Research Article Impact Factor: 4.226 ISSN: 2319-507X
A. K. Kamble, IJPRET, 2016; Volume 5 (2): 560-569 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

SPECIAL ISSUE FOR
INTERNATIONAL CONFERENCE ON
"INNOVATIONS IN SCIENCE & TECHNOLOGY: OPPORTUNITIES & CHALLENGES"

DEVELOPMENT OF THERMO EFFICIENT BIOMASS COOK STOVE FOR RURAL HOUSEHOLD

DR. A. K. KAMBLE

Assistant Scientist, All India Coordinated Research Project on Energy in Agriculture and Agro-based Industries, College of Agricultural Engineering & Technology, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS)-444 104 Email:anilkumar_kamble@hotmail.com

Accepted Date: 07/09/2016; Published Date: 24/09/2016

Abstract: *The thermo efficient biomass cook stove was designed and developed in Department of Unconventional Energy Sources and Electrical Engineering, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS). The performance of the cook stove was evaluated viz., fuel burning rate, power output rating, thermal efficiency and carbon monoxide concentration in laboratory and actual cooking test at user's site. The thermal efficiency of the thermo efficient natural draft cotton stalks based biomass cook stove was found to be 31.34%, which was 20.56% higher than traditional biomass mud cook stove. It saved 39% cooking time over a traditional biomass cook stove. The CO concentration in flue gas emit by the thermo efficient cook stove was found to be 2.97g/MJ, whereas, the CO concentration was found to be 73.15% higher in traditional biomass mud stove cook stove than that of the thermo efficient cook stove. The cook stove is a relatively clean burning device, fuel efficient and easy to operate. User friendly and low cost thermo efficient biomass cook stove is recommended for cooking in rural households using cotton stalk as fuel. From the study, it reveals that use of thermo efficient cook stove would be perspective for rural households over the conventional cook stove.*

Keywords: *Cotton stalk, thermo-efficient and thermal efficiency*

Corresponding Author: DR. A. K. KAMBLE

Co Author:

Access Online On:

www.ijpret.com

PAPER-QR CODE

How to Cite This Article:

A. K. Kamble, IJPRET, 2016; Volume 5 (2): 560-569

INTRODUCTION

Biomass has a very high potential as a renewable energy resource because of its reliability and availability everywhere around the globe. It is the fourth highest primary energy resource in the world after oil, coal, and gas, contributing about 10.6% of the global primary energy supply. Globally, around 2.6 billion people 40 per cent of the world's population still rely on traditional biomass to meet their household cooking energy requirements. Also, nearly 1.3 billion people remain without access to electricity and 2.6 billion still do not have access to clean cooking account for two-thirds of those without electricity and in just three countries, India China, and Bangladesh which account for more than half of those without clean cooking facilities. Almost 80 to 90% of the energy used in rural household is for cooking and water heating, of which 75 to 95% of the energy is from wood and charcoal. An estimated 826 million Indians depend on simple cook stoves that burn solid fuel, mainly fuel wood or coal (Anonymous 2011 and 2012[a]). To mitigate Indoor air pollution and to get more efficient technology for cooking have been remain one of the major challenges for researcher. Indoor smoke from solid fuels is the tenth leading cause of avoidable death worldwide. It is the second-most important environmental cause of disease after contaminated water borne diseases. It has been found that every year 4.3 million people die prematurely from illness attributed to the household air pollution caused by the inefficient use of solid fuels. It is also estimated that three to four lakh people die of indoor air pollution in India every year (Tripathi, 2014).

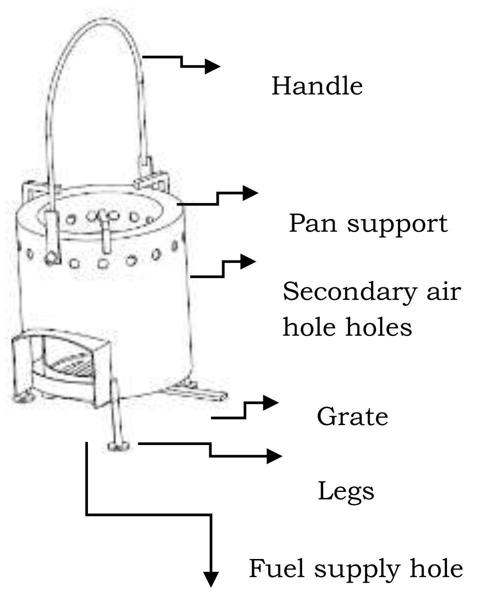
Growing demand of energy has necessitated the need for finding alternative means for meeting the demand in rural areas. With the change in rural scenario, agricultural practices, advent of gadgets the demand of energy has also increased manifold. Although, the Indian government is toiling to provide the sufficient electricity, cooking gas, petroleum oil to meet the growing demand of rural areas but due to limited resources, difficult geographical conditions and remoteness of villages, their reach is limited. In such conditions, the use of biomass energy with efficient technology may prove a ray of hope for resolving the energy problem in rural India. Approximately 70% of the population of India live in rural areas where biomass are primarily utilized for meeting the cooking and heating requirements through open firing, traditional stoves and having very low efficiencies, about 10%. Traditional biomass stoves cause significant greenhouse gas (GHG) emissions due to formation of products of incomplete combustion. Indoor air pollution is a major attributable factor for ill health in rural India.

