Development and Evlauation of Biomass Cook Stove

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Abstract

Biomass is considered as the renewable energy source with the highest potential to contribute in the energy needs for both the developed and developing economics worldwide. The current availability of biomass in India estimated at about 500million MT per annum.More than 3 billion people cook their food using open fires or traditional stoves. It leads to increased health hazards, drudgery in fuel collection, greater fuel requirements and ultimately deforestation. Improved cook stoves are safer and they provide more efficient combustion of alternative fuels in comparison with traditional stoves.

The study revealed that the average thermal efficiency of the developed cook stove was found as 17.44 per cent and 18.71 per cent in natural convection and 24.49 per cent and 25.93 per cent in forced convection using mango sticks and acacia sticks respectively, and the power output ratings for developed cook stove were found 1.66 kW and 1.70 kW in natural convection and 2.30 kW and 2.39 kW in forced convection respectively with mango sticks and acacia sticks. The maximum flame temperature attained by the developed cook stove in natural convection for mango sticks and acacia sticks were 894°C and 879.4°C and in forced convection it was 910.2°C and 985.4°C respectively. The time taken to boiling water to boiling temperature for mango sticks was less than acacia sticks in natural as well as forced convection and the maximum temperatures attained by the stove surface in natural convection during WBT were 68.6°C and 65.3°C and in forced convection 68.7°C and 68.3°C for mango sticks and acacia sticks respectively. Specific fuel consumption (SFC) was found as 0.326 and 0.297 in natural convection and 0.273 and 0.274 in forced convection for mango sticks and acacia sticks respectively because of higher calorific value of mango sticks and acacia sticks respectively i.e. 3796.8 kcal kg^{-1} and 3435.2 kcal kg^{-1}. The developed cook stove for different feedstock's produced less composition of CO/CO_2 ratio for the mango sticks and acacia sticks was found to be 0.039 and 0.032 in natural convection and 0.038 and 0.036 in forced convection respectively found within the limit 0.04 as benchmark given by BIS.

Keywords: Improved cook stove, performance evaluation, stove efficiency.

Introduction

Energy plays a vital role in daily life. In India, most of the energy among total energy demand is used for cooking in the domestic sector and it is fulfilled by using abundantly available biomass (Anon. 2010). Biomass is used as the primary cooking fuel in 58.68 per cent of households and 82 per cent of the rural households use biomass for cooking i.e.76 per cent firewood and chips, 6 per cent dung cake. LPG is used by 12 per cent and kerosene by only 0.79 per cent. In the urban areas, the situation is different. LPG is the most common cooking fuel used by 64.6 per cent of households, followed by biomass (19 per cent) and kerosene (6.4%). In India, 74 per cent households have access to electricity (66 per cent of the rural household and 94 per cent of the urban) (Anon. 2014).

Traditional cook stoves or chulhas, which have

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efficiencies less than 10 per cent and are known to be sources of large quantities of pollutants, are used by most rural households in India for cooking. In such households, women and children are often exposedto high levels of pollutants, for 3 to 7 hours daily overmany years.

Annually biomass burning is estimated to emit 22 million tons of methane and 0.2 million tons of nitrous oxides. These emissions have significant implications for climate change due to their considerably high global warming potential compared to CO_2 (Bruce and *et al*. 1995). Today, an estimated 2.5 billion people depend on biomass fuel for cooking. According to the World Health Organization (WHO), exposure to smoke from these open fires and cook stoves leads to pneumonia, chronic respiratory disease, and lung cancer causing an estimated deaths of 1.6 million each year out of which 400,000 in India alone.

The improved cook stove is a combustion device through which cooking activity can be performed at the countryside. It has great potential to minimize emission and yield better fuel efficiency and also have provision for exhaust of smoke produced during combustion of biomass to outside the kitchen with the help of chimney to ensure a better indoor environment.

Keeping in view, the importance of the improved cook stove in minimizing indoor air pollution and deforestation, the biomass cook stove was developed and evaluated at Department of Electrical and other Energy Sources, CAET, DBSKKV, Dapoli.

Materials and methods

The methodology adopted for development and evaluation of biomass cook stove includes Characterization of selected biomass, Design and development of biomass cook stove and Evaluation of newly developed biomass cook stove for family size.

Characterization of mango sticks and acacia sticks

The fuel characterization is important to evaluate the performance of the system. During the study, the mango sticks and acacia sticks were used in the developed cook stove as a fuel and characterized in terms of proximate analysis, ultimate analysis and calorific value of biomass.

Design and development of cook stove

The consideration of domestic cooking for a family of 5 to 6 persons, the amount of energy required was calculated for designing cooking stove. As per the required capacity of the fuel in cook stove for single family, cross- sectional area and height of combustion was designed. The amount of net oxygen required to burn the fuel was calculated for designing provision of the opening which made, the better combustion of fuel in the cook stove. The technical specification of improved cook stove is depicted in Table 1. The isometric and pictorial views of developed biomass cook stove are shown in Figure 1and Figure 2.

