INTRODUCTION

Background Information

The research experiment was carried out at Sustainable Community Development Services (SCODE) with elevation of 1,923m above sea level and water boiling temperature of 93.6. The data collection was conducted as from 30/08/209 to 03/09/2019. Version 4.2.3 of the water boiling test was used in this research to determine thermal efficiency, burning rate, fire power and specific fuel consumption of three stone, kerosene, LPG, unimproved jua kali, improved charcoal, DSEPCU (5L of 220w, 300w & 400w; 2.8 of220w) and push and pull stoves. The WBT consisted of three phases that immediately followed each other. For cold phase high power, the test began with the biomass stoves at room temperature and used fuel from a pre weighed bundle to boil 2.5 l of water in a standard pot. The initial weight of the stove was recorded and after refilling the fuel into the reactor weight measurements were taken too. A thermometer was placed in the pot using wood fixtures during each Water Boiling Test so that water temperature may be measured at the center, 5 cm from the bottom. A thermo couple was also placed in the combustion chamber near the pot to record real time data for temperature rise. The timer was then started once the fire had caught to record the initial and the final time to boil 2.5 l of water. The equipment used during water boiling test were; weighing scale with a capacity of at least 6 kg and accuracy of ±1 gram, heat resistant material to protect the weighing scale, digital Thermometer with accuracy of 0.5 ^{0}C having thermocouple probe suitable for immersion in liquids, Wood moisture meter and oven for drying wood, Timer, Tape measure for measuring wood and stove (cm), Standard pots that have a volume of about 7 liters for 5 L tests, Wood holder for holding thermocouple in water, a small shovel/spatula to remove charcoal from stove, Tongs for handling charcoal, Dust pan for transferring charcoal, Metal tray to hold charcoal for weighing, Heat resistant gloves. For electric pressure cookers, boiling time, amount of water boiled and evaporated and power consumed were used calculate thermal efficiency. Thermal efficiency, fire power, specific fuel consumption were calculated using equation 1.1 to 1.3

a) Thermal efficiency

Thermal efficiency *(H)* 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 (Arora et al., 2014). H is therefore a ratio of the energy used for heating and evaporating water to the energy consumed by burning wood as shown in equation 2.7 according to Berrueta *et al*. (2008)

$$H = \frac{4.186Ww(Tf - Ti) + 2260Wv}{fd \times LHV} \tag{1.1}$$

Where:

Ww - mass of water in the pot (g)

4186 - Specific heat capacity of water ($kJkg^{-1}.K$)

(Tf-Ti) - Change in water temperature (K)

Wv - Amount of water evaporated from the pot (g)

2260 - Latent heat of evaporation of water ($kJkg^{-1}$)

fd - dry-wood equivalent consumed during each phase of the test (g)

LHV - lower heating value.

While thermal efficiency is common 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 good looking TE because a great deal of water was evaporated. However the fuel used per water remaining may be too high since much water was evaporated and so much time was taken while bringing the pot to a boil (Bailis *et al.*, 2007).

b) Firepower

Firepower*(P)* is a ratio of the wood energy consumed by the stove per unit time (in W) during each phase of the test (Berrueta *et al*., 2008) given by equation 2.8:

$$P = \frac{fd \times LHV}{60(tf - ti)} \tag{1.2}$$

Where (*tf-ti*) is the duration of the specific test phase (Ayo, 2009).

c) Specific Fuel Consumption

Specific fuel consumption (S.f.C) 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 (Jetter and Kariher, 2009). In this way, the fuel used to produce a useful liter of "food" and essentially the time taken to do so is accounted for. S.F. C is therefore the amount of fuel wood consumed to the amount of water remaining at the end of the trial. In this case specific fuel consumption refers to a measure of the amount of wood required to produce 1L or kilogram of boiling water given by equation 2.9:

$$SFC = \frac{fd}{Wwf} \tag{1.3}$$

Where Wwf is the mass of water boiled (g).