As per Ministry of Statistical and Programme Implementation, National Survey Office, Energy Sources of Indian households for cooking and lighting, 2011-12, the rural households mostly used firewood & chips as primary source of energy for cooking. At all India level, firewood & chips were used by more than two-third (67.3%) of rural households, followed by LPG, which was used by 15.0% households. Only 9.6% and 1.1% of the rural households used dung cake and coke and coal, respectively as primary source. The remaining 4.9% households used other sources, i.e. biogas, charcoal, electricity and others. 1.3% rural households did not have any arrangement for cooking. In the *urban* areas, most of the households used LPG as primary source of energy for cooking. LPG was used by 68.4% of the *urban* households at all-India level, followed by firewood and chips, used by 14.0 % households and 5.7% of the households used kerosene and 6.9% households did not have any arrangement for cooking (Anonymous 2012[b]).

The cotton is cultivated by more than 10.0 million farmers in 12.7 million hectares in India. In India and Maharashtra cotton is the major principal crop and covers 12.70 Mha and 4.2 Mha, respectively and produced 38.1 MT and 12.6 MT cotton stalks in India and Maharashtra, respectively (Anonymous 2011). The cotton stalks are available with farmers at their farms. Considering the potential of cotton stalks and its availability in rural village, the stalks can be used as fuel for cook stove. There are many improved stoves are available but these are operated on wood fuel or briquettes and these are top fuel feeding. In this study the attempt has been made to develop thermo efficient natural draft cotton stalk crop residue based biomass cook stove for rural households.

MATERIALS AND METHODS

The thermo efficient cotton stalk crop residue based biomass cook stove developed in Department of Unconventional Energy Sources and Electrical Engineering, Dr. PDKV, Akola in 2015-16. The isometric of the developed stove is shown in Fig. 1.



In experimental study cotton stalk was collected from University field. The selected cotton stalks were dried in oven at 110^{o}C to bring about 4-8% moisture content. In present study, cotton stalks fuel was selected as it is available with the farmers at their own farm. From the proximate analysis of the selected cotton stalks showed very low ash content, highest carbon content and low sulphur content. The cook-stove performance tests had been performed as per Indian standard 13152: Part 1:1991 and modified draft December 2012 (Kshirsagar and Kalamkar, 2014).

The complete experimental set up for performance evaluation of thermo efficient cook stove is shown in Fig. 2. The various instruments viz., KANE 940 flue gas analyzer, infra red thermometer, temperature indicator, thermocouples (RTD), and weighing balance were used for evaluation of thermo efficient cook stove.

Fig. 2 Complete set up for evaluation of thermo-efficient cook stove

A flue gas hand held analyzer of model KANE 940 was used for measuring the concentration of carbon monoxide present in flue gas. The flue gas velocity was measured by anemometer-vane probe of model AM 4201 at the out let of the hood for determination of flue gas flow rate. The flue gas flow rate was found out by the observations of flue gas velocity, cross sectional area of opening of hood and flue gas density (Harshika *et al.*, 2014 and Motghare *et al.*, 2015).

The fuel consumption rate was found out with reference to the BIS standard to determine the fuel burning rate per hour. To determine burning rate, the cook stove's combustion chamber was filled up to 3/4 of the height of cook stove as recommended by BIS procedure. Initial and final weight of the cook-stove with weighed test fuel was measured before lighting the fuel (Panwar and Rathore 2008 and Venkataraman *et al.,* 2010). The further method and steps were adopted as per BIS testing norms and the fuel consumption rate was determined. On the basis of fuel consumption rate the heat input per hour was estimated using the following equation.

$$Heat\ input, kcal/kg = (M_1 - M_2) X\ CV \qquad \dots\dots\dots\dots (1)$$

Where,

M_1 – Initial mass of cook stove with test fuel, kg

M_2 – Mass of cook stove with fuel residue after burning the test fuel for half an hour, kg

CV - Calorific value of fuel, kcal/kg

The power output rating of cook stove is a measure of total useful energy produced during one hour by the fuel (Bansal *et al*., 2013). It was calculated as follows.

