International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 8 Issue 10 Series. I || October 2019 || PP 15-22

The Use of Ethanol Gel Cook-Stove as a more Accessible Alternative Cooking Energy

[1]Okusanya M.A*, [2]Ibrahim G.W. and [1]Ogunlade C. B.
[1]Lecturer: Agricultural & Bio-Environmental Engineering Technology, Federal Polytechnic Ilaro, Ogun State, Nigeria.
[2]Lecturer: Mechanical Engineering, Federal Polytechnic Ilaro, Ogun State, Nigeria.
**Corresponding Author: Okusanya M. A*

Abstract : *In recent years, there has been growing interest in the use of more accessible alternative energy for cooking as a consequence of continued increases in global oil prices, depletion of forest and the escalating costs of electricity. This has heightened interest in development of Ethanol Gel cook-stove as alternatives to fossil products and fuel woods. The Ethanol gel cook-stove is a wickless stove. It consists of a combustion chamber made of stainless steel, seat for pot and air inlet section controlled by choke adjuster. Construction method was by tinkering and riveting. The results from its evaluation show better performance when compared toexisting records on cook stoves with fossil products and fuel woods. Cooking test conducted with the gel stove and kerosene stove showed difference in cooking time and specific fuel consumption of about 1minutes and 20g/l respectively. Direct implication of this is that what the gel fuel lacks in heating value is compensated for in efficiency. The cook stove CO and PM were 6.57 ppm and 0.022 mg/m^3 respectively. This shows that ethanol gel can be a better clean cooking fuel in the household.The blue flame output generated makes the stove more user-friendly in terms of health and efficient energy appliance. Consequently, Ethanol gel cook-stove, a product of renewable energy will be relevant as long as the world seeks to address fossil fuel depletion and show concern for green-house gases.*

Keywords:*Ethanol gel, cook-stove, fossil fuel, green-house gases, alternative energy, firewood.*

Date of Submission: 01-10-2019 Date of acceptance: 16-10-2019

I. Introduction

Household energy, especially cooking energy often counts for a big part of the overall energy consumption in many developing countries. In rural areas of tropical and subtropical countries like Nigeria, wood is still the main energy source. Steadily rising firewood consumption for cooking purposes results in deforestation of large areas, creating severe ecological, economical and sociological problems.

According to Stumpf (2006), more than 2.5 billion people prepare their food on open fires using firewood or plant residue. This not only destroys the environment, emissions of the open fire are also hazardous to the health of the users. Such inefficient cooking fuels and technologies produce high levels of household air pollution with a range of health-damaging pollutants(Formaldehyde, acetaldehyde, acrolein, polycyclic aromatic hydrocarbon, benzene, etc.) including small soot particles that penetrate deep into the lungs. Exposure is particularly high among women and young children, who spend most of the time near the domestic hearth.

Zwick (2011) reported that twice as many people die each year from lung disease caused by indoor pollution as die from AIDS, and open fire is the primary cause of that indoorpollution.Recent record from World Health Organization (2012) buttresses that every year; over 3.3 million people die from illness attributed to indoor air pollution caused by these fire places. Health test conducted to measure smoke level in the lungs reveals 7.55ppm for women and 6.48ppm for children – these tally with the result from a person smoking 7 cigarettes in a day. Health effects of inhaling fine particles from wood smoke are Pneumonia, Lung inflammation, bronchitis, emphysema, etc.

Clean cook stoves can slash the said pollution. More so, voluntary carbon markets are becoming a key source of funding (Zwick, 2011).With increasing urbanization, fuel use may slowly shift from firewood to charcoal - it would be possible to increase the efficiency of charcoal. But a more reasonable solution would be to use renewable fuels with lower emissions impact and a high heating value like gas, oil products and gel from agricultural residues.

This work borders on development of a wickless cook-stove that uses biofuel gel as energy source. The performance of the stove developed were tested using parameters like burning rate, specific fuel consumption, calorific value, thermal efficiency, and cooking time as compared to cooking effect of conventional fuel like kerosene and charcoal.

The ultimate mission of this research is to promote energy independence and as well contribute to reduction of noxious gas emission by encouraging the use of a renewable energy like bio-fuel gel in place of wood, kerosene and other fossil fuels.

II. Materials and Methods

This section borders on the design philosophy, major component parts of the expeller, variables considered during evaluation, design calculation, experimental procedure, materials used for evaluation and method of analysis of results.

