Experimental evaluation of performance of pressure stove by using plant oil and kerosene blends

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ABSTRACT

In the present study, possibilities of operating conventional (Bureau of Indian standards recommended: IS 8808) pressures stove at 10-50 % blend of plant oil (Jatropha Curcus L.) to the kerosene were investigated. Various parameters such as calorific value, specific gravity, viscosity and the effect of thermal efficiency and emission characteristics of the blended samples were studied. From the properties and performance test results, it has been established that 20-30 % of jatropha oil blend is found to be optimum that can be substituted for kerosene at the existing burner design of the high pressure stove. However, further investigation is going on for improvisation of the conventional burner design for smooth running of stove at 100% plant oil utilization.

Key Words: Fuel Characteristics, High-Pressure Kerosene Stove, Jatropha, Transesterification

Nomenclature:

cS	Centistoke
ppm	Parts per million
t_1	Initial temperature of water in °C
t_2	Final temperature of water at simmering in °C
T	Time in minutes taken to heat water from t_1 to t_2
w	Weight of the water in the vessel in kg
W	Weight of the vessel complete with lid and stirrer in kg
X	Weight of fuel consumed per hour in kg
η_{th}	Thermal efficiency

I INTRODUCTION

In the era of energy crisis of fossil fuel depletion and environmental degradation, the efforts are being focused on alternative energy sources. Household energy, especially cooking energy, often counts for a big part of the overall energy consumption in many developing countries. The total kerosene consumption in India for 2000-01 was around

11.5 million tons. After, 55 years of independence, there are 63% of total rural households; that use only kerosene as one of the prime source of energy for lighting. Similarly, rural areas in India use about 180 million tons of biomass fuel for cooking through various inefficient and smoky cook stove [1]. Such type of low efficient biomass chulhas creates hazardous environmental impact. Now a day's extensive research has carried out for wide implementation of biogas and solar energy. Due to technical and handling problems, utilization of this technology is limited in the cooking energy sector [2].

In the US and Europe, alcohol based fuel became popular in late 1920s [3]. Nimbkar agricultural research institute (NARI) has developed pressurized stove running on 85% (v/v) ethanol [4-5]. Utilization of plant oil as cooking fuel presents an alternative to yet known cooking method and offers a variety of ecological, economical and sociological benefits. Stumpf and Mühlbauer had introduced plant oil pressure stoves by developing a completely new design. Capillary fed wick stoves cannot be operated on plant oil blending, as the high

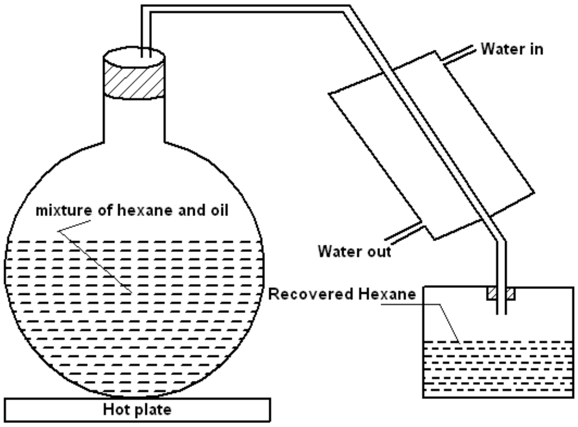
viscosity prevents the flow velocity of the oil through the wicks and consequently the flame is extinguished [6]. Therefore, the experimental investigations were confined to high-pressure stoves only.

The present work deals with plant oil utilization in domestic cooking stove, considering environmental and the economic aspect.

II EXPERIMENTAL METHODOLOGY

2.1Oil Extraction Techniques

In solvent extraction technique (fig: 1), chemical solvent such as hexane is used to saturate the crushed seed and pull out the essential oils. The plant material is removed and this renders a solvent. The solvent is then boiled off under a vacuum or in a centrifugal force machine to separate it from the required oil. Because the solvent has a lower boiling point (approximately 60^0C) than the oil, it evaporates and the oil is left. The solvent is cooled back into liquid state and the same can be collected for repeated use.



The high viscosity of the triglyceride of the plant oil leads to problem in pumping, combustion and atomization in injector system of the cooking stove. In long-term operation, plant oil normally introduces the development of the gumming and soot formation in the nozzle of the burner system. The inefficient mixing of oil with air contributes to incomplete combustion, leading to heavy smoke emission, and the high flash point attributes to lower volatility characteristics. Therefore, reduction in viscosity is of prime importance to make plant oil suitable alternative fuel for domestic cooking stoves. Transesterification of vegetable oils with simple alcohol has long been the preferred method for producing biodiesel [7].

The fig: 2 characterize the transestrification setup for conversion of plant oil into ethyl esters. To accomplish this conversion, oil is treated at room temperature with ethyl alcohol in the presence of a catalyst. This catalyst may be acid, alkali or lipase. During the process, the glycerol, which is produced, is insoluble in the ester product, and being heavier, settles out carrying most of the dissolved catalyst with it. Washing the ester product is necessary in order to improve its fuel properties, largely by removing residual free glycerol and small amounts of alkali remaining from the catalyst.

