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Performance Analysis of Dhaba Size Improved Biomass Cook Stove for Commercial Application as Clean and Efficient Cooking Solutions

Shradhdha Pandya [a*] and Jvalant Trivedi [b]

[a] Gujarat State Civil Supplies Corporation Ltd. (GSCSC), Near Borsad Chowkadi, Anand -388 001, Gujarat, India.
[b] Department of Mechanical Engineering, The Charutar Vidhya Mandal (CVMU) University, Anand-388120, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The current study evaluates the behaviour of the Dhaba-size cook stove for commercial applications in rural area. Further, the study focuses on its impact on the biomass saving and the surrounding environment. The Dhaba-sized cook stove system was installed for the experimental investigation in R.S.Gruh Udyog, Borsad, Anand, Gujarat. The results obtained based on pre-and post-installation of the system, the system was assessed the cooking pattern, biomass and time consumption, smoke emission, and socio- economic effect. During the experiment, 10 batches of Rice Papdi were cooked uniformly. The Dhaba-size Improved Biomass Cook Stove (IBCS) is used for only boiling water, and atta iscooked on Traditional type of Cook stove. Initially, the traditional type of cook stove was used for water boiling and the other for cooking of atta. Based on the results

**Corresponding author: E-mail: Shradhdha.pandya@gmail.com;*

for pre-installation and post-installation conditions, it was found that wood consumption per day was reduced with the reduction in time. As per discussion with the beneficiary, he is happy with the design, efficiency, and performance of it.

Keywords: Dhaba size cook stove; wood consumption; time saving; papdi; pre-installation; post-installation; performance analysis.

1. INTRODUCTION

In India, according to the year 2011 census, 65 % of people live in rural areas and still depend on solid biomass fuels to meet their energy needs for cooking. Firewood is the main source of energy for 2.7 billion people worldwide, and it can meet more than 90% of household energy needs for cooking and heating purposes [1-3]. Solid fuel combustion can also lead to deforestation and forest destruction, with 27-34% of global firewood harvesting being considered unsustainable [4-7]. Traditional biomass combustion contributes 34–45% of the warming caused by black carbon, according to recent estimates. According to the Global Burden of Disease 2010 evaluation, household air pollution caused by solid cooking fuels caused approximately 1.04 million premature deaths and 31.4 million disability-adjusted life years in India [8,9] accounting for 6% of the national burden of disease. National exposuremodels developed for solid fuel-using households estimate daily average PM 2.5(particulate matter less than 2.5 lm inaerodynamic diameter) exposures of 337, 204, and 285 l g/m^3 for women, men, and children, respectively [10-12], far exceeding the current WHO air quality guideline (WHO- AQG) values (WHO 2006). Since dealing with solid biofuel for cooking is inconvenient, some people prefer the electric cook stoves and LPG, but these are more costly alternatives [9,11,13]. The penalty area of the effort is to assess the acceptability and efficacy of implementing better cookstoves in developing countries like India in a locally customized manner [14]. This study investigates the suppressing the increased levels of indoor air pollution (IAP) caused due to biomass burning in the rural households of India [15,16].

1.1 Improved Biomass Cook Stove (IBCS)

Figs. 1 and 2 shows the Dhaba type improved biomass cook stoves to reduce the drudgery of the people involved in Dhaba or small eateries. Rural residents mostly used conventional-style C-type cook stoves for domestic use and Dhaba-size cook stoves for commercial or community- based applications [17]. Roadside Dhaba uses wood as a cooking fuel in commercial applications. These types of cook stoves have a very low efficiency of about 10-12 %andproduce a lot of smoke [18-20]. Cooking with solid biomass fuel releases dangerous gases on alarge scale and has a direct impact on the greenhouse effect and carbon emissions [21].