2.1 Design Criteria

A cook stove is best considered as a consumer specific device. Both engineering and non-engineering parameters need to be taken into consideration in designing an appropriate cook stove using biofuel. This makes the exercise much more complex when compared with the design of other types of engineering equipment or of a kerosene burning stove. Ethanol gel cook-stove design considerations and criteria can be classified into three major criteria, namely: social, developmental and ecological criteria. The design utilizes air/fuel combustion principle to combust the gel fuel and give off blue flame for cooking endeavour.

2.2 Materials for Construction

The materials used for the stove include galvanized iron and biofuel gel which forms a composition for the combustion chamber. A 1 mm galvanized iron metal sheet 0f 600 mm x 600 mm square dimension was used for frame construction and few other relevant parts. The construction work was achieved by tinkering and riveting work. No welding of whatever form was involved. A flat metal cross bar clip was used for holding the combustion chamber to the designed frame member. Pot stand was bought readymade.

2.3 Component Parts of the Biofuel Gel Cook Stove

The component parts include the member frame, the combustion chamber, the choke adjuster, the pot stand, the air inlet section, etc. The function of some of the aforementioned component parts are as discussed in the subsections below. See figure 1 below for details and clarity.

2.3.1 Combustion chamber

The combustion chamber was made from stainless steel. Raw biofuel gel was poured directly into the chamber. The stove was molded by tinkering and riveting work into rectangular solid member frame via the use of local materials available. The design of the chamber is such that it has stainless steel cylindrical bowl for the fuel. The bowl is held in place by cross bars riveted to member frame. The dimension of the combustion chamber is as given in the subsection of 'design calculations below.

2.3.2 The choke adjuster

The stove design is such that it does not require use of wick to achieve combustion process. There is therefore no need of incorporation of wick adjuster knob to control heat intensity. Choke adjuster was incorporated instead, to control the flow of air inlet into the combustion chamber. The adjuster also serves to quench the fire whenever the user is done with cooking. At this level, the chamber is totally closed to prevent air inlet into the combustion chamber. See figure 1 for the choke adjuster.

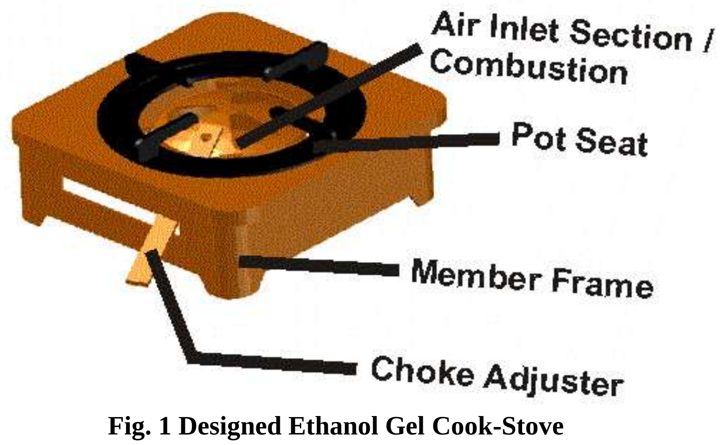

Fig. 1 Designed Ethanol Gel Cook-Stove

2.3.3 The frame of the stove

The frame considered for construction of the stove is galvanized iron of gauge 1mm. The size used for construction work was 800mm by 800mm. The frame has a square shape of dimension of 280mm by 280mm. The height is 80mm. The frame serves as housing for the chamber and as well seat for pot stand. The seat has outer diameter of 190mm and inner diameter of 150mm.

2.4 Design Description

The Biofuel gel cook stove (see plates 3 below) is rectangular in section and generally consists of a combustion chamber, a top section and a base. The chamber is made of stainless steel, the outside of which is not lined at all to allow for cool off of the chamber and encased in a mild steel formed by tinkering and riveting work. The base of the stove consists of outlet at the top controlled by choke adjuster for loading biofuel gel. The adjustable openings at the top are four in number – they serve as air inlet section for combustion process.

The design of the chamber was incorporated in such a way that it can easily be removed and replaced to allow for ease of cleaning and maintenance at the base. Since the end product of combustion process is always carbon four oxides ($C0_2$) and Water (H_20), there is therefore no need for frequent removal of ash while cooking unlike wood cook stove. The top of the stove consists of the pot seat – the design of the refractory ring used for pot seat was considered to accommodate different sizes of pot. There was no need of incorporating any chimney section since the stove is a smokeless type.