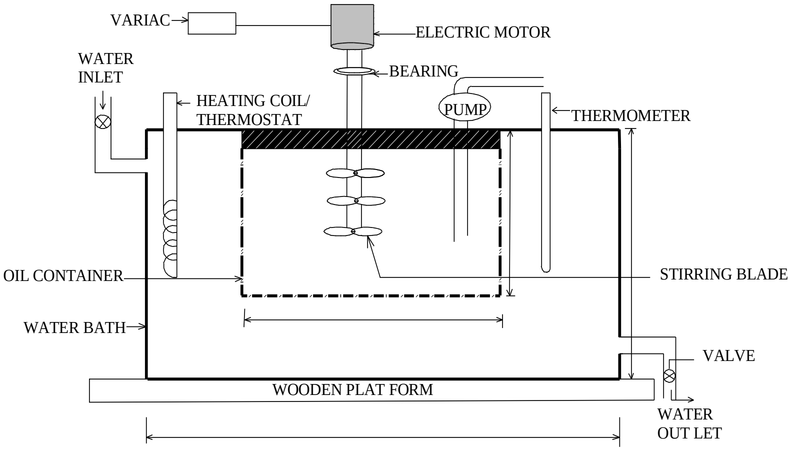


Fig: 2 Transesterification set up

2.2 Physical and Chemical Properties

In a dry seed of jatropha, the net oil content is about 35 – 40%. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids [8]. The viscosity of raw jatropha oil is about 75 cS. Experimental data obtained from the analysis of the physical and chemical properties of bends of transesterified jatropha oil and kerosene are mentioned below in the Table-1. The heating value of sample 2-4 (from Table-1) is almost comparable with kerosene oil (10,520 kcal/kg).

Table 1: Chemical and physical properties of 5 blended samples of Jatropha curcus L to kerosene

Sl.No.	Plant$_{oil}$/Kerosene$_{oil}$ (%)	Viscosity (cS)	Calorific Value (kcal/kg)	Specific gravity at 30^0 C
1	Sample 1 0/100	2.20	10520	0.814
2	Sample 2 10/90	4.13	9612	0.817
3	Sample 3 20/80	5.90	9522	0.822
4	Sample 4 30/70	7.12	9601	0.828
5	Sample 5 40/60	9.68	8897	0.835
6	Sample 6 50/50	12.63	8687	0.850

2.3 Performance Tests

Figure 1 shows the schematic set up high pressure-cooking stove. The stove body comprises of a fuel tank, burner assembly, control valve and a manual pump. The burner (Rorer type) assembly is comprises of a spray nozzle, vaporizer, oil plate and a burner head. The burner of the stove is connected vertically to fuel supply pipe of the fuel tank. The fuel supply can be regulated through a control valve. The fuel tank can be pressurized using a manual pump. The fuel tank of the stove is connected to a pressure gauge so that an average pressure of 1.4 kgf/cm^2 is maintained throughout the experiments for continuous supply of oil to the burner assembly [9].

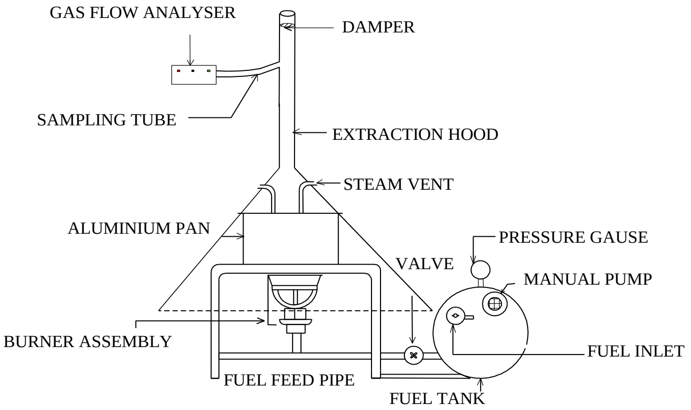


Fig: 3 Schematic set up of conventional high-pressure kerosene stove with extraction hood

Experiments (Thermal efficiency and emission test) were conducted according to the specification provided by IS 8808. [9]. Thermal efficiency was determined by carrying out the Water Boiling Test (WBT) recommended by

VITA (1985) [10]. Hood method is employed for estimating the emission factors of the cook stove. The stove to be tested at different proportions of blended sample was placed under an extraction hood to capture the emission. Since high extraction rate may influence the combustion characteristics of the stove, extraction was chosen to be strong enough to avoid flue gas to escape from the bottom of the hood but not strong enough to have any effect on combustion flame [11]. The hood is provided with a probe for CO, CO_2 *and HC* measurements. A standard infra gas flow meter is used as CO, CO_2 and *HC* analyzer.