RESULTS AND DISCUSSION

Comparison of Average Boiling Time

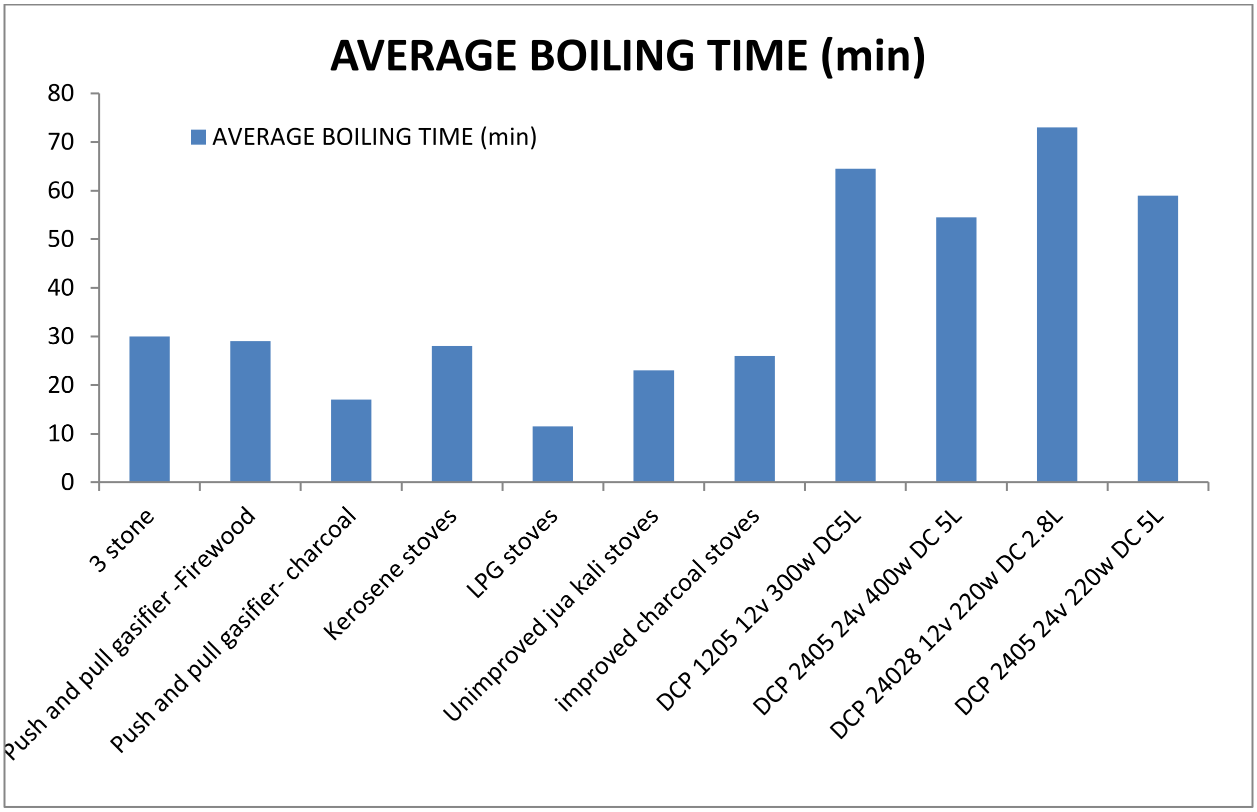

Figure 4.1: Average boiling time for different stoves

Figure 4.1 indicates the average boiling time for cold and hot phase obtained from the difference between the start and finish times during the WBT test. The recommended domestic time is about 15- 20 minutes which gives the user some time to prepare for cooking, however, some users prefer quick ones to slower ones. The equipments that were within the range of 20 minutes are; push and pull – charcoal and LPG. It's also important to note that, any cooking equipment that takes more than 60 minutes to boil 2.5 L or 5L should be discarded. All the tested equipment boiled water using less than 60 minutes apart from DCP 1205 12v 300w DC5L and DCP 24028 12v 220w DC 2.8L. As shown in figure 4.1, it can be concluded that the solar electric pressure cookers slower in boiling time hence they should not be used purposely for boiling water.