The diameter of the combustion chamber is such that it is smaller than the pot seat or the external diameter of the smallest pot that can be utilized on the stove. This is to ensure that the maximum amount of heat is transferred to the base of the pot before it proceeds to be ejected out. The distance between the fuel bed and the pot seat is also selected to allow for enough time for the complete combustion of the burning fuel particles before it strikes the base of the pot mounted on the pot seat.

2.5 Design Analysis and Calculations

Based on the choice of a domestic-size stove, the following parameters are selected for the design: height of the combustion chamber, Lcc= 80mm; internal radius of combustion chamber, r1 = 65mm; internal radius of mild steel casing, r2 = 75mm; external radius of mild steel casing, r4 = 95mm; height of stove, Hsb= 80mm; height of pot seat chamber, Hps= 40mm; measured external temperature of combustion chamber, To = 31^{o}C.

2.5.1 Design calculations

Combustion chamber design

The chamber has cylindrical shape and is held in place to member frame by cross bars riveted to the fame. It is 55mm high and has diameter of 130mm. Since it is cylindrical in shape, the formula for calculating volume of a cylinder was adopted for use.

$V = \pi r^2 h = \frac{22}{7} x 75^2 x 55$ = **0.97232 litres**

V ≈ 1 litre

Combustion Air Requirement

The principal constituent of the gel fuel is ethanol (C_2H_5OH). Thickening agent used to make the fuel pour like gel is calcium acetate ($C_4H_6CaO_4$). Both the chemical formula of the fuel and the combustion reaction it entails are as given below.

The general combustion equation is as given as:

$C_nH_mO_y + (n + m/4 – y/2) (O_2 + 3.76N_2) \rightarrow nCO2 + m/2\ H_20 + 3.76\ (n + m/4 – y/2)$

$C_2H_5OH + C_4H_6CaO_4$ becomes $C_6H_{12}O_5Ca$

Going by the general combustion equation, CnHmOy = $C_6H_{12}O_5Ca$

It implies that n = 6, m = 12 and y = 5

$C_6H_{12}O_5Ca + 6.5O_2 + 24.44N_2 \rightarrow 6CO_2 + 6H_20 + 24.44N_2 + Ca$

$(A/F)stoich. = \frac{6.5 \ x\ 32+24.44\ x\ 28}{12\ x\ 6+1\ x\ 12+16\ x\ 5+40} \approx 4.4$

Therefore (A/F) stoich. = 4.4kg air/kg fuel

ϕ = <u>(A/F) stoich.</u>

(A/F) actual

According to Samuel (2009), actual air supply is 20% in excess of stoichiometric value. Actual air / fuel ration is (A/F) actual = 20/100 x 4.4 + 4.4

= 0.88 + 4.4 = 5.28 air/kg fuel

Therefore, (A/F) actual = 5.28kg air/fuel.

ϕ = 4.4/5.25 = 0.833

Since 0.833 < 1, it means the mixture of the gel fuel and air is a lean mixture. There is therefore likelihood of complete combustion.

III. Results and Discussion

3.1 Performance Testing of the Biofuel Gel Stove

Biofuel stoves are characterized by their square deal of low emission impact on the environment with good quality, simple design, easy to use and continuous operation. The water boiling test was utilized to compare the performance of the biofuel gel stove to traditional or conventional kerosene stoves with the same test conditions. The water boiling test includes three phases; the cold-start test, the hot-start test and the simmer test (see tables 1, 2 and 3 below). The cold-start test begins with the cool stove and measures the time and amount of fuel used to boil three liters of water. The hot-start test begins immediately after cold start test with the still warm stove and one liter of new room temperature water. The simmer test is conducted following the hot-start test and measured the amount of fuel used to maintain a boil for 30 minutes. The tests were conducted with the air opening of the stove fully opened with the exception of simmering test which required maintaining water at constant temperature of $99^{O}C$ of even $100^{O}C$ for about 30 minutes.