Fig. 1. Front viewimage of Dhaba-sized cook stove system

Fig. 2. Top view image of Dhaba-sized cook stove system

1.2 Site of Experiment

First, The Dhaba size IBCS has been installed at R.S. Gruh Udhyog (Dhruvi Papad) at Borsad, Anand to produce PAPDI, MATHIYA, and SUVALI. R. S. GRUH UDHYOG is well- known to produce a different flavour of PAPDI, MATHIYA, SUVALI, and FARALI products. The name of the product is DHRUVI, different types of PAPDI are the main products, and others are seasonal products. Average production is 150 to 200kg/day, and changes based on demand through 15 labour employees. The organization can supply its product to local dealer as well as other countries through parcel services.

2. MATERIALS AND METHODS

For the evaluation of Dhaba size cook stove collected pre- installation and post-installation data for impact analysis at R.S. Gruh Udyog, Vasna, Borsad,Anand. To carry out an effective analysis, some of the key elements listed below were assessed based on a comparison of collecteddata.

a) Cooking pattern [22],
b) Biomass consumption,
c) Smoke emission [21],
d) Cycle Time
e) Socio-economic Impact

The total 22 products have been made like Mathiya, Suvali, Farali based on product demand. For cooking of rice papdi, 10 kg of riceflour, 500gm salt, 10gm soda are mixed and 20 litres of water is heated at its boiling point then transferred to processing unit. The capacity of utensil used for boiling water is 100 litres.

biomass cook stove for efficient and economic use in Small restaurants, Dhaba, and Nasta houses in rural areas. The criteria like daily fuel wood consumption, wood size, cooking time, and ash disposal were considered in designing the cook stove. For the development of the Dhaba size imp roved biomass cook stove, in-house testing was carriedout, and the performance of various parameter of the Dhaba size improved biomass cook stove was analyzed by SPRERI, Anand**.**

2.1 Cooking Pattern

Papadi making process can be categorised into three parts: (i) Cooking atta, (ii) Papadi making unit and (iii) Packing. It was observed that for the atta cooking process, during pre-installation survey, they used 2 nos. of Traditional type of Cook stove (TC) was used. One (TC-1) is used for boiling water and another one (TC-2) is used for mixing masala and cooked rice atta. Cooked atta is transfer to papdi making machine, with help of papdi making machine papdi prepared and dry it for 5 to 7 hours in open sundry. For continuous process, biomass feeding is continuously needed to maintain temperature and 2 nos. of labors were required for feeding biomass and supplying raw materials during the cooking process and others are working in papdi processing unit for operating machines and other operations.

After installation of dhaba size IBCS, total of 2 nos. of cook stove is used, in which dhaba size IBCS is used for boiling water and mixing masalas and TC is used for cooking atta only. The whole cooking process must require continuous cooking process of papdi production is mentioned here:

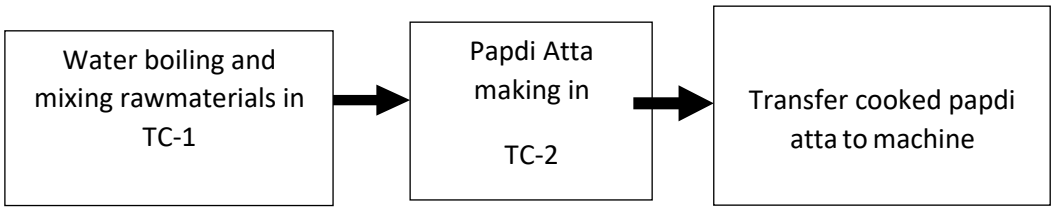

Fig. 3. Traditional Cooking process for papdi production

2.3 Biomass Consumption

Biomass consumption per day is a very important parameter for the cooking process. The papdi-making process is a continuous process and for this observed biomass feeding in dhaba-size cookstove and traditional- type cook stove for 10 batches of rice papdi atta cooking cycle. After installation of dhaba size IBCS, the whole cooking process of 10 batches is done through 2 nos. of the cook stove. During this process, we observed biomass feeding in the dhaba size cookstove and TC.