2.4 Formulation

The thermal efficiency of the stove can be calculated by using following formula [9]:

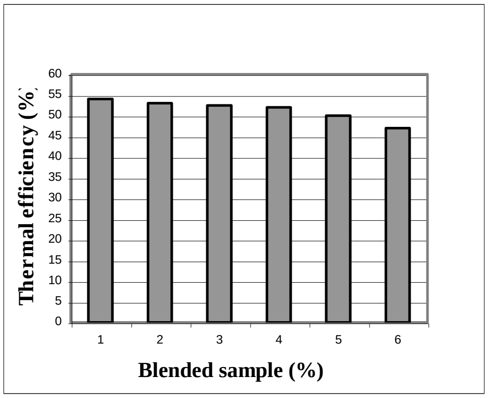
$$\eta_{\mathrm{TH}} = \frac{(W \times 0.214 + w)(t_2 - t_1)}{X \times T \times 10500} \times 60 \times 100$$

III RESULTS AND DISCUSSION

The tests were conducted with 10%, 20%, 30%, 40%, and 50% jatropha oil blended with kerosene. The performance parameter included thermal efficiency and emissions in terms of *CO*, CO_2 and *HC* were evaluated.

The results for the variation in thermal efficiency of the conventional high pressure stove with kerosene and 10-50% of plant oil blending are presented in fig: 4.The value of thermal efficiency at neat kerosene is about 54%. At 10-30% jatropha blend shows thermal efficiency (53%, 52.5%, 52%) almost in the comparable range to kerosene. However, the thermal efficiency of 47% at 50% blend is generally lower as compared to the conventional fuel.

The comparison of emission parameters of the stove at neat kerosene and jatropha blend are shown in the fig: 5,6,and 7. The figure shows the trend of variation for lower emission at different proportions of jatropha blend. For conventional burner operating at neat kerosene, the emission value of carbon monoxide and hydrocarbon is about 0.11% and 350 ppm respectively. The significant reductions in those parameters were observed at the different proportions of jatropha blend. The *CO* (% vol) emission at 20% blend was found to be 81% lower than the emission of conventional burner operating at kerosene. Likewise, the hydrocarbon emission at the same ratio is 69 ppm that is approximately 5 times lower than that of kerosene stove



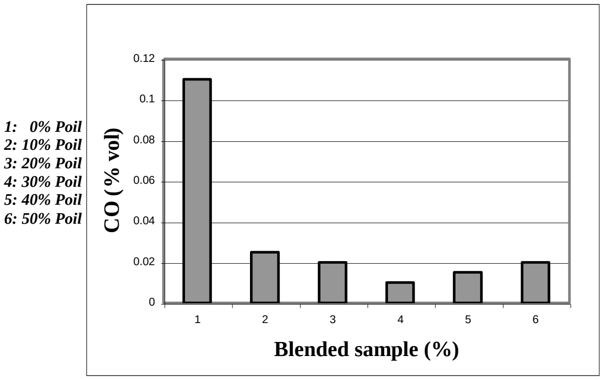
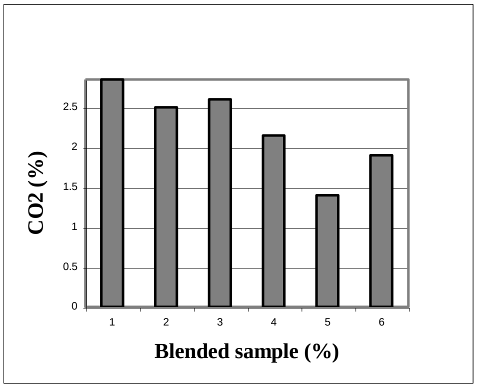


Fig 4: Comparison of thermal efficiency (%)

Fig 5: Comparison of emission [CO (% vol)]



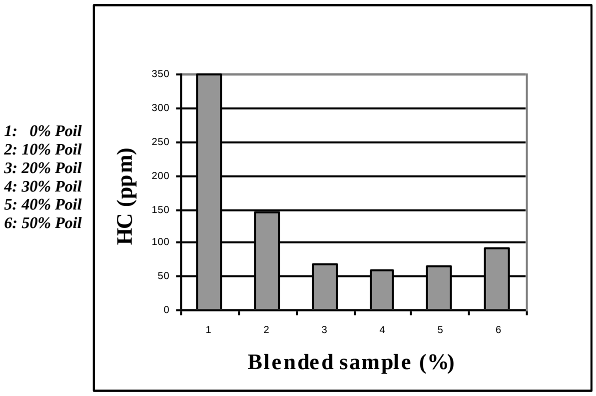


Fig 6: Comparison of emission [CO2 (% vol)]

Fig 7: Comparison of emission of [*HC (ppm)*]

IV CONCLUSION

The following conclusion can be out lined from the present experimental study

- Viscosity can be reduced by transesterification process up to 84%.
- From the present study, jatropha blend in the ratios of 20-30% can be used in pressure stove without any burner modification.
- 20-30% of blending gives optimum thermal efficiency in the range of 53-52%, which is almost comparable to the conventional burner running at kerosene.
- Tremendously lowers the hazardous emission.
- The price of kerosene in open market is about Rs.22-30/litre; poor people can hardly afford it.

- Besides, the most of the developing countries like India, where the fuel scarcity is acute, plant oil can play a challenging role in revolutionizing the cooking energy sector.

The results achieved in this experimental study are very promising and can help in developing a new design of an improved burner for 100% plant oil utilization and put to use in rural sectors.

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