Performance and Emission Characteristics of Commercial Kerosene Stoves using Waste Cooking Oil-Kerosene Blends

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Abstract: Pump stoves and wick stoves are extensively used in and around India for cooking and other household purposes. Kerosene being a non-renewable source of energy is not expected to last longer. So in order to reduce the amount of kerosene consumption alternative fuels must be thought of. In this work, it is intended to use the Cooking oil in both the pump stove and the wick stove. Since the cooking oil has more viscosity it cannot be used directly. So the cooking oil and kerosene blends are being used for the study. This study includes the use of blends before esterification and after esterification. The suitable characterization and transesterification of the cooking oil is carried out in the laboratory before being subjected to testing. Blends of 20%, 30%, 50% and 70% cooking oil-kerosene mixture and cooking oil-kerosene ester have been tested for emission aspect also. Various performance parameters like fuel consumption per unit time, time taken to raise the water temperature for a 200 have been considered for the comparison of the blends. 20%-30% cooking oil and kerosene blend came out to be the most efficient and is ~50% for pump stove and ~30% for the wick stove. During the testing it was observed that the CO emission is decreased with the increase in the cooking oil proportion in the blend. The drastic change has been observed in the Flash point and Fire point of the blends before and after esterification. The viscosity of the blend increased with the increase in the cooking oil proportion in the blend.

Keywords: Bio kerosene, Esterification, Cooking oil, Cooking stove, Emission.

1. Introduction

The fossil fuels which are being used for the commercial and household purposes are depleting faster. The fossil fuels are depleting in a significant way with serious warning of ending in a few year may be due to mishandling of reserves, drastically increased demand, uncontrolled increment in population and vehicles[1-2]. The rate of economic evolution is untenable unless we save or stops misusing the fossil fuels like coal, crude oil or fossil fuels. For most of the house hold purposes like cooking kerosene is the most popular fuel used in the rural areas of India. In wick stove the capillary action which raises the fuel to the tip of the wick facilitates the combustion. In pump stove the pressure developed inside the fuel tank facilities the fuel to come to tip of the burner where the combustion takes place. Since the viscosity of the cooking oils very high (~15 times the viscosity of kerosene) it cannot be used directly. So the kerosene and cooking oils blends are used for the testing purpose. According to Enweremadu and Rutto, esters of fatty acids (biodiesel), derived from the transesterification of edible oils has properties similar to petroleum based Diesel fuel [3]. Out of the edibles oils available waste cooking oil is abundantly available so it is decided to use waste cooking oil. The analysis by Enweremadu, Mbaruwa help in understanding the properties of cooking oil based biodiesel like optimum conditions for the transesterification and the chemicals to be used [4]. Further motivation to continue the test is obtained after seeing a research by Rao GLN, Sampath S, Rajagopal K. on the emissions and characteristics of biodiesel based on cooking oil [5]. The quality of biodiesel from waste cooking oil is understood by referring the work by Refaat, Atia, Sibak, heltawy, Diwani[6,7]. Bio kerosene is a mixture of kerosene and edible oils. In this case it is the mixture of waste cooking oil and waste cooking oil methyl ester is mixed with different proportions of kerosene. The characterization of the blends is based on the viscosity, flash and fire points. Emission of the CO and CO₂ are measured during combustion. The main aim of the work is to determine the appropriate blend that can be used in cooking stoves.
2. Preparation of blends

The blends are prepared on volume basis. A mixture of kerosene and neat waste cooking oil / waste cooking oil methyl ester have been tried in proportions of 10, 30, 50, 70% v/v. The performance and emission characteristics are evaluated for both wick and pump stove using neat as well as esterified blends. Esterification is the process of removing glycerol content in the oil to improve the combustion quality. Esterification process carried out at 60°C following the procedure reported in literature [8-10]. The Cleaveland open cup tester is used to determine the flash and fire point. Efficiency of stove at different blends is calculated by recording time taken for increasing constant volume of water for fixed temperature 20°C. The emission of CO and CO₂ is evaluated using gas analyser for all neat and esterified blends.

3. Experimental Investigation

The experimental work is carried out by taking two commercial wick and pump stove without modification. The table 1 & 2 shows the specification of wick and pump stove.

| Tank Size | 5L |
|-----------------|----|
| Number of wicks | 10 |
| Total Height | 240mm |
| Mantle height | 25mm |
| Diameter of Tank | 680mm |

| Tank Size | 5L |
|-----------------|----|
| Number of Burners | 1 |
| Total Height | 160mm |
| Mantle height | 25mm |

The fuel which is prepared is poured into the stove tank. After allowing the fuel rise the wick is held at optimal position, fire was started and the mantle was put in its place. In a steel vessel 1 litre water is poured and was heated by placing it on the stove. The time taken to rise the temperature by 20°C. The temperature of water is monitored. By measuring the quantity of fuel remaining in the stove tank with the original fuel taken the quantity of fuel consumed is determined. Experiments were performed by taking blends of cooking oil and kerosene in the same proportion as in the pump stove also. Number of pumping’s are done in order to build the pressure the fuel in the tank. The time allowed from starting of flame to beginning of heating process. Kerosene and neat cooking oil and kerosene and esterified cooking oil blends were used to conduct the experiments.
4. Results and discussions

In the operation of wick stove one of the important parameter for efficient working is capillary action. Higher capillary action is required for continuous replenishment of oil to the wick tip. The kerosene and esterified Cooking oil blend has higher capillary action compared to the kerosene and neat Cooking oil blend.