2.4 Smoke Emission

The location of the papdi cooking unit is behind the beneficiary's home and due to the continuous cooking process, smoke emission may have harmful gases. The polluted local environment may have dangerous effect on labours, family members and neighbours. Smoke emission is based on wood consumption per day.

2.5 Cycle Time

The papdi-making process is a continuous process and observed the time required for 10 batches of rice papdi making. Dhaba-size cook stove is used for boiling water during the post-installation survey. The time required for boiling water in TC during pre- installation is also observed and it also effect on the temperature required for cooking.

2.6 Socio-economic Impact

his Gruh Udyog has been started in October 2017.Average daily production is 150 to 200 kg and also it depends on demand. The quality of all products is good and certified by the Food and Drug Control Administration, Gujarat. The owner can facilitate customized products based on the demand of customers. So, some famous products are demanding in other countries through parcel services. During pick season (Diwali and Janmashtami) Mathiya, Suvali, Cholafali, etc. products are in high demand. During pick season, daily production is around 300-350 kg. The stability and durability of the cook stove are important for continuous and efficientoperation.

2.7 Analysis

The performance evaluation of biomass cook stove involves monitoring the various factors related to its efficiency, gas emissions, safety, and overall effectiveness [3,18,19,24-26]. Performance analysis of Cook stove involves a combination of laboratory testing, field trials, and user surveys. Governments, NGOs, and research institutions may conduct these analyses to promote the adoption of cleaner and more efficient cooking technologies, particularly in regions where traditional stoves contribute to indoor air pollution and deforestation.

Table 1. Depicts the monitored parameterswhich reflect the enhanced performance ofDhaba size improved biomass cook stove. Performance testing of the newly designed Dhaba-size biomass cook stove based on Higher efficiency & lower emission compared to traditional CHULHAS.

- Multi-fuel acceptability.
- Portable, safe, and convenient for ease ofoperation.
- Better control of the heat.
- Easy ash removal while in use.

3. RESULTS AND DISCUSSION

Initial assessment of behavior and Impact of Dhaba size IBCS compared to TC, we have emphasis initially on five features as mentioned earlier. Its impact is accessed and found hindrances while using dhaba size IBCS which may affect directly and indirectly on the cooking process and production rate.

3.1 Cooking Pattern

Based on Fig.1, the papdi- making process is in three parts as discussed earlier. During this process, In the case of the pre- installation process only two nos. of TC is used and two no of labours had worked for material supply and biomass feeding in the cook stove. In the case of post-installation process also two no of cook stoves have utilised and only one labour is required to supply raw materials and simultaneously maintain continuously biomassfeeding. Due to this continuous process higher temperature is maintained and at the time of more demand (pick season) 2 nos. of cook stove can use to cook atta forfast process.

3.2 Biomass Consumption

During pre- installation, 2 no of TC and long mixed wood were used for the cooking process. Long mix wood is purchased at 40 ₹ per 20 kg

Table 1. Measured performance parametersof dhaba-size improved biomass cook stove

Parameter	Burningrate (kg/h)	Thermal efficiency (%)	Power rating (kW)	CO (g/MJd)
On field Conditions	3.9	31.7	6.75	0.0619

rate. During 10 batches, wood consumption for boiling water was 26kg and for cooking atta 54kg of wood was consumed. In the case of the post-installation condition, traditional type of cook stove have utilized for cooking and Dhaba size cook stove was used for water boiling.During 10 batches, wood consumption for boiling water was 12.5kg, and wood consumption for TC was 35 kg. Overall wood consumption for 10 batches of papdi making more in the pre-installation process compares to post-installation. After the installation of dhaba size cook stove wood consumption per day is less. Around 50% of the wood had been saved for the 10 batches of boiling water. Daily 20 batches of papdi atta cooking and 25 kg of wood saving per day. Average 6750 kg of wood saving per year. As a result of the combustion efficiency was improved by 48% and annual 2,70,000 ₹ savings, this is a huge amount for a beneficiary.

