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PERFORMANCE EVALUATION OF BIOMASS COOK STOVE

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Abstract: *This paper presents the study of an improved biomass cook stove suitable for an Indian family of 5 to 6 members. The cook stove was designed, developed and tested as per BIS 13152 (Part 1): 2013. The performance of the cook stove was evaluated for different tests viz. fuel consumption rate (FCR), thermal efficiency test (WBT), power output, emission test (CO & CO_2), quenching test for grate, surface temperature and stability test for babul wood, mango wood, nilgiri wood and palmarosa grass briquette. The average FCR, average thermal efficiency and average power output of cook stove was found to be 1.46 kg/h, 27.5 % and 1.95 kW respectively for used feedstocks. The average CO/CO_2 ratio was found to be 0.0175 i.e. it's within the limit 0.04 given by BIS for used feedstocks. Any crack or deformation was not shown by the cast iron component (grate) after quenching test.*

Keywords: *biomass, fuel, cook-stove, design, performance evaluation, thermal efficiency etc.*

1. Introduction: Biomass contribute major source of fuel for energy in India. It has been a major source of households' energy in rural as well as urban area. In general, biomass is burnt through open fire stoves. These traditional stoves are characterized by low efficiency which results in inefficient use of scarce fuel-wood supplies.[1] Biomass is a CO_2-neutral but traditional open fire stoves are known to lead to high emissions of health damaging air pollutants.[1,2] To save wood fuel and spare rural communities from acute respiratory infection (ARI), it is important to replace a traditional open fire stove by an improved one.[3,4] Improved biomass cook stove are efficient combustion devices which has great potential to minimize emission and yield better fuel efficiency [5].

In Gujarat, people of tribal areas commonly use long branches of trees or crop residues as fuel for cooking. Presently the designs having better thermal efficiency are batch type operating on pieces of fuels, fed from top and majority of local designs having side feeding provisions for long woods have thermal efficiency lower than 25%. This work is concerned with the utilization of local fuels especially long wood branches as energy source, hence to develop a portable, less smoke emitting cook stove having provisions, for fuel feeding and ash removal, for continuous operation and of thermal efficiency ≥ 25%.

The cook stove was designed on the basis of energy required for an Indian family consisting of five to six members. The energy required to cook the food for single family was calculated. By using energy requirement fuel consumption rate (FCR), diameter and height of combustion chamber estimated. Also the provision of air inlet (primary and secondary) was given as per the estimated amount of air required. A fuel opening from the side of cook stove was provided for the continuous operation. The cook stove was fabricated as per design parameters obtained and its performance evaluation was carried out for different tests as per BIS 13152 (Part 1): 2013 at Thermo-Chemical Conversion Department (TCC) SPRERI, V. V. Nagar, Anand, Gujarat. The cook stove was evaluated for fuel consumption rate (FCR), thermal efficiency test (WBT), power output, emission test (CO & CO_2), quenching test for grate, surface temperature and stability test.

Four different feedstock's *viz.* babul wood (*Acacia nilotica*), mango wood (*Mangifera indica*), nilgiri wood (*Eucalyptus*) and palmarosa grass (*Cymbopogon martini)* briquette were used as fuel for cook stove. The wood fuel was in the form of long logs and briquette in small circular size. The prepared fuel was stored in a dry place for further use. The proximate analysis of all the four fuels was carried out as per ASTM D3173-11. Also the calorific values of four fuels were determined with help of bomb calorimeter as per ASTM-711.

2. Materials and Methods

2.1 Proximate Analysis and Calorific Value of Biomass Feed Stock: The proximate analysis of selected biomass feedstocks was carried out to determine the physical properties of fuels as per ASTM D3173-11. The biomass used for the study of proximate analysis was long sticks of babul wood, nilgiri wood, mango wood and palsmarosa grass briquettes. The calorific values of the value of babul wood, mango wood, nilgiri wood and palmarosa grass feed stocks were determined by standard procedure with the help of Bomb calorimeter.