3.2 Experimental procedures for water boiling test (cold and hot test)

The stove and pot were thoroughly cleaned and dried. The test was conducted in an enclosed kitchen environment. A measured amount of biofuel gel was weighed out for each test. The same type of gel was used for the series of tests. The pot and lid were weighed, and then a measured amount of water by volume (about one liter) was added to the pot and weighed again to determine the weight of the water. This was repeated two other times for each test.

The already weighed fuel gel was introduced into the combustion chamber. The pot was placed on the stove the moment the fuel gel was lit. The environmental conditions (ambient temperature) and the initial temperature of the water were recorded. Thereafter the commencement of the test and the temperature of the water were recorded at intervals of two (2) minutes until the moment the water came to a vigorous boil. To determine the time to boil accurately, it was necessary to record the temperature in the pot every two minutes while stirring. The pot was then removed from the stove and the fire immediately put out with the help of choke adjuster. The final weight of the remaining water, fuel gel and the final temperature of water were then measured and recorded. See figure 2 for further illustration.

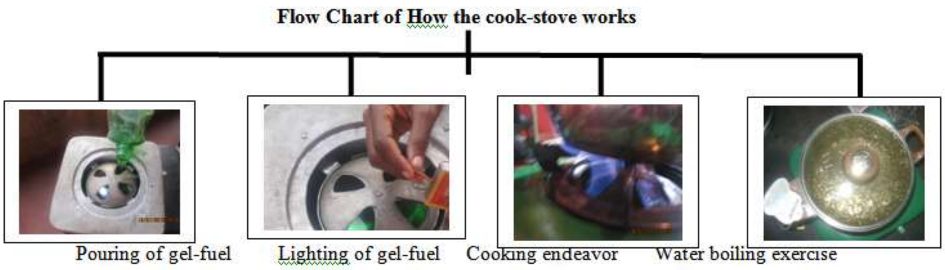

Fig. 2 Flow chart on how the cook-stove works

3.3 Test Procedures for Simmer Test

Simmering involves heating of boiling water at a constant temperature for about thirty or forty five minutes. The procedure for the test is the same as that for the boiling test. At the end of the test, measurements of amount of water evaporated, fuel consumption, simmer temperature and test duration were taken and recorded accordingly.

3.4 Test Results

In this test, cold, hot and simmer tests were performed on the stove. In the cold test, the stove was not allowed to warm up before the pot containing the water was added. Timing commenced immediately the pot of water was actually placed on the stove. In one case, the stove was also allowed to stay running to boil a second litre of water to conduct the hot test. The results for cold, hot and simmer test are as reported in tables 1, 2 and 3 below.

Table 1 Water Boiling Test for 1 Litre of Water (Cold Test)

Time (min.)	Temp. T1 (°C)	Temp. T2 (°C)	Temp. T3 (°C)
0	31	31	31
2	34	43	42
4	50	54	54
6	60	64	63
8	70	74	73
10	80	86	84
12	90	100	94
14	100 (12min: 50sec)	-	100 (12min: 30sec)

Calorific value of the fuel was taken as: B_f = 15.1kJ/g, Burning rate = 4.4g/min, Me = 25g, M_f = 55g, Thermal Efficiency was estimated as: η = 43%.

Table 2 Water Boiling Test for 1 Litre of Water (Hot Test)

Time (min.)	Temp. T1 (°C)	Temp. T2 (°C)	Temp. T3 (°C)
0	32	42	31
2	42	43	42
4	52	54	54
6	62	64	63
8	82	74	73
10	90	86	84
12	100 (10min: 40sec)	100 (10min: 30sec)	94 (10min:20sec)

Calorific value of the fuel was taken as: B_f = 15.1kJ/g, Burning rate = 4.4g/min, M_f = 46g, Me = 36g, Thermal Efficiency was estimated as: η = 52%

Table 3 Water Boiling Test for 1 Litre of Water (Simmer Test) for 3 runs

Time (min.)	Mass of Water Evaporated (g)			Mass of Fuel Consumed (g)		
00	-	-	-	-	-	-
05	48.7	46.7	50.7	16	17	18
10	48.6	48.8	48.7	17	16	18
15	47.0	49.0	48.6	17	17	17
20	47.2	48.8	49.8	18	17	16
25	49.7	48.9	47.3	17	16	18
30	50.7	48.7	46.7	16	17	17
Total	291.9	290.9	291.8	101	100	104

Calorific value of the fuel was taken as: Bf = 15.1kJ/g, Burning rate = 3.4g/min, Me = 291.53g, Mf = 102g, Thermal Efficiency was estimated as: η = 43%