$$Power\ output\ rating\ (Po), kW/h = F\ x\ CV x\ \eta\ x\ 860 \qquad \dots\dots\dots (2)$$

Where,

Po - Power output, kWh

F - Fuel consumption rate of cook stove, kg/h

CV - Calorific value of fuel, kcal/kg

η - Thermal efficiency of the cook stove, %

The thermal efficiency of a cook stove is usually defined as the ratio of heat utilized to the heat theoretically produced by complete combustion of a given quantity of fuel. The thermal efficiency is the significant parameter to find out performance of the stove. Water boiling test was performed on cook stove. The constant heat output method was used for calculating the thermal efficiency of the cook stove. In this method, known quantity of water was heated in a pot on the cook stove till it attained a desired temperature. The heating temperature of the water was about 96^{o}C. At this temperature it was replaced by another pot with the same quantity of water at ambient temperature. The process was repeated till the completion of the combustion process. The thermal efficiency of the stove was calculated as per Indian Standard 13152: Part 1 [6]. It is expressed and calculated by the following equations.

$$Thermal\ Efficiency, \% = \frac{Heat\ utilized}{Heat\ produced} x\ 100 \quad \ldots\ldots\ldots..(3)$$

$$Heat\ utilized = (n-1)\ x\ (W\ x\ 0.896 + w)\ x\ (t_2 - t_1) + (W\ x\ 0.896 + w)\ x\ (t_3 - t_1) \quad ..(4)$$

$$Heat\ produced = m\ x\ CV \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

Where,

m - Mass of fuel used, kg

CV - Calorific value of fuel, kcal/kg

RESULTS AND DISCUSSION

The fuel burning rate of the cook-stove was performed as per BIS standard and the results are shown in Table 1. The fuel consumption rate was found to be 1.089 kg/h. The power output rating was calculated and it was found to be 1.513 kW. However, the fuel consumption rate of traditional mud cook stove was found to be 1.264 kg/h. The power output rating of traditional mud cookstove was found to be 0.683 kW.

Table 1. Fuel burning rate and power output rating of thermo efficient and traditional cook stove

Sr. No.	Particulars	Thermo- efficient cook stove	Traditional cook stove
1.	Fuel burning rate, kg/h	1.089	1.264
2.	Power output rating, kW	1.513	0.683

The thermal efficiency of the agricultural residue based cook stove was worked out by using cotton stalks as fuel and results are represented in Table 2. It was observed that the average thermal efficiency of the cook stove was found to be 31.34%.

Table 2. Thermal efficiency of thermo efficient natural draft biomass cook stove

SN	Particulars	Tests		
		T_1	T_2	T_3
1	Calorific value of cotton stalk biomass, kcal/kg	3757.5	3757.5	3757.5
2	Ambient air temperature, ^{0}C	33.8	34.6	31.2
3	Quantity of water taken in pot for heating (m), kg	4	4	4
4	Initial temperature of water (T_w), ^{0}C	26.1	26.0	26.3
5	Water heating temperature (T_x), ^{0}C	96	96	96
6	Highest temperature attainted by the last pot (Tb),^{0}C	46	41	51
7	Total quantity of water heated (M_t), kg	32	32	32
8	Total quantity of water heated at 96^{0}C (excluding quantity of water from last pot (M), kg	28	28	28
9	Quantity of water heated in last pot (m), Kg	4	4	4
10	Total amount of water evaporated (M_1), kg	0.4829	0.5154	0.4270
11	Specific heat of water (C_p), kcal/kg	1	1	1
12	Latent heat of vaporization (H), kcal/kg	586.436	586.436	586.436
13	Quantity of biomass used, (W), kg	2	2	2
14	Thermal efficiency, %	31.25	31.56	31.19
15	Average thermal efficiency, %	31.34		

The thermal efficiency of the single pot traditional biomass cook stove was found to be 10.78% and which was 20.56% less than that of the thermo-efficient cook stove. The increase in thermal efficiency of the thermo efficient cook stove could be due to improved heat transfer to the pot by the cook stove and thus heat produced was effectively utilized than traditional stove tested in the laboratory. The higher thermal efficiency of thermo efficient cook stove was due to the minimal heat losses and also the higher burning rate of fuel in traditional single pot mud stove.

Due to improper design of combustion zone and low thermal efficiency, cook stove emits gaseous pollutants like CO. Such emissions have a serious health consequence on household members especially women involved in the cooking and on young children who spends time around their mother while playing. The CO concentration in flue gas emit by the thermo efficient cook stove was found to be 2.97 g/MJ, whereas, the CO concentration was found to be 11.06 g/MJ in traditional cook stove and which was 73.15% higher than that of the thermo efficient cook stove (Table 3).

