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Performance Evaluation of Smokeless Cook Stove for Different Agricultural Waste

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***Abstract*:-A smokeless stove is intended to reduce dangerous exposure to unnecessarily high levels of smoke, avoiding the aforementioned illnesses, while maintaining desirable aspects of current cooking techniques, including reliability, simplicity and low cost. In addition, the design intends to promote sustainable practices and encourage future endeavors in healthy and sustainable designs. It is proposed that this smokeless stove design is developed as a replacement to existing cooking methods. The cook stove is tested by biomass energy of dry wood, sugarcane waste and groundnut shell as fuel. Two tests on this cook stove is carried out by boiling water and cooking food, time is noted to boil water and to cook food (rice) by keeping quantity of fuel, water and food constant.**

Keywords: Smokeless, reliability, biomass, proximate

I. INTRODUCTION

Worldwide more than three billion people continue to depend on solid fuels, including biomass fuels (wood, dung, agricultural residues) and coal, for their energy needs. A disproportionate fraction of these people reside in poor nations. Specifically, it has been estimated that half of the population of developing countries rely on solid fuels and nearly 95% in extremely poor countries (Biswas and Lucas, 1997). Cooking and heating with solid fuels on open fires and/or traditional stoves may result in high levels of health-damaging pollutants (including particulates and carbon monoxide). In fact, the use of traditional stoves in poorly ventilated houses may cause particulate pollution levels to be much higher than the commonly accepted guideline values.

The high levels of particulate matter emitted by traditional stoves may have large effects on health. In addition to possible negative effects on health, traditional stoves may also impact climate change by accelerating deforestation (Pandey, 2001). The traditional stoves are inefficient in producing energy and, thus, require large quantities of wood to cook even a simple meal.

In response to these global health and environmental problems, improved stove technologies have been developed. Our proposal, a smokeless stove, is intended reduce dangerous exposure to unnecessarily high levels of smoke, avoiding the aforementioned illnesses, while maintaining desirable aspects of current cooking techniques (Smith-Sivertsen *et al* 2004) , including reliability, simplicity and low cost. Biomass combustion provides basic energy requirements for cooking and heating of rural households and for process in a variety of traditional industries in the developing countries. In general, biomass energy use in such cases is characterized by low energy efficiency and emission of air pollutants. Biomass fuels currently used in traditional energy systems could potentially provide a much more extensive energy service than at present if these were used efficiently (WHO 2000). For example, new stove designs can improve the efficiency of biomass use for cooking. Thus, the energy service provided by biomass in this case could be potentially provided by one third to half of the amount of biomass used currently; the amount of biomass saved through efficiency improvement can be used to provide further energy services.

II. MATERIAL AND METHODS

A. *Preparation of cook stove:-*

Clay is extracted from a depth of at least 40cm to reduce its organic matter content, concentrated in the topsoil. First the clay soil is graded to remove any large rocks or debris. Then sand is thoroughly mixed in at a ratio of approximately three parts clay to one part sand. By trial and error method the quantities will vary depending on particular composition of the clay deposit. Local clay workers are likely to have some knowledge of clay composition within the area. Mixture of clay and water is prepared and cook stove is developed as per design manually. Aluminum pipe is used of diameter 1ft and 5ft for removal of smoke from cook stove. Iron plate is used for base of cook stove. After preparation of cook stove it is kept for compaction in shade After 2-3 days cook stove is tested by using wood, sugarcane waste and groundnut shells.

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Fig. 1 smokeless cook stove

B. Biomass properties

(1) Proximate Analysis

1.1 Volatile Matter

One gram sample was measured into known weight of VM bottle with lid. The bottle was then transferred into a high temperature carborlite furnace already set at 900°C and heated for 7 minutes. Then, the VM bottle was taken out from the furnace and it was allowed to cool down in the desiccator. The weight of sample was determined again when it reached the room temperature, both initial (Wi) and final (Wf) weights were recorded. The volatile matter content was calculated using equation (1). Three replications were carried out and the average result was obtained.

$$\text{Volatile Matter Percentage (VM)} = \frac{(Wi - Wf)}{Wi} \times 100 - MC \quad ...(1)$$

1.2 Ash Determination

One gram of briquetted sample was measured into known weighted ash tray with lid. The sample was then transferred into a high temperature carborlite furnace already set at 825°C and heated for 1 hour. Then, the ash tray is taken out from the furnace and it is cooled in the desiccators until it reaches room temperature, both initial (Wi) and final (Wf) weights were recorded. The ash content was calculated using equation (2). Three replications were carried out and the average result was obtained.