Comparison of Burning Rate

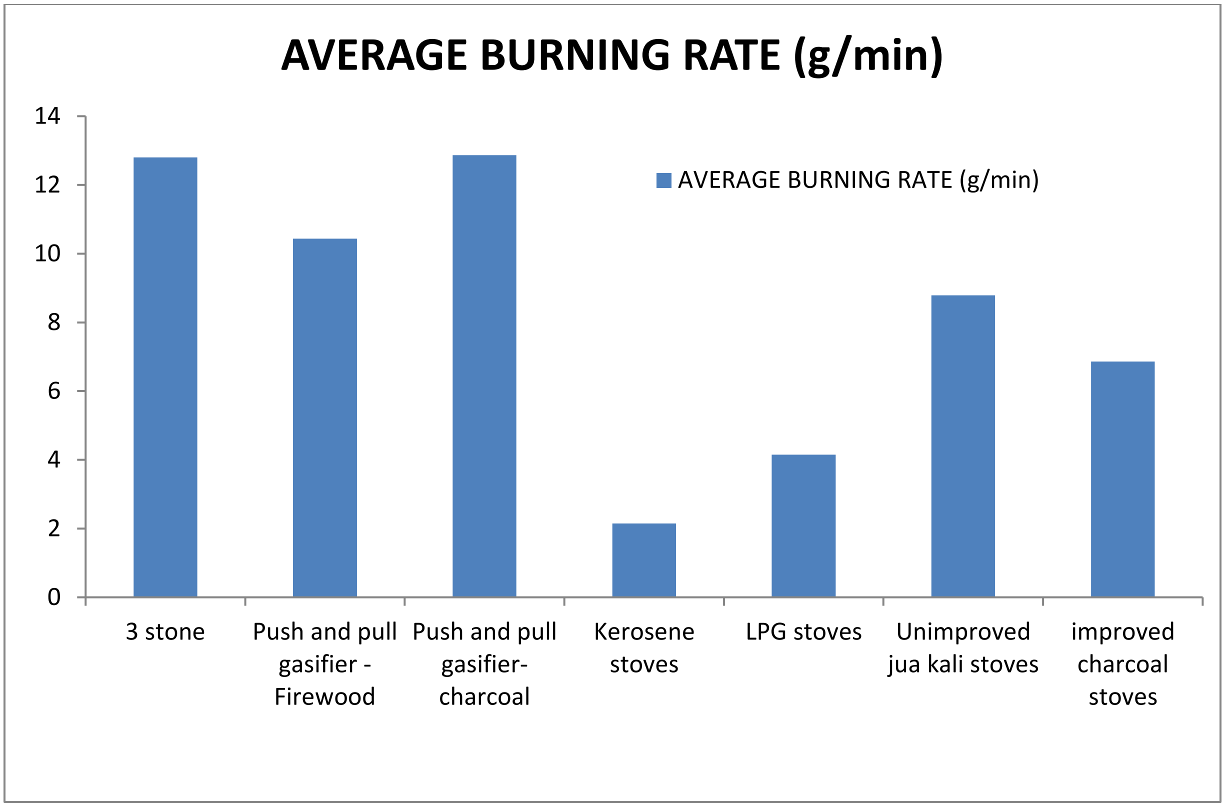

Figure 4.2 Average burning rates for different stoves

Burning rate is the measure of the rate of fuel consumption while bringing water to boil. Push and pull – charcoal and 3 stone recorded the highest average burning rate. Kerosene was the lowest in terms of burning rate. It therefore important to note that, push and pull is best suited for non carbonized fuels which are yet to undergo pyrolysis.

