraft SDGS have less fuel consumption with high firepower and a higher burning rate than the traditional TSCS at an interval of 486.67gm,8277.67watt,26.95gm/min, and 500gm, 3735.74watt, 12.16gm/min respectively

Table 3. Mean comparison of hot start phase for Updraft SDGS and TSCS

Parameters	units	Updraft biomass gasifier			TSCS		
		Mean	STD	COV	Mean	STD	COV
time to boil	min	11.33	1.15	0.10	30	-	-
Tcore- time to boil	min	11.62	1.48	0.13	33.61	0.58	0.02
fuel consumed (dry)	gm	473.33			500		
Burning rate	Gm/min	30.21	4.92	0.16	12.42	1.78	0.14
Thermal Efficiency, Ƞ (%)		0.25	0.02	0.09	0.15	0.02	0.11
Specific fuel consumption, SFC	g/liter	125.31	12.12	0.10	118.11	15.18	0.13
Temp corrected SFC	g/liter	128.09	7.57	0.06	132.13	14.83	0.11
Temp-corrected SEC	kJ/liter	2360.64	139.44	0.06	2435.16	273.23	0.11
Firepower	watts	9280	1512.01	0.16	3813.79	545.61	0.14

The experimental results show that from the above table of Mean comparison test of the hot start phase for Updraft SDGS and TSCS; the updraft SDGS performance indicates better boiling time than the cold start phase.

II, Specific fuel consumption, SFC, and its Temp corrected SFC

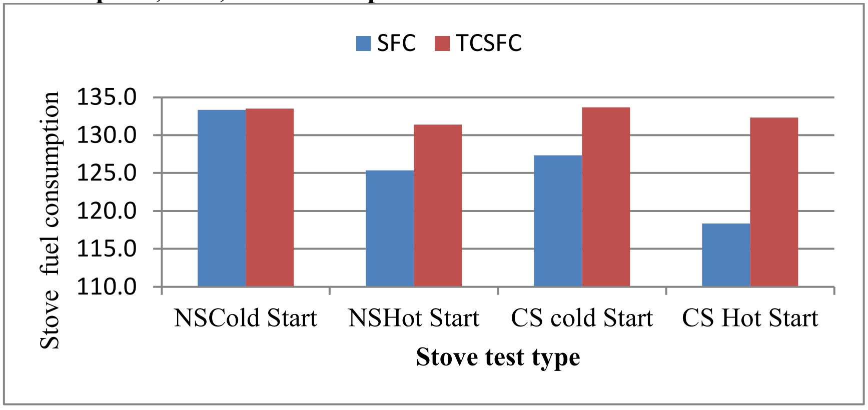

Fig 3. Graph of Specific fuel consumption, SFC and its Temp corrected SFC for all phase

The experimental test indicates that stove fuel consumption was high for both in case of cold start high power phases. Whereas, medium for hot start phases because the pot was pre-heated and it does not require more fuel.

III, Thermal Efficiency and its Temp-corrected SEC

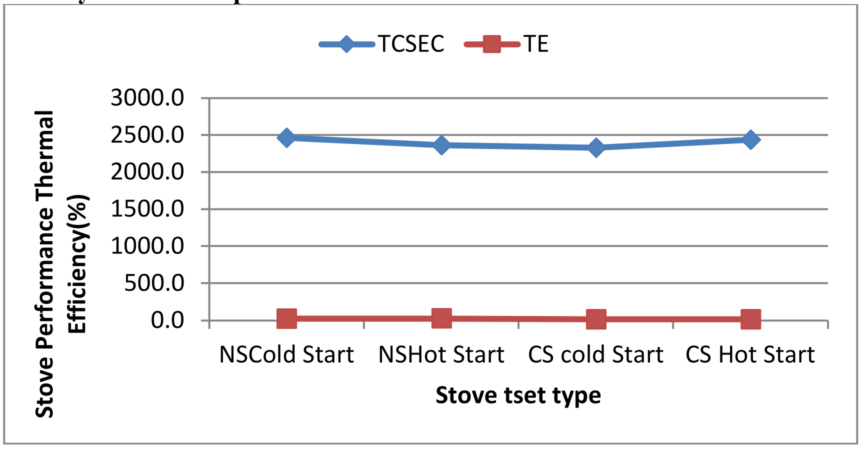

Fig 4. The graph of Thermal Efficiency for both phases of the Updraft SDGS and TSCS

The experimental tests were conducted on the Water boiling test (WBT) by using 500gm of air-dry sawdust as biomass for fueling to boil three liters of water and the highest thermal efficiency was recorded for water boiling tests conducted during hot start test for updraft SDGS and TSCS respectively. The least efficiency was recorded during clod start test phases for updraft SDGS and TSCS respectively. The high-power thermal efficiency was 24.6% and 15.6% for updraft SDGS fabricated at BAERC for hot start phases and TSCS as control respectively according to (Ayalew B. *et al,* 2019) 26% and 12%, and low power efficiency was 20.3% and 14.3% for updraft SDGS fabricated at BAERC for cold start (high power) phases and TSCS as control respectively according to (Ayalew B. *et al,* 2019) 21% and 13.5%. the fabricated updraft sawdust biomass gasifier stove has the best combustion efficiency of 84.2% as the results of the experimental performance evaluation indicate it.

Conclusion

An environmentally friendly updraft biomass gasifier stove was developed, built, and tested using sawdust as a fuel source. It can burn fuels effectively and emit fewer pollutants into the atmosphere. Particularly in rural areas, its ease of use, effectiveness, and safety make it an easy choice for homeowners as well as business owners. The performance evaluation of an updraft biomass gasifier stove was tested by using 0.5kg of sawdust per batch and has a combustion efficiency of 84.2% and thermal efficiency of 24.6% respectively. The updraft SDGS has a thermal efficiency of 24.6% during hot start phase high power tests and 15.6% when compared with Traditional cooking stoves (TSCS) and 20.3% for cold start high power phases for an updraft SDGS and 14.3% for control. The stove performed better than TSCS for all performance indicators of thermal parameters. The technology performed better than traditional stoves by most thermal performance indicators and it is important to promote to end users.

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