2.2. Design and Fabrication of the Cook Stove: With the considerations of domestic cooking for a family of 5 to 6 persons, amount of energy required was calculated for designing the improved cooking stove. The energy required to cook food for single family was computed to estimate fuel consumption rate, diameter and height of cook stove's combustion chamber. Also the size of air inlet (primary and secondary) was calculated based on amount of air required for fuel combustion.

2.3. Performance Evaluation of the Cook Stove: The developed cook stove was tested as per BIS 13152 (Part 1): 2013. The tests of fuel consumption rate (FCR) burning Rate, thermal Efficiency of developed cookstove for different biomass materials viz. mango wood, nilgiri wood, babool wood and palmarosa grass briquette were carried out. The following (Table-1) parameters were recorded to evaluate the performance of the cook stove.

Table-1: Observations for performance evaluation of solid biomass cook stove.

Sr. No.	Parameter	Unit
1	Flame temperature	°C
2	Water temperature	°C
3	Stove surface temperature	°C
4	Weight of fuel taken	kg
5	Weight of water taken	kg

2.4. Emission Testing: The emission contents evolved from the feed stocks during the operation of developed cooking stove were measured with the help of NDIR module exhaust gas analyzer at Cookstove Testing Lab, Sardar Patel Renewabele Energy Research Institute, Vallabh Vidyanagar, Anand (Gujarat). The peak emission from cookstove for differrent biomass feedstocks was recorded during operation of the cookstove. The test was carried out according to BIS standards 13152 (Part 1): 2013

2.5. Quenching Test for Grate: The test was carried out for grate to test its ability to withstand against high temperature without any crack or deformity using the BIS standards 13152 (Part 1): 2013 procedure. The test was carried out for 10 times for evaluation of grate.

2.6. Stability Test: Stability test for developed cookstovewas carried out BIS standards 13152 (Part 1): 2013.

3.0 Results and Discussion

3.1. Proximate Analysis: The result of proximate analysis is given in Table-2. The moisture content of babul wood, mango wood, nilgiri wood and palsmarosa grass briquettes were found as 8.27, 13.54, 10.97 and 7.17 percent respectively and fixed carbon was found as 19.65, 13.16, 19.87 and 16.06 percent respectively. The volatile matter for babul wood ,nilgiri wood, mango wood and palsmarosa grass briquettes were found to be79.15 and 83.92, 76.59 and 76.05 percent respectively and the and ash content were found to be 1.19, 2.90, 3.53 and 7.88 percent respectively.

Table-2: Proximate analysis of feedstocks used for testing of the cook stove

Sr. No.	Biomass	Proximate composition (%)				Calorific value (Kcal/kg)
		Moisture content	Volatile matter	Fixed carbon	Ash content	
1.	Babool wood	9.01	79.15	19.65	1.2	4290
2.	Mango wood	15.67	83.92	13.16	2.92	4250
3.	Nilgiri wood	12.32	76.59	19.87	3.54	3987
4.	Palmarosa grass briquettes	7.72	76.05	16.06	7.89	4226

3.2. Calorific Value of Feed Stocks

Table-3: Calorific value of the feed stocks used for study

S.No.	Feed Stok	Calorific value (Kcal/kg)
1.	Babool wood	4290
2.	Mango wood	4250
3.	Nilgiri wood	3987
4.	Commercial briquettes	4226

The calorific value of babool wood, mango wood ,nilgiri wood and palmarosa grass briquettes are depicted in Table-3. The calorific value of babool wood was found maximum among the selected biomass materials followed by mango wood and palsmarosa grass briquettes. The lowest calorific value among the selected biomass was found for nilgiri wood.

3.3. Design and Fabrication of Cook Stove: The improved domestic cook stove was designed considering various parameters and fabricated locally. Technical specifications of the developed cook stove are mentioned in Table-4. The schematic view and photograph of designed cook stove are given in Fig. 1.