Testing of developed cook stove

The developed cook stove was tested by carrying efficiency tests [IS Standard 13152 (Part I): 1991]. The thermal efficiency of the cook stove was determined

Table 1. Technical specifications of developed biomass cook stove

Sr. No.	Parameter	Dimensions
1.	Height of combustion chamber, m	0.14
2.	Length of combustion chamber, m	0.14
3.	Width of combustion chamber, m	0.14
4.	Cross-sectional area of combustion chamber, m^2	0.0196
5.	Volume of combustion chamber, $m^3\ sec^{-1}$	
	a) Mango sticks	0.00250
	b) Acacia sticks	0.00279
6.	Height of stove walls, m	0.265
7.	Total Length of stove, m	0.52
8.	Diameter of Pot I, m	0.16
9.	Diameter of Pot II, m	0.12
10.	Distance between two pots, m	0.10
11.	Height of chimney, m	0.50
12.	Diameter of chimney, m	0.076
13.	Height of legs, m	0.0508
14.	Thickness of insulation, m	0.02

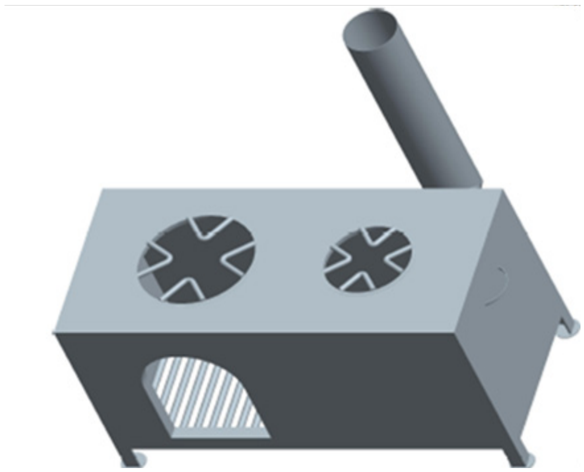

Figure 1. Isometric view of developed cook stove.

Figure 2. Developed cook stove after fabrication.

by conducting Water Boiling Test (WBT) for different biomass such as mango sticks and acacia sticks. The known quantity of water was heated from ambient temperature to the boiling temperature of water. The pre measured quantity of biomass was burned in the cook stove and water evaporated was measured. The summation of the sensible heat required for the water heating and latent heat of vaporization of evaporated water were treated as the output of the cooking stove. The amount of heat supplied by the fuel during the testing was treated as input to the cook stove. During the test, various parameters were measured such as flame temperature, stove surface temperature, ash and water temperature. The testing of developed cooking stove was conducted in natural as well as supplementary secondary air convection. The actual cooking test of the newly developed stove was carried out by conducting the cooking test for local food items. The emissions coming out of the developed biomass cook stove were measured.

Results and Discussion

The proximate analysis, ultimate analysis and calorific value of biomass were determined.The results obtained are summarised in Tables 2, 3 and 4.

Performance evaluation of developed cook stove

The maximum flame temperature attained by the developed cook stove in natural convection for mango sticks and acacia sticks were 894°C and 879.4°C and in forced convection it was 910.2°C and 985.4°C respectively.

The maximum temperatures attained by the stove surface in natural convection during WBT were 68.6°C and 65.3°C and in forced convection 68.7°C and 68.3°C for mango sticks and acacia sticks respectively.

The chimney temperatures attained by the chimney during WBT were 99.3°C and 90.3°C in natural convection and 83.1°C and 80.5°C in forced convection for mango sticks and acacia sticks respectively.

Temperatures of stove body

The different temperatures of the different parts during WBT i.e. the temperature at the left side wall, temperature at the right side wall, temperature at the front side, temperature at the back side of stove, temperature between two pots, temperature near the bend of chimney and temperature at exhaust were recorded and are depicted in Figures 3a and 3b.

For mango sticks and acacia sticks in natural convection the average ash produced in WBT were found as 41 gm and 39.66 gm respectively, and in forced convection it was found as 38.60 gm and 32 gm respectively.

In WBT, for mango sticks and acacia sticks in natural convection the total quantity of unburned fuel was found as 940 gm and 500 gm respectively and in forced convection it was found as 925 gm and 470 gm, respectively. In CCT, for mango sticks and acacia sticks in natural convection the total quantity of unburn fuel was found as 750 gm and 800 gm, respectively and in forced convection it was found as 850 gm and 845 gm

Table 2. Proximate composition of feed stock

Sr. No.	Biomass	Proximate composition, %			
		Moisture content, % (w.b.) (Average)	Volatile matter, % (Average)	Ash content, % (Average)	Fixed carbon, % (Average)
1.	Mango sticks	9.28	59.91	3.43	26.36
2.	Acacia sticks	7.31	68.63	4.01	20.03

Table 3. Ultimate composition of feed stock.

