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Performance evaluation of forced draft gasifier based cook stove by using neem stalk

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Abstract
The evaluation of "Performance Evaluation of Forced Draft Gasifier Based Cook Stove by using Neem stalk" was carried out at Department of Renewable Energy Sources, Dr. Ulhas Patil College of Agricultural engineering and Technology, Jalgaon, M.S in 2013 for improving the performances of the cook stove. Neem stalk was used for this performance evaluation research as a feed. Neem has been cultivated in India, Sri Lanka, Bangladesh, Myanmar, etc. countries which is grown principally for shade, fuel wood, non-wood products. This Neem stalk utilizes for energy (cooking food) in rural areas of the respective region. The total power output of the cook stove was found to be 13.71 kW. The results of controlled cooking test (CCT) show the specific fuel consumption of a stove is 1.44 kg/kg i.e. mass of a fuel used to cook a mass of a food. The burning capacity and thermal efficiency of the cook stove was found to be 7.52 kg/h and 36.47 per cent respectively.

Keywords: forced draft gasifier, cook stove, gasifier, neem stalk, CCT, thermal efficiency

1. Introduction
Over 3 billion people use plant material or animal waste as fuel for cooking. Biomass use requires families to spend a considerable amount of their income, energy and time collecting and preparing the fuel.1.6 million people die each year from indoor air pollution. Using biomass as fuel contributes to deforestation which is a devastating problem in many developing countries.

Biomass fuels continue to play an important role both in the domestic and industrial sector in most of developing countries, as it is an agricultural- based economy. Fuel wood often accounts for a major fraction of the total biomass use. Biomass is the main source of energy for a large number of small, rural, and cottage industries and commercial activities along with the majority of rural households. Fuel wood is generally preferred to non-wood biomass residues due to its higher energy density and convenience in use and transportation. In developing countries, biomass is still and will remain the major fuel for cooking energy; at household, industrial, commercial and religion.

In India, fuel wood, crop residues and animal manure are the dominant biomass fuels, which are mostly used in the rural areas, at very low efficiencies. Industrial and municipal (urban) residues such as wastewater, municipal solid wastes (MSW), and crop residues such as rice husk can also be used for energy generation. The total potential of energy from these sources in 1997 is estimated to be equivalent to 5.14 EJ, which amounts to a little more than a-third of the total fossil fuel use in India. The energy potential in 2010 is estimated to be about 8.26 EJ (N.H. Ravindranath).

Biomass contributes over a third of primary energy in India. Biomass fuels are predominantly used in rural households for cooking and water heating, as well as by traditional and artisan industries. Biomass delivers most energy for the domestic use (rural - 90% and urban - 40%) in India (NCAER, 1992). Wood fuels contribute 56 percent of total biomass energy (Sinha *et al,* 1994). Consumption of wood has grown annually at 2 percent rate over past two decades.

The Ministry of New and Renewable Energy (MNRE) launched National Biomass Cook stoves Initiative (NBCI) with an aim to enhance the availability of clean and efficient energy for the energy deficient and poorer sections of the country. Under the initiative, a series of pilot scale projects were undertaken using several commercially available better cook stoves and different grades of process biomass fuel. The cook stoves technology has improved considerably in the past few years and those efforts need to be continued to further improve the designs to make them efficient and cost effective. The revision has been prepared for all types of portable biomass cook stoves (both family and community size).

Neem (*Azadirachta indica*)
Neem has been cultivated in India, Sri lanka, Bangladesh, Myanmar, etc countries which is grown principally for shade, fuel wood, non-wood products and it has many uses like medicinal and according to our topic –its wood is use as fuel or it is use as firewood and for making of charcoal which has high calorific value and which is easily available in everywhere in India. We test this feed stock for gasifier based cook stove because it has relatively high calorific value of 6.94 kcal/g (Parotta John A. and Chaturvedi A. N.,1994).