Comparison of Thermal Efficiency

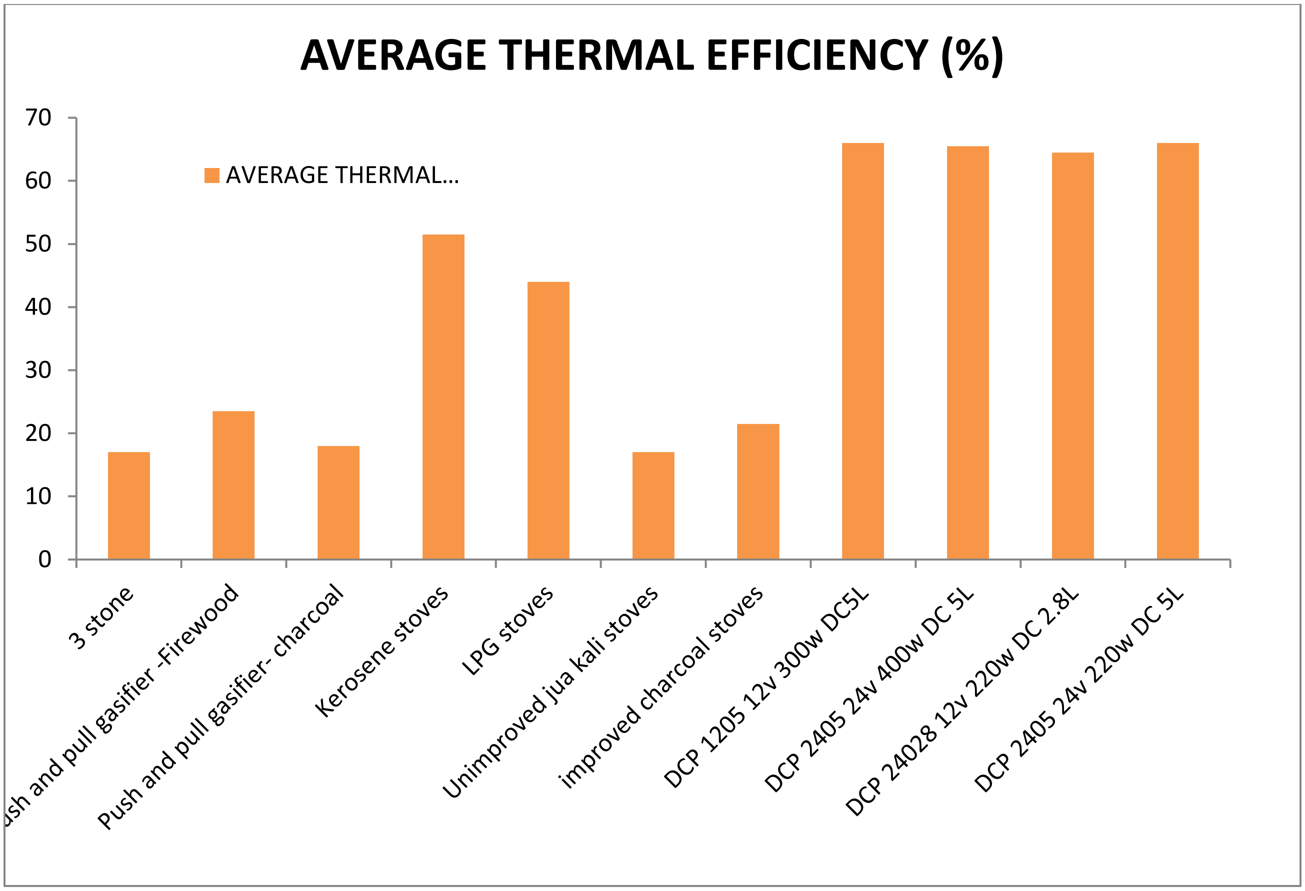

Figure 4.3 Average thermal efficiency for different stoves

Thermal efficiency and emissions are some of the key performance indicators of the stove apart from safety, durability and time. Most of the stoves in rural dwellings have utilization efficiency between 10% and 20% assessed by water boiling test. Figure 4.3 shows DCP 1205 12v 300w DC5L, DCP 2405 24v 400w DC 5L, DCP 24028 12v 220w DC 2.8L and DCP 2405 24v 220w DC 5L recorded highest efficiencies of above 60% representing tier four. LPG and kerosene stove had thermal efficiency above 40%. Three stone, push and pull – charcoal and unimproved jua kali stoves had the least thermal efficiencies of about 17%. Since solar electric pressure cookers have almost zero emission, it can be concluded that to the best performing for the consumer.

