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Development and Performance Assessment of a Pressurized Cook Stove Using a Blend of Pongamia Oil and Kerosene

Engineering

KEYWORDS : Renewable energy, Pongamia oil, Cook stove

Y. Nagaraju — The Energy and Resources Institute (TERI), Southern Regional Centre, 4th Main, 2nd Cross, Domlur 2nd stage, Bangalore – 560 071

Dr. Lasya Gopal — The Energy and Resources Institute (TERI), Southern Regional Centre, 4th Main, 2nd Cross, Domlur 2nd stage, Bangalore – 560 071

ABSTRACT

Pongamia oil can be used as an alternative fuel in cook stoves. However, commercially available wick stoves and pressurised stoves are not compatible to use 100 % pongamia oil. The Energy and Resources Institute (TERI) designed, developed and pilot tested a pressurised stove which uses a blend of pongamia oil and kerosene. The paper provides details of the pilot trials and performance of the pongamia oil stove. Modification of the stove design, testing of blends, and field tests prove that a blend of pongamia oil and kerosene in the ratio of 30:70 on a volumetric basis is a viable model for domestic use.

1. Introduction

In India the major energy sources for cooking in rural areas are biomass and kerosene. It has been estimated that nearly 855 million people use 9.101 MT (TEDDY 2011-12) of kerosene for cooking. Kerosene has been promoted as an alternative fuel to biomass in rural areas and is used in either wick stoves or pressurised stoves. It is easy to use, has a higher efficiency, and produces less smoke, but is limited in its availability. A steep increase in prices and withdrawal of subsidy is making it a scarce commodity. LPG is considered a rich man's fuel; its availability and affordability has not reached the desired level of penetration in rural areas. It is in this context that pongamia oil, which can be locally produced in rural areas, assumes importance as a biofuel.

Pongamia plant is botanically called "*Pongamia Pinnata*". Pure bio-oil can be obtained by crushing the seeds of this plant, which is non-edible, thick and brown in colour. In rural areas, this oil is sold in shops, which is used for lighting and some medicinal purpose (Arotel & Yeole 2010). It has good commercial value as it is also used in different industries like leather tanning, soap making ("Pongamia Fact Sheet", 2009), etc. The seeds cost about Rs. 13 per kilogram (average market price as on January 2012), the oil costs Rs. 45 to 50 per kilogram and the cake costs about Rs. 6 to 8 per kilogram. Pongamia oil can be compared to kerosene or diesel in terms of characteristics; however, the higher density of pongamia oil, i.e. 0.9389 at 15^{0}C as compared to kerosene (0.806 g/cc at 15^{0}C) makes it difficult to use pongamia oil in existing commercial cook stoves in its pure form.

By demonstrating the feasibility of using non-edible oils in commercial cook stoves it is expected that this is likely to open up new opportunities through value addition to the local resources and enable income generation in rural areas. The objective of the project was to develop an appropriate stove for rural areas which could use pongamia oil as a fuel. Under the project the following were carried out;

i) Performance study of using pure and different blends of pongamia oil in commercial cook stoves ii) Modification of commercial cook stoves to use pure pongamia oil or blends with kerosene.

2. Methodology

2.1 Testing setup

2.1.1 Setup: A room surrounded by outer boundary walls with floor dimension of 5.2 metre X 8.1 metre and a height of 2.43 metre was selected for the experiment. The function of the enclosure was to reduce effects of external wind and to maintain uniform ventilation conditions in the room throughout the experiment. To reduce the wind effects, the windows, ventilators, and doors fitted in the outer boundary wall were closed during the experiments.

2.1.2 Instruments: The instruments used for testing the stoves were i) Electronic Weighing Balance ii) Mercury Thermometer iii) Stop watch iv) CO/CO_2 Monitoring device V) Suspended Particulate Matter (SPM) filters.

2.1.3 Materials: The materials used for the experiment were kerosene and pongamia oil. Pogamia oil was blended with kerosene and the blends were categorised and given codes as in Table 1

Table 1: Blends of Pongamia oil with Kerosene

Blend Code	Percentage of blends
K100	100% Kerosene
P10	10% Pongamia oil and 90% Kerosene
P20	20% Pongamia oil and 80% Kerosene
P40	40% Pongamia oil and 60% Kerosene
P60	60% Pongamia oil and 40% Kerosene
P80	80% Pongamia oil and 20% Kerosene
P100	100%Pongamia oil

2.2 Testing methods

Three key parameters were evaluated, which were i) Power output ii) Specific Fuel consumption (SFC) iii) Emissions. Water Boiling Test (WBT) was taken as the basis to calculate the power output and SFC, which was used to determine the efficiency of the stove. The method by Bureau of Indian Standards (BIS, 2002) appeared to be the most comprehensive and hence taken for testing the stove.

3. Results

3.1Baseline

Tests were first conducted on commercial wick and pressurised stoves using kerosene as fuel to identify baseline of performance parameters like efficiency, SFC and emissions.