From above discussion we proposed our research work on performance evaluation of gasifier based cook stove by using neem feed stock. The gasifier based cook stove was designed by Er. Ranjit Powar *et al.* (2014)

The proposed objectives were assessment of different properties of feed stock and performance evaluation of gasifier based cook stove for neem feed stalk

2. Material and Methods
This chapter deals with the materials and methodology used for design of gasifier based cook stove and performances evaluation of gasifier based cook stove.

Selection of Raw Material
Neem stalk were selected as a feed stock which have different properties like density, calorific value etc. for checking out

the best performances of the cook stove and appropriate use of biomass.

Forced draft gasifier stove

Forced draft gasifier stove (Fig. 1) which was designed and developed at department of Electrical and other energy sources, Dr. Ulhas Patil college of Agricultural Engineering and Technology Jalgaon. It consists of reactor chamber, grate, ash removal, primary air suppler fan, pot support and producer gas removal system.

Operational Features of forced draft gasifier stove

The operation of cook stove depends upon the principal of forced down draft gasifier cook stove. The primary air supply at bottom of combustion chamber and the need of secondary air was satisfied from the extraction of fuel gas plus some amount of primary air from the combustion chamber. The developed gasifier based cook stove was batch type feeding system. It needs to fill by fuel before starting of the system. If biomass was filled then ignite the biomass by match box. Then start the fan system for supplying primary as well as secondary air. The forced feed air system of fan which create the explosive burning in the cook stove.

Characterization of sample

The methods for finding the, bulk density, and proximate analysis of neem stalks were discussed in this section. The observations were recorded and average values were used.

Bulk density

Bulk density is the ratio of mass to bulk volume of the sample. Density of Soybean crop residues was measured using a standard measuring cylinder having 500 ml capacity. It was filled up with cotton stalk and then the content was weighted. The formula used for determination of bulk density given below:

$$\text{Bulk density} = \frac{\text{Mass}}{\text{Bulk volume}}$$

Proximate analysis

Proximate analysis characterized the cotton stalk for volatile matter, fixed carbon, and ash content.

Moisture content

Electric oven available was used to determine the moisture content of neem stalk. A known quantity of sample was dried at 110 ± 5ºC until constant weight was attained and the moisture content was calculated by using formula:

$$\text{Moisture \% (dry basis)} = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$$

Where,

W_1 = weight of empty crucible, g

W_2 = weight of the crucible and sample, g

W_3 = constant weight of crucible and sample after drying, g

Fig 1: Pictorial view of cook stove

Fig 2: Pictrial view during operation

Volatile matter

A known quantity oven dried sample of neem stalk sample was heated at 600 ± 25 ºC for six minutes and then at 900 ± 25 ºC for another six minutes in a pre-weighed open silica crucible in a muffle furnace. The amount of weight loss in the sample gives the volatile matter of the biomass sample estimated using the formula given below:

$$\text{Volatile Matter \% (dry basis)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

Where,

W_1 = weight of empty silica crucible, g

W_2 = weight of the crucible and sample, g

W_3 = constant weight of crucible and sample after heating, g

Ash content

A known quantity oven-dried sample of neem stalk was combusted in a pre-weighed and closed silica crucible at 750 ± 25 ºC for a minimum four hours in a muffle furnace. The amount is estimated using the formula given below:

$$\text{Ash contain \% (dry basis)} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

Where,
W_1 = weight of empty silica crucible, g
W_2 =weight of the crucible and sample, g
W_3 =constant weight of crucible and sample after combustion, g

Fixed carbon
The amount of fixed carbon (FC) present gives a rough indication of the charcoal yield. Also, a higher FC material was generally better suited for gasification than a lower FC material. The fixed carbon was estimated by using the following formula:

Fixed carbon per cent (wet basis) = 100 – volatile matter (per cent) – ash content (per cent)

Performances evaluations cook stoves
The biomass fired gasifier stoves at the department were tested using different parameters. Efficiency test and emission test were carried out. Efficiency was determined by carried out water boiling test for different biomass. During test various parameters were measured such as flame temperature, outside stove temperature, remaining ash and water temperature.
The following parameters were used in evaluating the performance of the biomass gasified gas stove.