$$\text{Ash Content (AC), \%} = \frac{Wf}{Wi} \times 100 \quad .....(2)$$

1.3 Fixed carbon

The fixed carbon (FC) indicates the heating value of the biomass. This is obtained by subtracting the percentages of moisture, volatile matter and ash content from 100 (eq^n 3).

$$FC = 100 - (MC + VM + AC) \quad ...(3)$$

1.4 Calorific Value

The calorific value of briquettes was measured by using an oxygen bomb calorimeter (shown in fig.2). One gm of briquette sample was taken in a nichrome crucible. A 15 cm long cotton thread was placed over the sample in the crucible to facilitate ignition. Both the electrode of the calorimeter was connected by a nichrome fuse wire. Oxygen gas was filled in the bomb at a pressure of around 25 to 30 atm. The water (2 litter) taken in the bucket was continually steered to homogenous the temperature. The sample was ignited by switching on the current through the fusing wire and the rise in temperature of water is automatically recorded. The following formula was used to determine the calorific value of the sample.

(GCV) = {(2500- T) / (initial weight of sample) – (heat released by cotton thread + heat released by fuse wire)} kcal/kg

Fig. 2 Bomb Calorimeter

Fig. 3 Hot Air Oven

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C. *Percentage moisture content:*

Percentage moisture content was determined by measuring 16 g of pulverized briquettes into a crucible (w1).The content was dried in an oven at 104^{0}C to 106 ^{0} C for 24 hr to obtain over dry weight (w2) Moisture content was then calculated according to this formula as:

$$\text{Mc}\,(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100 \qquad \dots\dots(4)$$

D. *Testing of cook stove performance*

1. *Boiling water tests/Efficiency test:-*

There are 4 tests being used as standard methods:

- A fixed quantity of water is evaporated, with fuel and time as variables.
- Quantities of *fuel* and water are fixed, with time as a variable.
- A fixed quantity of fuel is burnt, with the quantity of water evaporated and time as variables.
- The quantity of water evaporated within 30 minutes is determined, with fuel as a variable.
    - Weights of wood used and remaining and
    - The amount of water evaporated at each evaporating time. These measurements are then used to calculate heat utilization.

2. *Cooking food test:-*

Simulated cooking (rice) tests measure the amount of fuel used and the time taken to cook a variety of standard meals under controlled conditions. The principle objective of the cooking test is then to determine the influence of the stove design on the amount of fuel used and time taken to cook a meal to stewing.

Fig.4 cooking food test

3. *Combustion test:-*

In combustion tests (Joseph, 1979), gas analysis and measurement of the stack temperature were obtained. These data gave a measure of how much heat was being lost due to process combustion. According to this test, fuel is burning efficiently if The percentage of CO is less than 0.5%; The average amount of oxygen in the flue gas is less than 11% and the average carbon dioxide content in the flue gas is approximately 6-8%.

Measurement of the chimney temperature, in the combustion test indicates how much heat is being transferred to the pots. A high stack Temperature means that the pot cannot absorb the amount of heat being liberated. As the temperature of gases decreases, the amount of air being drawn into the combustion chamber also decreases.

III. RESULT AND DISCUSSION

Results and discussion regarding physical, combustion properties and proximate analysis of the biomass were found different because of the properties of biomass varies with the biomass used.

A. *Proximate analysis of biomass*

The data recorded during the proximate analysis of the biomass is presented in table 1.

Table no.1: Proximate analysis of biomass.

Biomass	M.C. (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific value (Kcal/kg)
Dry Wood	8.59	69.49	26.90	4.98	3900
Sugarcane Waste	9.49	68.16	28.44	6.09	3500
Groundnut Shell	9.36	71.72	24.59	5.67	4000

The graph 5 represents the percentage of Moisture content, volatile matter, Ash content and fixed carbon content of the different biomass used. The maximum moisture content was found as 9.36 % for the Groundnut shell and minimum 8.59 % for Dry wood. The percentage of Volatile matter was recorded maximum as 71.12 % for Groundnut and minimum in sugarcane waste as 68.16%.