Comparison of Fuel consumed in Ksh

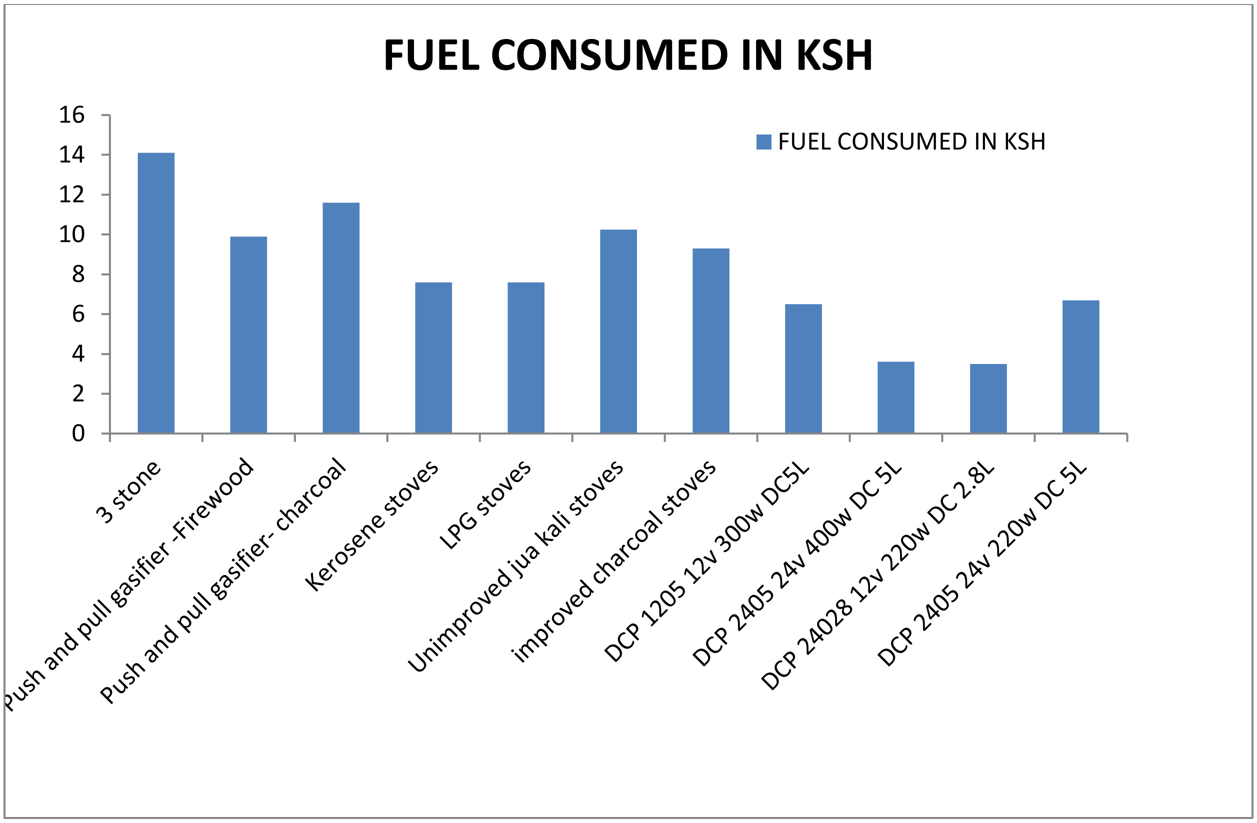

Figure 4.4: Average fuel consumed in Ksh

Average fuel consumed was obtained from the mean fuel during cold and hot start water boiling tests for 2.5L. This is a translation of efficiency into the amount of money saved based on the cooking equipment used. DCP 24028 12v 220w DC 2.8L used Ksh. 3.5 to boil 2.5L which was the least. Generally, the solar electric pressure cookers used Ksh. 3.5 – 6.7 to boil 2.5L of water. The highest amount was consumed by 3 stone at Ksh. 14.1 followed closely by push and pull – charcoal which was at Ksh. 11.6. LPG and kerosene spent a similar amount of Ksh. 7.6 to boil 2.5L. Unimproved consumed at Ksh. 10.25. From the above observation, it's clear that any improvement on the cooking equipment translates to saving money. The solar electric pressure cookers will therefore save more money while cooking and the energy is freely available. Apart from the initial capital, it therefore recommended for the end user.

Conclusions and Recommendations

1. The solar electric pressure cookers take longer time in boiling water hence not good for water boiling purposes
2. Push and pull – charcoal recorded the highest burning rate which translates to the highest amount of fuel consumed hence the equipment is not good for carbonized fuels.
3. The solar electric pressure cookers recorded the highest thermal efficiencies of above 60% representing tier four according global alliance for clean cookstoves.
4. Any improvement on the cooking equipment translates to saving money.
5. The solar electric pressure cookers save more money while cooking and the energy is freely available. Therefore, apart from the initial capital, it therefore recommended for the end user.