Flame temperature
The flame temperature of gas burning was measured by using thermocouple K-type (chromel-allumel) with temperature indicator.

Outside stove temperature
The outside temperature of stoves was measured with the help of non-contacting thermometer.

Thermal efficiency
Thermal efficiency of a Cook stove may be defined as the ratio of heat actually utilized to the heat theoretically produced by complete combustion of a given quantity of fuel (which is based on the net calorific value of the fuel).

Efficiency Test
Efficiency was determined by carrying the standard water boiling test (WBT). The quantity of water evaporated after complete burning of fuel was determined to calculate the efficiency by using following formula,

$$\eta = \frac{m_{wi}\, c_{pw} (T_e - T_i) + m_{i,evap} H_1}{m_f H_f}$$

Where,
m_{wi} – Mass of water initially, kg
c_{pw} – Specific heat of water, KJ $kg^{-1}k^{-1}$
T_e – Temperature of boiling water, K
T_i – Initial temperature of water, K
$m_{i,evap}$ – Mass of water evaporated, kg
H_1 - Latent heat of vaporization of water
m_f - Mass of fuel burned, kg
H_f - Calorific value of fuel, KJ kg^{-1}

The steps followed in testing gasifier cook stoves were given as below.

A. Fuel
The dried neem stalk samples were taken which having moisture content less than 15per cent. Before starting the test, sample feed or fuel was weighed.

B. Vessel
The flat bottom cylindrical vessel made of stainless steel was used. The diameter of vessel for boiling should be taken as 1.5 times the outer diameter of exposure slit.

C. Water
Clean potable water should be used for water boiling test. Known quantity of water was filled into the vessel, so as to occupy its 2/3 volume. Initial temperature of water in the vessel was noted using mercury thermometer (T_1).

D. Igniting the fuel
The fire was started by igniting well dried neem stalk with the help of paper pieces by match stick. As soon as the fuel sample caught the fire, vessel containing water was placed properly on the burner.

Determination of Burning Capacity Rate
If the fuel burning rate is not given by the manufacturer, the cook stove is operated with method described below and the same shall be used to estimate the burning capacity of the Cook stove.

a. Stack the fuel in a honey comb fashion in combustion chamber as given in up to 3/4 of the height for continuous feeding type Cook stove, or in a pattern recommended by the manufacturer.
b. Weigh the Cook stove with fuel, let the mass be M_1 kg.
c. Sprinkle 10 to 15 ml of kerosene on the fuel from the top of Cook stove fire box mouth.
d. After half an hour of lighting weigh the chulha with fuel residues again and let the mass be M_2 kg.
e. Then calculate the burning capacity of the Cooks tove as heat input per hour as follows:

Burning capacity rating = 2 (M_1 – M_2) kg/hr

Heat input per hour = 2 (M_1 – M_2) × CV kcal/hr

Where,
M_1 = the initial mass of the Cook stove with test fuel in kg,
M_2 = the mass of the Cook stove with fuel residues, after burning the test fuel for half an hour in kg, and
CV = Calorific value of the test fuel in kcal/kg.

Power Output Rating
The power output rating of cook stove is a measure of total useful energy produced during one hour by the fuel. It shall

be calculated as follows:

$$\text{Power output rating, } Po = F \times CV \times \eta / 360000 \text{ kW}$$

Where,
Po = Power output
F = rate of consumption of fuel wood (kg/h)
CV = calorific value of wood (or solid fuel), in kJ/kg
η = thermal efficiency of the *chulha* in percent

Instruments and other Accessories
1. Weigh balance
2. Stop watch or time measuring device
3. Electronic Temperature indicator
4. Thermocouple Wire Thermometer
5. Paper pad and pencil for recording the observations
6. Testing vessels
7. Exhaust Gas Analyzer

3. Results and Discussion
This chapter gathered the practically generated data of cook stove. The data shown in this chapter was average value of no of replication. The detail of design and performances of cook stove as follows.