3.2Testing blends on unmodified stoves

After identifying the baseline parameters, blends of pongamia oil and kerosene were tested with varying amounts of kerosene as described in table 2. The tests were carried out on commercial wick and pressurised stoves (3 number offset burner type).

Wick stove: The experiment revealed that it is extremely difficult to ignite a wick stove with blends of kerosene and pongamia oil. The reason being, in commercially available wick stoves, the distance of wick (burning tip) from the oil reservoir is high, thus reducing percolation capacity of oil. Hence wick stoves could not be lit with pongamia oil or with its blends.

Pressurised stove: The pressurised stove was tested with Kerosene (K100) and blends P10 and P20. The experiment revealed that the blend of P20 worked well in a pressurised stove without any technical modifications and blends beyond P20 clogs the burner due its high viscosity. The test results of the pressurised stove are given in the figure 1.

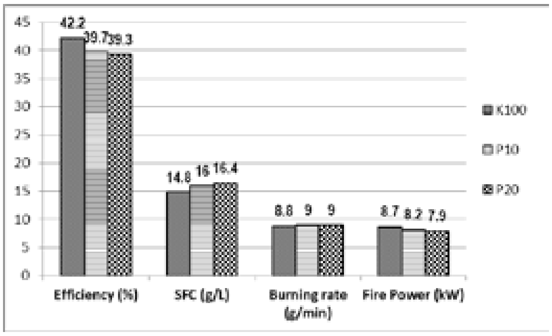

Figure 1: Comparative test results of pure kerosene and pongamia – kerosene blends on unmodified pressurised stove

The graph illustrates that efficiency and fire power decreases when there is increasing blend of pongamia oil with kerosene. SFC and burning rate of fuel increased when there was an increase of blend of pongamia oil with kerosene

3.3 Testing of blends on modified stoves

Literature review revealed that whenever a vegetable oil is not at optimum temperature before ignition, it sticks to the burner of the stove. The injecting oil should be at operating temperature otherwise it results in accumulation of carbonaceous deposits. Thus pre-heating of pongamia oil was considered to be the optimum solution to overcome clogging of the burner nozzle. Hence, usage of blends beyond P20 requires modification of commercial pressurised stoves (Srinivas et.al 2006).

Three modifications were made in the stove. These were, i) modification in the fuel tank (to accommodate two types of fuel, i.e. pure kerosene and a blend of kerosene and pongamia) ii) providing separate oil lines for kerosene and blend iii) providing a pre-heating coil (copper coil of 6 mm diameter) around the burner to pre-heat the pongamia oil blend. After several iterations with different blends, it was found that P30 gave optimum results.

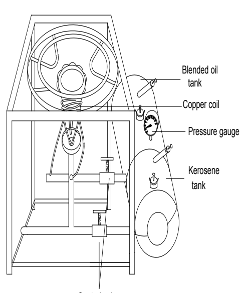

Figure 2: Line diagram of a modified pressurised stove

The single burner of the modified stove was first pre-heated with kerosene for three minutes till it is red hot. The heated burner was then supplied with the P30 blend, simultaneously cutting-off the kerosene supply. The P30 blend gets pre-heated on the red hot burner and flows for further burning. The results of the P30 blend in the modified pressurised stove are as follows:

Table 2: Test results of finalised pressurised stove model

SN	Parameter	P30	K100
1.	Efficiency (%)	37.2	42.4
2.	SFC (g/L)	17.5	14.7
3.	Burning rate (g/min)	8.6	8.8
4.	Power output (kW)	6.8	8.7
5.	Carbon Monoxide (%)	0.02	0.02
6.	Carbon Dioxide (%)	1.25	1.50
7.	Sulphur Dioxide (μg/m^3)	7.5	11
8.	Suspended Particulate Matter (mg/m^3)	0.345	0.48

The efficiency of the modified stove was found to be about 37.2%, whereas SFC, burning rate and firepower were found to be 17.5 g/L, 8.6 g/min and 6.8 kW respectively. The efficiency drop of about 4 to 5% in the modified pressurised stove may be attributed to the lesser calorific value of the blend compared to pure kerosene. There was a reduction in emissions on all counts in the stove using pongamia blend when compared to kerosene. There was 30% reduction in case of carbon monoxide, 16% in case of carbon dioxide, 32% in case of sulphur dioxide and about 28 % in case of suspended particulate matter when both the stoves were compared.

3.4 Field testing

The modified pressurised stove was field tested in the households in Puttapurlahally village of Gouribidanur Taluk, Kolar district of Karnataka to obtain feedback from users. The efficiency of the stove in the field was 37.5%. Kitchen Performance Test (KPT) showed that the fuel consumption was about 26 gms/meal/person. The users expressed satisfaction with the stove.

4. Conclusion

The pressurised stove developed under this project uses 30% pongamia oil and hence directly reduces 30% of kerosene requirement. Thus the modified pressurised cook stove has the potential to considerably reduce the usage of kerosene, a fossil fuel. Key stakeholders who can benefit and take forward the modified pressurised stove are primarily the rural community, small enterprises and enterprises engaged in manufacture and sale of domestic cooking devices.

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