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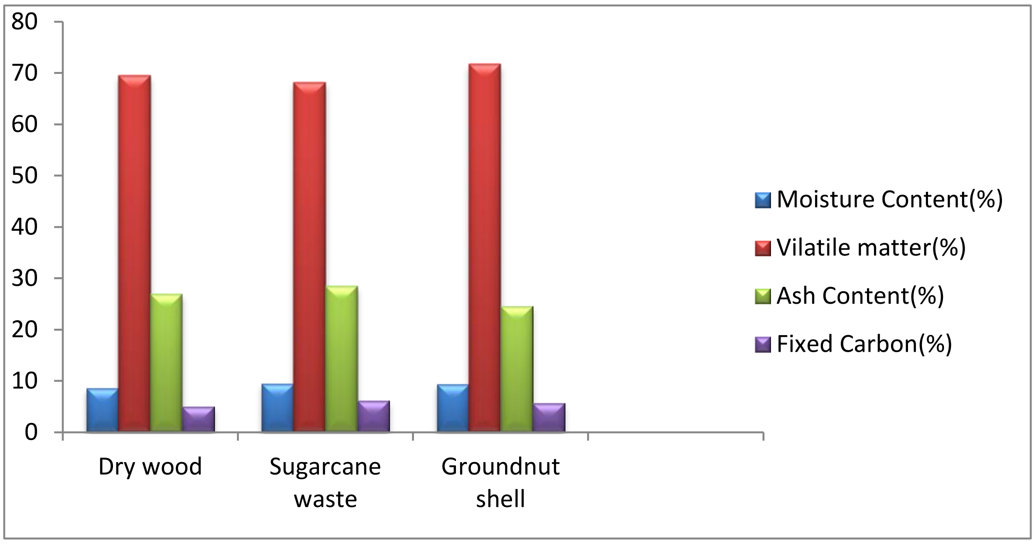

Fig.5 Proximate analysis of biomass

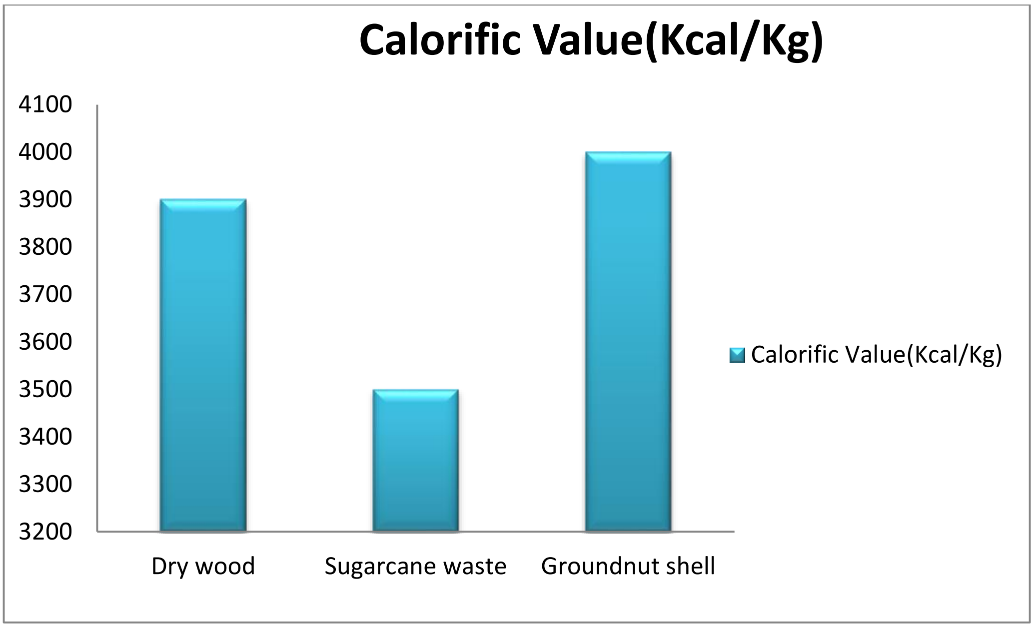

Fig.6 calorific value of biomass.

Graph 6 represents the calorific value of different biomass used as fuel in the developed cook stove. The Calorific value 3900 Kcal/kg, 3500 Kcal/kg and 4000 Kcal/kg were obtained for dry wood, sugarcane waste and groundnut shell respectively.

B. Combustion test

The combustion test of biomass was carried out for the evaluation of the performance of developed cook stove. Boiling and cooking time recorded during the combustion test is presented in table 2.