Table 3. CO concentration in flue gas emits by thermo efficient and traditional cook stove

Sr. No.	Particulars	Thermo- efficient cook stove	Traditional cook stove
1.	CO concentration, g/MJ	2.97	11.06

The cooking test of the thermo efficient cook stove was conducted at user's site of Mrs. Bebinanda Sanatan Tayade, At Yeota, Tq. Distt. Akola and the following items were prepared (Muralidharan and Thomas, 2015). The details of the test are given in the following Table 4 and Fig. 3.

Table 4. Preparation of meal using thermo efficient cook stove

Sr. No.	Particulars	Wt. of material, gm/ml	Time required, min	Fuel required, gm
1.	Tea	250	05.5	117
2.	Chapati	500	23.5	469
3.	Curry	525	12.5	214
4.	Rice	125	11.0	198
	Total		52.5	998

The total time requirement for preparation of meal for five adult's family members by using thermo efficient cook stove was worked out to be 52.5 min and the fuel requirement was 998 g.

Fig 3. Cooking test of thermo efficient cook stove at village Dagadparva, Tq. Barshitakali, Distt. Akola

The advantages of the thermo efficient cook stove over the traditional mud cook stove are;

- Higher thermal efficiency of the cook stove
- Reduction in smoke and healthier environment for women and children
- Reduces drudgery of women for collection of fuel wood from forest
- Reduced deforestation due to use of cotton stalks available with the farmers
- Reduction in cooking time by 39%
- Less exposure of women to kitchen smoke
- Less cost of fabrication of the stove (INR 700/-)

The feedback from users were collected and given as below:

The thermo efficient cook stove emitted very less smoke, no irritation to the eyes, it is very easy to operate, continuous fuel feeding arrangement in the stove, portable and it can move at any corner of the house, it can be hang to the nail in the house after cooking and ash collection tray facilitate for clean kitchen.

CONCLUSIONS

The thermal efficiency of the thermo efficient biomass cook stove was found to be 31.34% and which was 20.56% higher than traditional single pot biomass cook stove. It saved 39% cooking time over a traditional biomass cook stove. The CO concentration in flue gas emit by the thermo efficient cook stove was found to be 2.97g/MJ, whereas, the CO concentration was found to be 73.15% higher in traditional mud stove cook stove than that of the thermo efficient cook stove. The cook stove is a relatively clean burning device, fuel efficient, low cost and user friendly.

REFERENCES

1. Anonymous, 2011. Future potential of biomass energy in India. Bioenergy India, Ministry of New and Renewable Energy, Government of India: 6-11.

2. Anonymous, 2012[a]. Energy Sources of Indian Households for Cooking and Lighting, 2011-12 Ministry of Statistics and Programme Implementation.12-22.

3. Anonymous, 2012[b]. World Energy Outlook. International Energy Agency. 6-7.

4. Bansal M, Saini RP, Khatod DK, 2013. Development of cooking sector in rural areas in India. *Renewable and Sustainable Energy Reviews.* 3: 44-53.

5. Harshika K, Chandra A, Kaushik SC, 2014. Comparative Study on Emissions from Traditional and Improved Biomass Cook stoves Used in India. International Journal for Research in Applied Science and Engineering Technology. 2 (8):249-257.

6. Kshirsagar MP and Kalamkar VR, 2014. A comprehensive review on biomass cook stoves and a systematic approach for modern cook stove design. *Renewable and Sustainable Energy Reviews.* 30: 580–603.

7. Motghare KA, Rathod AP, Waghmare SS, Wasewar KL and Labhsetwar NK, 2015. Performance evaluation and heat transfer studies on biomass gasifier cook stove. *International Journal of Application or Innovation in Engineering & and Management*. 4: 47-63.

8. Muralidharan V and Thomas E, 2015. Field testing of alternative cook stove performance in a rural setting of western India. *Int. J. Environ. Res. Public Health*.12: 1773-1787.

9. Panwar NL and Rathore NS, 2008. Design and performance evaluation of a 5 kW producer gas stove. *Biomass and Bio-energy*. 32:1349-1352.

10. Powar R, Bandgar PS and Kadu P, 2014. Clean energy from cotton stalk exercise of cook stove. *International Journal of Emerging Technology and Advanced Engineering*.4 (7).

11. Tripathi AK, 2014. Renewable energy for rural areas. *Akshay Urja*. 8 (2): 28-32

12. Venkataraman C, Sagar AD, Habib G, Lam N and Smith KR, 2010. The Indian National Initiative for advanced biomass cooks stoves: The benefits of clean combustion. *Energy for Sustainable Development*. 14: 63-72.