3.3 Smoke Emission

More smoke emission in pre-installation conditions though 2 nos. of TC is used. The local atmosphere is polluted due to smoke emission, which is harmful to family members, labours and children. Ash depositionon walls and vessels and tough to clean. As discussed earlier, while using dhaba size cook stove, biomass consumption is less due to the complete combustion of biomass. As a resultof this smoke, emissions are less. The design of forced draft cook stove has two types of air inlets in the forms of holes: Primary holes located at the bottom and secondary holes located at the periphery of the inner body. The fan continuously supplies air to help with the combustion process. Due to the complete combustion process, less smoke emission and more heat is produced. More heat produced causes less time required for cooking and woodconsumption rate per day.

3.4 Cycle Time

During the pre-installation condition, 2 nos. of TC was used, and a long mix of wood is used. The total time required for 10 batches is 215 minutes and the average time required for one batch is 21.5 minutes. After installation of dhaba size IBCS, the time required for 10 batches is 146 minutes and the average time required for one batch is 14.6 minutes. Overall time saving for 10 batches of papdi making is 69 minutes. Based on the comparison of time required in pre-installation and post-installation conditions, average of 6.9 minutes was saved per batch which reflects the significant reduction of approximate 30% time saving. Daily production of papdi is 200 kg in 20 nos. of batches. Overall, 69 minutes can be saved and can be utilized for further productionof 40 kg of papdi.

3.5 Socio-economic Impact

R.S. Gruh Udyog is3 years old business in Vasna area. Only this Gruh Udyog have a machine facility to make papad and dry it open sundry. The name of its product is Dhruvi papad and supply is based on demand in the market and season. The beneficiary had used 2 no of traditional type cook stoves for cooking papdi. But its time consuming and emits more smoke. As per discussion with the beneficiary, he thinks that complete combustion of biomass generates less smoke and more heat. As result, the overall efficiency of boiling water is increases and less wood consumed. Beneficiary like the design of IBCS because a fan is forced to combust biomass competently. The shape of dhabha size IBCS is cylindrical and at the bottom of IBCS, 4 nos. of primary holes and small holes are provided at the top side of the periphery. As a result of this design, more heat productionas well as more heat storage inside the cook stove. Beneficiary has a schedule that last 5 batches of sabudana chakri making and prefer to use stored boiled water (no need to boilwater separately). Ultimately Beneficiary has promoted saving of time to boil water, saving of wood (around 1.2 kg of biomass per batch for IBCS and 2.4 kg per batch for TC, and saving of money due to more heat storage capacity of IBCS in 100 liter of water. All the family members or beneficiaries have involvedin papdi making process, including Mother, daughter, son, wife, and around 10 nos. of labourers for daily wages. His wife has been helped with cooking papdi. After the adoption of dhaba size IBCS, his mother also helped in the cooking process due to less smoke emission. The location of the beneficiary house is beside cooking unit, Due to less smoke

emission, indoor air pollution decreased andthe working environment became good. All laboures are happily and efficiently work in cooking and processing units.

4. CONCLUSIONS

The conclusions that can be drawn from this study are:

1. Dhaba size cook stove has a positive environmental impact, whose significance is limited due to the low dissemination level, anda beneficial socio-economic impact.
2. The socio-economic impact of the stove is beneficial and improves the localenvironmentand lifestyle.
3. This stove helps households to save time (138minutes on average per day).
4. Secondly, households purchasing 50 % wood save money.
5. Thirdly, a switch from the traditional to the Dhaba size cook stove for boiling water continuously.
6. Smoke emission reduction and indoor air pollution decrease, which can increase the safety of the kitchen environment.
7. In terms of future recommendations, greater dissemination of the Dhaba size cook stove should be pursued with customized contribution (based on the demand for accessories).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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