**Figure.3** Percentage increase in flash point w.r.t. kerosene

The percentage increase in the flash point with respect to kerosene for both kerosene – neat waste cooking oil and kerosene- esterified waste cooking oil blends is elaborated in Fig.3. It can be observed from the fig.3 that the flash point is increasing by increasing the blend percentages however the flash point for the esterified blends has shown lower values compared to neat blends. The reason behind increasing flash point is because of increasing content of cooking oil in blend which increases the viscosity and glycerol of the blend.

**Figure.4** Percentage increase in fire point w.r.t. kerosene

The variation of fire point for different blends is with respect to kerosene is as depicted in Fig.4. It can be observed from the fig that the fire point is increasing by increasing the blend percentages however the fire point for the esterified blends has shown lower values compared to neat blends. Increasing content of cooking
oil which increases the viscosity of the blend and thereby increasing the glycerol content is the reason for this increase of fire point[11].

**Figure. 5** Percentage increase in time consumed for wick stove w.r.t. kerosene

The time taken for heating water for 20° C for both the esterified and neat cooking oil blends in the wick stove is elaborated in Fig 5. From the fig we can observe at least 5-8% reduction of time taken for the esterified blends compared to the neat blends. It can be observed that with the increase in percentage composition of the blend the time taken to heat the water is increasing because as the composition of cooking oil in the blend increases its viscosity increases which in turn reduces the ability of fuel to rise through the wick.

**Figure. 6** Percentage increase in time consumed for pump stove w.r.t. kerosene

The time taken for heating water for 20° C for both the esterified and neat cooking oil blends in the pump stove is elaborated in Fig 6. From the fig we can observe at least 2-4% reduction of time taken for the esterified blends compared to the neat blends. It can be observed that with the increase in percentage composition of the blend the time taken to heat the water is increasing because as the composition of cooking oil in the blend increases its viscosity increases which in turn reduces the flow ability of the fuel in the stove.
Figure 7 Percentage reduction in efficiency and fuel consumption for wick stove

The variation of Fuel consumed and the Efficiency of the wick stove for both the esterified and neat cooking oil blends is depicted in Fig 7. It can be observed that fuel consumed is increasing with the increase in percentage composition however the esterified oil consumption is less compared to the neat oil and efficiency is slightly decreasing with the increase in percentage composition as the fuel consumed is increased however with the esterified oil efficiency reduced with respect to kerosene is less compared to the neat oil.

Figure 8 Percentage reduction in efficiency and fuel consumption for pump stove

The variation of Fuel consumed and the Efficiency of the pump stove for both the esterified and neat cooking oil blends is as observed in Fig 8. It can be observed that fuel consumed is increasing with the increase in percentage composition of blends. But, the esterified oil consumption is less compared to the neat oil. Efficiency is decreasing with the increase in percentage composition of blend as the fuel consumed is increased however, with the esterified oil efficiency is less compared to the neat oil.
The variation of emission of CO and CO₂ for different blends of esterified and neat cooking oil in wick stove is as shown in Fig. 9. It can be observed that the CO₂ emission is increasing with the raise in the composition of cooking oil in the blend and it is further increasing in case of esterified oil. In case of CO the curve is opposite with the increase in the cooking oil in the blend the emission of CO is decreasing and it is further decreasing in case of esterified oil. Since waste cooking oil is an oxygenated fuel provide more oxygen for complete combustion in turn reduce carbon monoxide. It was observed that the wick is completely burning out and forming ash at higher blends because of lower capillarity of the fuel at higher percentage of waste cooking oil may be one of the reasons for the increase in the emission of CO₂.

The variation of emission of CO and CO₂ for different blends of esterified and neat cooking oil in pump stove is observed in Fig. 10. From that it can be understood that CO₂ emission is increasing with the increase in the composition of cooking oil in the blend and it is further increasing in case of esterified oil. But, emission of CO is decreasing with the increase in the cooking oil in the blend the and it is further decreasing in case of esterified oil.

5. Conclusion

Comparing the performance of both the pump stove and wick stove using kerosene and cooking oil before
and after esterification it observed that the pump stove gave a better performance than the wick stove because the pump stove has pressurized fuel tank which allows more fuel for combustion but wick stove is based on the capillary action of fuel through the wick. The percentage of variation of Flash and Fire points has been reduced after esterification. Since waste cooking oil is an oxygenated fuel it provides more oxygen for complete combustion which in turn reduce carbon monoxide emission. This helps in reducing the CO emission which is a harmful gas. On observing the performance characteristics of both the stoves using the esterified cooking it can be recommended to use some additives in this blend to improve the performance of the stove.

6. References

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