Sr. No.	Biomass	Ultimate composition, %			
		Carbon content, % (Average)	Hydrogen content, % (Average)	Nitrogen content, % (Average)	Oxygen content, % (Average)
1.	Mango sticks	64.26	5.91	0.88	26.51
2.	Acacia sticks	63.40	6.42	0.72	25.43

Table 4. Higher calorific value of feed stocks used in the study.

Sr. No.	Biomass	Calorific Value (kcal kg^{-1})
1	Mango Sticks	3796.8
2	Acacia Sticks	3435.2

Table 5. Results of emission testing.

Sr. No.	Feed Stock	Natural convection				Forced convection			
		CO, %	CO_2 , %	HC, ppm	O_2, %	CO, %	CO_2 , %	HC, ppm	O_2, %
1.	Mango Sticks	0.153	3.89	0.02	24.20	0.124	3.25	0	23.80
2.	Acacia sticks	0.157	4.89	0.02	25.85	0.129	3.50	0.02	23.30

respectively.

Average thermal efficiency obtained in natural convection for mango sticks and acacia sticks were 17.44 per cent and 18.71 per cent respectively. In forced convection the average thermal efficiency obtained for mango sticks and acacia sticks were 24.49 per cent and 25.93 per cent respectively.

For mango sticks and acacia sticks the power output ratings found for natural convection were 1.66 kW and 1.70 kW and for forced convection 2.30 kW and 2.39 kW respectively.

The actual cooking test was carried out by cooking rice with selected feed stocks. The time spent in cooking rice per kg of cooked food was found to be 0.181 h kg^{-1} and 0.163 h kg^{-1} in natural convection and 0.140 h kg^{-1} and 0.146 h kg^{-1} in forced convection for mango sticks

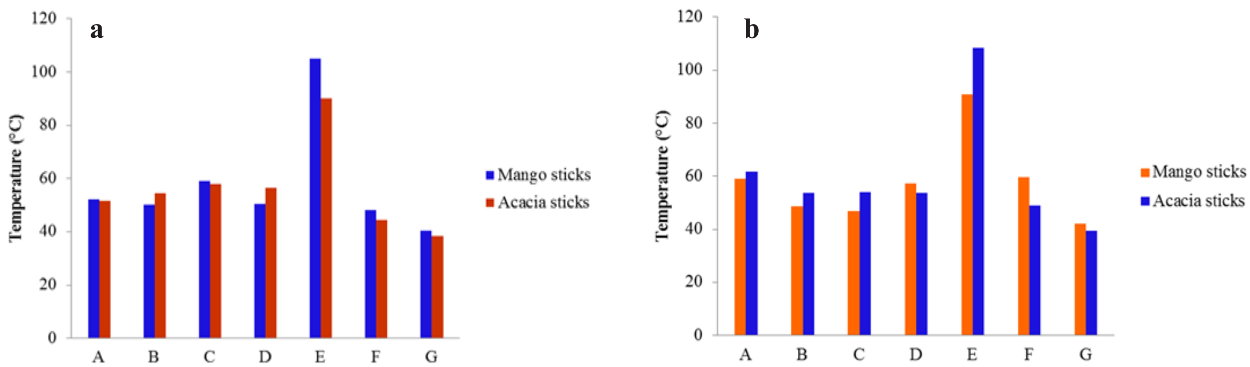

Figure 3. Average temperatures of stove body in natural convection (a) and forced convection (b) by using mango sticks and acacia sticks as feed stocks. Here, A: Temperature at left side wall, B: Temperature at right side wall, C: Temperature at front side of stove, D: Temperature at back side of stove, E: Temperature near bend of chimney, F: Temperature between two pots, G: Temperature at exhaust.

and acacia sticks respectively and the specific fuel consumption (SFC) was calculated 0.326 kg of fuel kg^{-1} of food and 0.297 kg of fuel kg^{-1} of food in natural convection and 0.273 kg of fuel kg^{-1} of food and 0.274 kg of fuel kg^{-1} of food in forced convection for mango sticks and acacia sticks respectively.

The emission contents of CO, per cent from the developed stove were found as 0.157 and 0.153 for mango sticks and acacia sticks in natural convection and in forced convection they were found as 0.124 and 0.129 respectively. The CO_2, per cent were found as 3.89 and 4.89 in natural convection and 3.25 and 3.50 in forced convection for mango sticks and acacia sticks respectively and depicted in Table 5.

Conclusions

The family size biomass cook stove was developed and evaluated using standard testing procedures in order to minimizing indoor air pollution and deforestation. The mango sticks and acacia wood were used as feedstock for heat supply. The study revealed that, the thermal efficiency of the developed cook stove was found to be more than 17.44 per cent in natural convection and 24.44 per cent in forced convection mode of operation. The power output ratings for the developed cook stove were found 1.66 kW and 2.30 kW in natural and forced convection. The overall cost of the developed cook stove was found to ₹ 2971.00. The developed cook stove gives better performance at forced convection mode using acacia fuel wood as compared to mango sticks as a fuel.

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