Table-4: Technical specification of developed improved cooking stove

Sr. No.	Parameter	Dimension (mm)
1	Internal diameter of combustion chamber, m	145
2	Height of combustion chamber, m	230
3	Thickness of air insulation	20
4	Thickness of insulyte-7 insulation	20
5	Diameter of primary air inlet holes	15
6	Number of primary air inlet holes	4
7	Diameter of secondary air holes	10
8	Number of secondary air holes	15
9	Fuel inlet opening	100 x 100

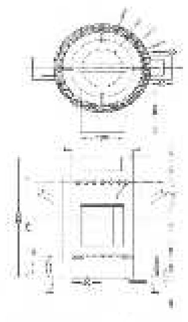

Fig.1 -Line diagram of cookstove

Fig.2-Photograph of the Developed Cook Stove

4. Testing of Cook Stove

4.1. Fuel Consumption Rate (FCR): Fuel consumption rate of the developed cook stove was found to be 1.5, 1.57, 1.66 and 1.15 kg/h for babul wood, mango wood, nilgiri wood and palmarosa grass briquette respectively (Fig.-3). The fuel consumption rate was found to be maximum for nilgiri wood among all feedstocks followed by mango wood and babool wood and minimum for palmarosa grass briquette. The maximum fuel consumption for nilgiri wood was because of it has low calorific value among all feedstocks and minimum for palmarosa grass briquette. Fig. 2 shows photograph of the developed cook stove.

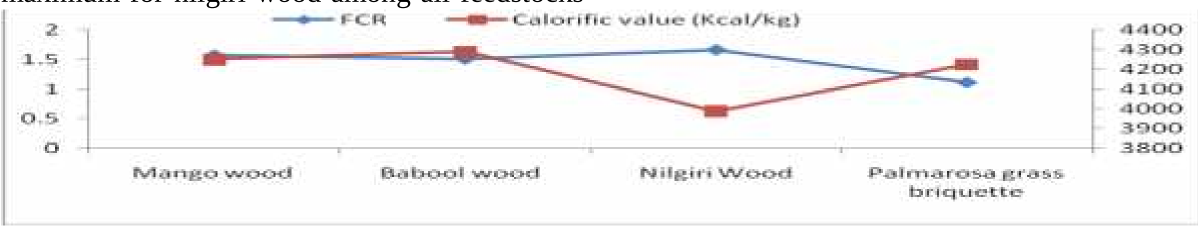

Fig.3: Variation of Fuel Consumption Rate (FCR) with calorific value of different feedstock

4.2. Thermal Efficiency of Cook Stove: Thermal efficiencies obtained for selected biomass feedstocks are depicted in Table 5. The differences in thermal efficiencies were obtained with different feedstock due to difference in calorific values of feed stocks. The thermal efficiency of cook stove was found to be maximum for babul wood among all the feedstocks followed by mango wood and palmarosa grass briquettes and minimum for nilgiri wood. As the thermal efficiency greatly depends on the calorific value of fuel, palmarosa grass briquettes have maximum calorific value among all the feedstocks followed by babul wood, mango wood and minimum for nilgiri wood. Efficiencies obtained were found to be more than thermal efficiency of traditional mud stove 17.9 percent with wood fuel and are greater than the limits mentioned in BIS 13152 (part 1) :2013 i.e. 25 %. The enhanced performance could be attributed to factors such as insulation around combustion chamber for minimizing the heat loss across the wall of the combustion chamber and availability of sufficient preheated secondary air ensuring complete combustion of flue gases.

Table -5: Thermal efficiency of cookstove for different biomass feedstocks

Sr. No.	Feedstock	Thermal efficiency (%)
1	Babool wood	28.07
2	Mango wood	27.94
3	Nilgiri wood	27.04
4	Palmarosa grass briquette	27.08

4.3. Power Output Rating: The power output rating for the developed cook stove with different feed stocks is presented in Table 6. Mango wood performed the best than all other selected fuels followed by babul and nilgiri wood and minimum for palmarosa grass briquette. Typically, the minimum power requirement to cook food for a meal (for a family of 4-5 persons) is about 1.5 to 2 kW with burning time about 1.0 to 1.5 h. The obtained values of power output ratings for selected biomass feedstock were found more than this required value except palmarosa grass briquette. Hence, the developed cook stove was found effective using all selected biomass fuels except palmarosa grass briquette for meeting the cooking requirements for a family of 5 to 6 persons.