3.5 Determination of Thermal Efficiency of the Stove

The efficiency was determined by measuring the rate of water loss and fuel consumption. The rate of water loss while boiling was essentially independent of the volume of water in the pot, and whether the pot was covered with a lid or not. It was only slightly affected by the diameter of the pot. Equation one below was used to determine the thermal efficiency of the stove. The common law on heat transfer (heat loss = heat gain) was adopted for use in calculating thermal efficiency.

$$\eta = \frac{MwCp(\theta b-\theta i)+MpCp(\theta b-\theta i)+Mel}{MfBf} \text{ X } 100 \quad \ldots\ldots 1$$

Mw = mass of water boiled, Cw = Specific heat capacity of water
CP = Specific heat capacity of pot, θb = boiling point temperature, θi = initial temperature
Me = mass of water evaporated, l = latent heat of evaporation, Mf = mass of fuel consumed
Bf = calorific value of fuel, η = thermal efficiency

3.6 Discussion

The accurate determination of the time to boil was found to be quite difficult. All manner of variables had to be carefully controlled to obtain reasonably consistent and reproducible results – for some cookers even the positioning of the pot could have an effect on boiling time, fuel consumption and thermal efficiency estimation. Table 1 and 2 above reveal the minimum time required to boil one litre of water for both cold and hot test. It takes an average time of about twelve minutes thirty seconds to boil one litre for cold test and an average time of ten minutes thirty seconds for hot test. This shows that 6.8g of fuel is saved each time one litre of water is boiled when the stove is still hot. Simmer test in table 3 assisted in determining the fuel consumption rate and rate of water loss every minute of operation. Based on conditions in table 3, the water loss was estimated as 9.72 g/minute and the fuel consumption rate as 3.4 g/minute.

Then, the water loss represents an evaporation energy of 2.261kJ/g water, equivalent to 2.261 x 9.73/60 = 0.367 kW - see the annex of main report for details of calculations. The fuel in this case was ethanol gel with a net calorific value of 15.1kJ/g (Lloyd and Visagie, 2011). So, the stove power was 15.1 x 3.4/60 = 0.856kW (calorific value x burning rate). Heat gained by pot all through 30 minutes of stove operation is zero since simmer test was at constant temperature. Thermal efficiency was estimated as 0.367/0.856 = 43 % (evaporation energy / Stove power). The formula in equation one was equally used to estimate thermal efficiency of cold and hot test as 43% and 52% respectively – see the annex of this report for details of all calculations.

The said thermal efficiencies estimated compare reasonably with existing records on cook stoves with similar fuel. Nevertheless, the heating value of the gel in the cook stove can be improved upon so that the thermal efficiency can be reasonably raised to 70% and above possibly- empirical fact has it that only electric stove has efficiency in that range as at present. Ethanol in the gel fuel can be replaced with isopropanol to get higher heating value from the fuel with higher thermal efficiency.

The performance of the stove was carried out using relevant parameters in line with International Organization for Standardization.Cooking test conducted with the gel stove and kerosene stove showed difference in cooking time and specific fuel consumption of about 1minutes and 20g/l respectively. Direct implication of this is that what the gel fuel lacks in heating value is compensated for in efficiency. See the annex of the main report for details. The improved stove CO and PM were 6.57 ppm and 0.022 mg/m^3 respectively. These emission levels were far below the world health organization set limit. This shows that ethanol gel can be a better clean cooking fuel in the household.

IV. Conclusions

4.1 Conclusions

The following conclusions were therefore made:

1. The biofuel gel used in this endeavour has high promise of providing satisfactory solution to the problem of cooking safety, largely because it burns with blue flame with little emission impact.
2. Cooking test conducted with the gel stove and kerosene stove showed difference in cooking time and specific fuel consumption of about 1minutes and 20g/l respectively. Direct implication of this is that what the gel fuel lacks in heating value is compensated for in efficiency.
3. The gel stove cooks slowly when fuel gets low; at times it does not burn when too low.
4. The stove boils 1 litre of water for 10 minutes 30 seconds whereas kerosene stove boils the water in about 8 minutes or less – this implies that its heating value is low as compared to kerosene or other petroleum fuels.
5. The fuel does not burn continuously and when cooking endeavor is too long, the stove will have to be put off and refueled to complete the cooking endeavor.
6. The initial smell of the fuel can be irritating.