Table 2- Combustion performance of cook stove

Biomass Fuel Used	Boiling Water Test Time(Min.)	Cooking Food Test (Rice) Time(Min)
Dry Wood	16.23	25.10
Sugarcane Waste	16.10	24.59
Groundnut Shell	17.46	27

Graph 3.3 represents the time required in minute for boiling water and cooking food i.e. rice for different biomass used as a fuel. It shows the performance of the cook stove for different biomass.

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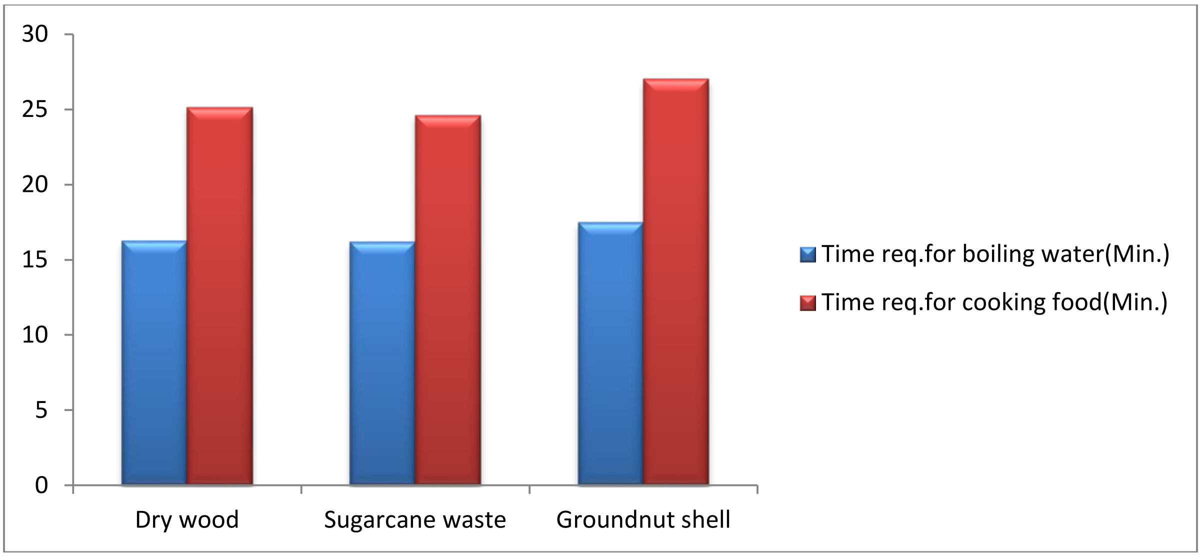

Fig.7 Performance of cook stove

C. Cost estimation of smokeless cook stove

Table 3- Cost estimation of smokeless cook stove

Item	Purpose	Quantity	Cost (Rs.)
Clay/sand mixture	Stove Body	Aprox.10 Kg	-
3” GI Pipe	Chimney	3ft	200
Aluminium Sheet Metal	Chimney cap	0.144 m^2	100
Cast Iron	Grate	1.4 Kg	50
Labour Cost	-	-	100
Total Cost (Rs.)			450 /-

It can be easily constructed by using locally available material and developed cook stove is useful for any solid dry biomass available at our local place which makes its operation easier and costless. The maintenance of clay body is makes its life longer at least 10 years or more. Developed cook stove has improved technically and environmentally, which makes it eco-friendly and economical as compare to the tradition cook stove. The total cost of construction of cook stove is 450 rupees. Detailed about constructional material of the cook stove is given in table 3.

IV. SUMMARY AND CONCLUSION

From moisture content determination we found that dry wood has low moisture content hence it produces less smoke than sugarcane waste and groundnut shell but the percentage of ash content of groundnut shell is less than other two samples. From calorific values of biomass groundnut shell has more calorific value than dry wood and sugarcane waste but in water boiling and food cooking test found that sugarcane waste fuel boils the water in less time than dry wood and groundnut shell.

- Our smokeless stove design is generally around 50% more efficient at burning wood than traditional cooking stoves.
- The air vent, wood ash insulation and combustion chamber improve the efficiency of the cook stove.
- The construction of cook stove is easier and components made up by the locally available materials which make it more popular in rural areas.
- Diseases due to smoke inhalation, which is a major cause of death in developing countries, are not likely to be contracted due to the health benefits of the stove.
- Any biomass such as wood, sugarcane waste, groundnut shell can be efficiently used as fuel in this cook stove.

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