Table-6: Power output rating of cookstove for different biomass feedstocks

Sr. No.	Feedstock	Power rating (kw)
1	Babool wood	2.1
2	Mango wood	2.16
3	Nilgiri wood	2.08
4	Palmarosa grass briquette	1.48

4.4 Emission Testing: Table-7 shows the peak values of CO and CO_2 emmisions recorded during the operation of cookstove for selected biomass. It was observed that maximum CO emission evolved for nilgiri wood among all other feedstocks followed by palmarosa grass briquette and mango wood. The minimum CO emission was observed for babool wood. The maximum CO_2 emission evolved for mango wood among all other feedstocks followed by palmarosa grass briquette and nilgiri wood. The minimum CO emission was observed for babool wood.

Table-7: CO, CO_2 emissions and CO/CO_2 ratio

Sr. No.	Feedstock	CO (ppm)	CO_2 (ppm)	CO/ CO_2
1	Babool wood	170	10700	0.015
2	Mango wood	180	16100	0.011
3	Nilgiri wood	360	12600	0.028
4	Palmarosa grass briquette	260	16000	0.016

Also the peak value of CO/CO_2 ratio recorded during the operation of cookstove for selected biomass. It was observed that maximum CO/CO_2 ratio was found for nilgiri wood among all other feedstocks followed by palmarosa grass briquette and babool wood. The minimum CO/CO_2 ratio was observed for mango wood and found within the limit 0.04 as given by BIS. Hence, the developed stove was safe regarding health point of view for all the feed stocks.

4.5. Surface Temperature Test: The test was carried out by recording the temperature of surfaces which, in normal use, have to be touched for short periods like handles. The peak surface temperatures recorded at various locations of the cookstove for different feedstock's are as given in Table 4.9.

Table-8: Surface temperatures of cookstove at various locations

Sr. No.	Feedstock	Location (at outer surface of combustion chamber)			
		near the top	at middle	near grate	on handle
		Temperature (°C)			
1	Babool wood	150	140	110	65
2	Mango wood	150	140	130	65
3	Nilgiri wood	130	120	120	65
4	Palmarosa grass briquette	130	110	90	65

4.6. Quenching Test for Grate: The test was carried out for grate to test its ability to withstand against high temperature without any crack or deformity. The test was carried out for 10 times for evaluation of grate and at the end of the test it is observed that grate showed no crack and deformation or no change in its shape and size was observed.

4.7. Stability Test: It was observed that the cookstove was stable against overturning when tilted in any direction to an angle of 15°from the vertical.

Conclusion: The combustion efficiency of cookstove for different fuels *viz.* babool wood (*Acacia nilotica*), mango wood, nilgiri wood and palmarosa grass briquette was found to be more than 25 % which is the minimal requirement as per BIS 13152 (Part 1): 2013. Hence the cookstove is suitable for all such fuels. The average power rating of cookstove was found to 1.95 kW, that is the cookstove is classified as medium size as per BIS. Therefore the developed cookstove can save considerable amount of wood fuel as compared to traditional low efficient open fires and stoves currently in use and would be the better alternative to rural and village area people.

References

1 Anozie, A. N., Bakare, A. R., Sonibare, J.A., Oyebisi, T. O. (2007). Evaluation of cooking energy cost, efficiency, impact on air pollution and policy in Nigeria. *Energy*, 32:1283–90.

2. Bhattacharya, S.C., Albina, D. O., Khaing, A. M. (2002). Effects of selected parameters on performance and emission of biomass-fired cookstoves. *Biomass & Bioenergy*,23:387–95.

3. Granderson, J., Sandhu, J. S., Vasquez, D., Ramirez, E., Smith, K.R. (2009). Fuel use and design analysis of improved woodburning cookstoves in the Guatemalan Highlands. *Biomass & Bioenergy*, 33:306–15.

4. Panwar, N.L., Kurchania, A.K., Rathore, N.S. (2009). Mitigation of greenhouse gases by adoption of improved biomass cookstoves. *Mitig Adapt Strateg Glob Change*, 14:569–578.

5. Parikh, J., Balakrishnan, K., Laxmi, V., Biswas, H. (2001). Exposure from cooking with biofuels: pollution monitoring and analysis for rural Tamil Nadu, India. *Energy*, 26:949–62.