References

[1]. Lloyd PJD and Visagie (2011) E. F. Energy Research Centre, University of Cape Town, Cape Town, South Africa.
[2]. Stumpf E. (2006). Plant oil as cooking fuel:development of a household cooking stove for tropical and subtropical countries. Institute for Agricultural Engineering in the Tropics and SubtropicsHohenheim University. Garbenstr.9, 70599 Stuttgart, Germany.
[3]. United Nations Environment Programme, 2009.Towards sustainable production and use of resources: Assessing Biofuels, International Resource Panel.
[4]. World Health Organization, 2012. WHO air quality guidelines – global update 20012? Copenhagen: World Health Organization.
[5]. Zwick S. (2011). Voluntary Carbon Offsetting Hits Three-Year High on US Action, Wind Farms, and Clean Development.

APPENDICES

Appendix 1

Calculation of Thermal Efficiency

Equation below will assist in calculating the thermal efficiency of the green gel stove.

$$\eta = \frac{MwCp(\theta b-\theta i)+MpCp(\theta b-\theta i)+Mel}{MfBf} \text{ X 100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Mw = mass of water boiled, SFC = specific fuel consumption

Cp = Specific heat capacity of water, θb = boiling point temperature

θi = initial temperature, Me = mass of water evaporated

l = latent heat of evaporation = 2.261 kJ/g/k, Mf = mass of fuel consumed

Bf = calorific value of fuel, η = thermal efficiency
tavg = time taken to boil the water, V = volume of water boiled

Calculation of Thermal Efficiency for Cold Test
Mf = {56 + 46 + 64} / 3 = 55g
Me = (24 + 28 + 22) / 3 = 25g
Mw = 951g, Mpot = 753g
tavg = (12:10 + 12:30 + 12:50) / 3, tavg = 12:30 min,
Cw = 4.2J/g/k
Me = (24 + 28 + 22) / 3 = 25g, l = 2.261kJ/g
Burning Rate = (g/min) = Mf / tavg = 55/12.5 = 4.4 g/min
SFC = Mf / v = 55/1 = 55g/l
Water loss = Me / tavg = 25 / 12.50 = 2g/min = 2/60 g/sec
Total power supplied by fuel to water: P1 = (mcΔθ)water + (mcΔθ)pot + water loss x L

$$= \frac{951x4.2x69}{12.5x60x1000} + \frac{753x0.5x69}{12.5x60x1000} + \frac{2 \text{ x } 2.261}{60} = 0.368 + 0.035 + 0.0754 = 0.4784kw$$

Stove Power = Burning rate x net calorific value of the ethanol gel (B).
Take B = 15.1kJ/g (Lloyd and Visagie, 2013).
Since burning rate = 4.4g/min = 4.4/60 g/sec =
Therefore, Stove power = 4.4/60 x15.1 = 1.11kw
Thermal Efficiency, η = 0.4784/1.11 x 100 = **43.1%**

Calculation of Thermal Efficiency Simmer Test
Mf = {101 + 100 + 104} / 3 = 101.67g ≈ 102g
Me = (291.9 + 290.9 + 291.8) / 3 = 291.53g
Mw = 951g, Mpot = 753g
tavg = 30min,
Cw = 4.2J/g/k
L = 2.261kJ/g
Burning Rate = (g/min) = Mf / tavg = 102/30 = 3.4 g/min
SFC = Mf / v = 102/1 = 102g/l
Water loss = Me / tavg = 291.53 / 30 = 9.72g/min = 9.72/60 g/sec
Total power supplied fuel to water Pi = (mcΔθ) water + (mcΔθ)pot + water loss x L

$$= \frac{9.72 \text{ x } 2.261}{60} = 0.3663kw$$

Stove Power, P2 = Burning rate x net calorific value of the ethanol gel (B).
Take B = 15.1kJ/g (Lloyd and Visagie, 2013).
Since burning rate = 3.4g/min = 3.4/60 g/sec
Therefore, Stove power = 3.4/60 x15.1 = 0.856kw
Thermal Efficiency, η = Pi/P2 x 100
=0.3663/0.856 x 100
= **42.8%**
≈ 43%