Characterization of sample
The proximate analysis of raw materials are given in table which shows that the Neem contains volatile matter 67.06% and less amount of moisture content 12.72%. Ash content in neem is 67.06. Whereas fixed carbon content in neem was found that 24.58% (d.b.). Bulk density of neem was 300 kg/m^3. Volatile matter evolves in the form of gas, hydrocarbon and tars. Ash content and moisture content affect the heating value of neem. Ash content depends upon the plant and soil condition in which the plant grows. There characteristics of raw material shows neem has ability to use as fuel for cook stove.

Table 1: Physical properties and Characterization of Neem

Sr. No	Properties	Average value of raw material
1	Moisture content (d.b.)	12.72%
2	Volatile matter, per cent (d.b.)	67.06%
3	Ash, per cent (d.b.)	8.36%
4	Fixed carbon, per cent (d.b.)	24.58%
5	Bulk density (kg/m^3)	300

Burning capacity
The burning capacity of neem was found to be 7.52 kg/hr. It should be more as design consideration because the air flow rate in the combustion chamber was high as required. There was no any provision for the control the air supply of the fan.

Combustion zone rate
The combustion zone rate for neem was found to be 0.329 m/hr.

Water-boiling test
The water boiling test carried out by pellet sample at two condition i.e cold water boiling test and hot water boiling test. The graph 1 show the graphical relation between the time verses increasing temperature of the water. It was seen that the water boil at hot condition in 2 minutes and water boil at cold condition in 5 min for pellet. It shows that hot water condition was more superior than the cold water condition. Because, it could be minimizes the initial thermal losses of the system. After reaches the water at saturation boiling condition then increasing time there would be not any significant increasing the temperature.

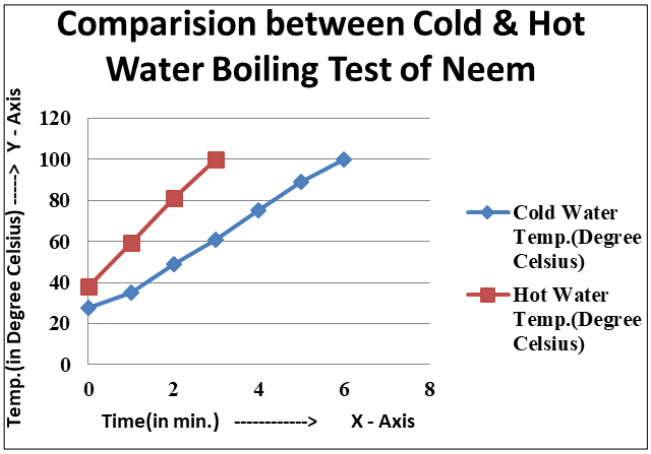

Fig 3: Comparison of hot and cold water boiling condition for Neem

Thermal efficiency
The thermal efficiencies obtained from the cook stove from neem 36.47 per cent. According to India standard developed cook stove was suitable for commercial application.

Control cooking test
The results of controlled cooking test (CCT) show the specific fuel consumption of a stove for neem was 1.44 kg/kg that mass of a fuel used to cook a mass of a food. It shows higher consumption of fuel due to inadequate condition of fuel.

Power output
The total power output of the cook stove for neem was found to be 13.71 kW respectively. It could be also higher than the design considerations. The excess air supply in the combustion chamber create excessive and explosive burning of fuel, which was the reason of higher power output compare with the rated output.

4. Conclusion
1. Neem feed stalk is suitable fuel for Developed cook stove
2. Burning capacity, thermal efficiency and total power output found much better.

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