Calculation of Thermal Efficiency for Hot Test
Mf = {43 + 46 + 49} / 3 = 46g
Me = 36g
Mw = 951g, Mpot = 748g
tavg = (12:10 + 12:30 + 12:50) / 3, tavg = 10:30 min,
Cw = 4.2J/g/k
Me = (34 + 36 + 38) / 3 = 36g, l = 2.261kJ/g
Burning Rate = (g/min) = Mf / tavg = 46/10.5 = 4.4 g/min
SFC = Mf / v = 46/1 = 46g/l
Water loss = Me / tavg = 36 / 10.50 = 3.43g/min = 3.43/60 g/sec
Total Power supplied by fuel to water: Pi = (mcΔθ)water + (mcΔθ)pot + water loss x L

$$= \frac{948x4.2x65}{10.5x60 \text{ x } 1000} + \frac{753x0.5x65}{10.5x60x1000} + \frac{36 \text{ x } 2.261}{10.5x60} = 0.411 + 0.0388 + 0.1292 = 0.579kw$$

Stove Power P2 = Burning rate x net calorific value of the ethanol gel (B).
Take B = 15.1kJ/g (Lloyd and Visagie, 2013).
Since burning rate = 4.4g/min = 4.4/60 g/sec
Therefore, Stove power, P2 = 4.4/60 x15.1 = 1.11kw

Thermal Efficiency, η = Pi / P2 x 100
= 0.579/1.11 x 100
= **52.16%**
≈ 52%

APPENDIX 2

Procedure for Making Gelled Alcohol

Materials needed in making the gelled alcohol are:

i. 25g of crushed chalk,
ii. 100ml Vinegar
iii. 30ml Alcohol (ethanol, methanol, or isopropyl)
iv. Funnel
v. Jar
vi. Coffee filter
vii. Spoon
viii. Water

Mix 25g of calcium carbonate (chalk is a good source) with 100ml of vinegar. Stir with spoon for 5 minutes or until most of the chalk is dissolved. If one is unable to weigh out the chalk precisely, one should not worry. One should keep adding the chalk until it won't dissolve any more. The excess chalk should then be filtered out. The acetic acid in the vinegar to form calcium acetate (C4H6CaO4) with the release of carbon IV oxide with excess water (H2O) and chalk (CaCO3) left over. Filter the excess chalk out.

Empirical fact has it that one portion of CaCO3 combine proportionately with 4 parts of grocery store white vinegar. After this, half or two third of the water evaporate away through heating it in oven at 200 degrees for 3 hours. Then, taking the rest of the mixture, one part of the concentrated calcium acetate is mixed with 9 part of ethyl alcohol or isopropyl alcohol. Once the two have been measured out in ratio of one to nine, adding the alcohol will cause the solution to quickly begin to gel on its own. Stir the solution to mix all of the alcohol with the calcium acetate water mixture. Experience has shown that the total compound must be 90% alcohol or else it will not burn efficiently. If you have dry calcium acetate, you will need to combine two part of water to three part of calcium acetate and stir them until the substance is dissolved. (Hubpages, 2013 www.hubpages.com, Assessed February 18, 2013).

APPENDIX 3

Comparison between Gel Stove and Kerosene Stove

Table Appendix 1 Comparison of cooking test between gel stove and kerosene stove (with one cup of rice and Calorific value of gel fuel (Bf) = 15.1kJ/g, Burning rate (kerosene stove) = 2.154g/min, Burning rate(gel stove) = 2.815g/min, Mf (kerosene) = 56g, Mf(gel) = 76g, Thermal Efficiency(η) = 43%

Time (min.)	Mass of fuel consumed with gel stove (g)			Mass of Fuel Consumed (g) with Kerosene stove		
00	-	-	-	-	-	-
05	14.07	14.12	14.00	10.77	11.20	11.22
10	28.15	27.85	28.10	22.70	22.22	22.55
15	42.22	42.18	42.10	30.04	30.12	30.05
20	56.30	55.13	56.15	45.38	45.12	45.25
25	70.40	71.05	70.32	56.73	56.45	56.34
26	73.20	72.96	73.00			
27	76.01	76.15	75.90			
Total	**76.01**	**76.15**	**75.90**			

Okusanya M. A" The Use of Ethanol Gel Cook-Stove as a more Accessible Alternative Cooking Energy" International Journal of Engineering Science Invention (IJESI), Vol. 08, No.10, 2019, PP 15-22