Hindawi Publishing Corporation
Advances in Mechanical Engineering
Volume 2012, Article ID 190518, 5 pages
doi:10.1155/2012/190518

Research Article

Utilization of Bio-Oil for Cooking and Lighting

P. K. Halder,[1] M. U. H. Joardder,[2] M. R. A. Beg,[1] N. Paul,[1] and I. Ullah[3]

[1] *Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi 6204, Bangladesh*
[2] *Queensland University of Technology, Brisbane, QLD 4701, Australia*
[3] *Central Queensland University, Brisbane, QLD 4701, Australia*

Correspondence should be addressed to M. U. H. Joardder, muhjoardder@gmail.com

Received 7 April 2012; Accepted 18 June 2012

Academic Editor: Hyung Hee Cho

Among the available alternative sources of energy in Bangladesh bio-oil is recognized to be a promising alternative energy source. Bio-oil can be extracted by pyrolysis as well as expelling or solvent extraction method. In these days bio-oil is merely used in vehicles and power plants after some up gradation .However, it is not used for domestic purposes like cooking and lighting due to its high density and viscosity. This paper outlines the design of a gravity stove to use high dense and viscous bio-oil for cooking purpose. For this, *Pongamia pinnata* (karanj) oil extracted by solvent extraction method is used as fuel fed under gravity force. Efficiency of gravity stove with high dense and viscous bio-oil (karanj) is 11.81% which of kerosene stove is 17.80% also the discharge of karanj oil through gravity stove is sufficient for continuous burning. Thus, bio-oil can be effective replacement of kerosene for domestic purposes.

1. Introduction

The energy crisis is the main problem to mankind facing today as non-renewable energy like fossil fuels, oils and natural gases are often scarce due to rapid depletion of these resources. Although the actual reserve of this most important fossil fuel of Bangladesh has not yet been ascertained, a recent survey shows that there is as much as 195400000000 m^3 of proven probable natural gas reserves in the country [1]. At present the country has 2,041 million tons of coal reserve [2]. Total storage capacity of petroleum products (Diesel, kerosene, petrol, and octane) in the country is 687,500 tons which is only 8% of the total demand [3]. Economic development and civilization of any country depend on reliable energy supply. In Bangladesh poverty and lack of access to energy are closely linked. Energy in Bangladesh is indispensible for almost all economic activities, ranging from farm irrigation to the manufacture of goods by small and microenterprises. Energy is also indispensible for attaining the Millennium Development Goals (MDGs) for Bangladesh. Indigenous natural gas supply now is the principal fuel and accounts for about 86% of electricity generation. If natural gas is used for power generation at the present rate, this would result in complete depletion of existing reserves within 10–12 years. At present to meet total demand of energy, Bangladesh imports annually about 1.3 million metric tons of crude oil and 2.7 million metric tons (approx.) of refined petroleum products per annum is imported [4]. In order to meet the increasing energy demand for development of agriculture and industry and for the generation of better employment opportunities, it is necessary to harness all the available alternative sources of energy immediately. Thus, the interest in renewable energy has been revived over last few years, especially after global awareness regarding the ill effects of fossil fuel burning. Bio-oil is recognized to be a promising alternative energy source. Bio-oil can be produced from many different kinds of biomass, including agricultural residues, forest residues, and municipal waste. Some industrial byproducts are also suitable feedstock including paper sludge and distillers grain [5–7]. This Bio-oil can be produced through pyrolysis, expelling, or solvent extraction method. Pyrolysis is a form of treatment that chemically decomposes organic materials by heat in the absence of oxygen typically occurs under pressure and at operating temperatures above 430°C (800°F)

[5]. Pyrolysis processes can be categorized as slow pyrolysis or fast pyrolysis. Fast pyrolysis yields 60% bio-oil and takes seconds for complete most widely used. On the other hand, slow pyrolysis takes several hours to complete and results in biochar as the main product [6]. The efficiency and nature of the pyrolysis process are dependent on the particle size of feed stocks. Bio-oil derived from agricultural wastes has moderate gross calorific value ranging from 15–38 MJ/kg with some advantages in transportation, storage, combustion, retrofitting, and flexibility in production and marketing [7–10]. Expelling is a method for extracting oils from oil seeds by using expeller (Hand expeller, Electric expeller). Electric expeller is more effective than hand expeller for large-scale production. Solvent extraction is a promising method for extracting oils from oil seeds by using a solvent. Solvent is usually a liquid substance that will dissolve another substance such as hexane, petroleum distillates, xylol, alcohols, and ester. In solvent extraction method a solvent is used to separate out various components within a material sample. In solvent extraction, a solvent is introduced to a material and as some components are more soluble than others, the sample starts to separate out, allowing people to remove the separated components individually. The time required for extraction varies depending on the sample. Existing solvent extraction methods use large volumes of solvent (typically several hundred milliliters) and long extraction times (8–16 h) to remove the oil from the seeds [11]. Solvent extraction plants use hexane as a solvent to extract oil from oilseed cake. These plants are expensive and only suitable for large volumes which justify the capital cost of equipment. Where large amounts of oilseed cake are available, solvent extraction becomes a commercially viable option to extract the residual oil left in the cake and leave an almost oil-free powder known as oilseed meal. Both cake and meal are incorporated in animal feeds. Solvent extraction is effective in treating sediments, sludges, and soils containing primarily organic contaminants such as PCBs, VOCs, halogenated solvents, and petroleum wastes. Acid extraction uses hydrochloric acid to extract heavy metal contaminants from soils. Acid extraction is suitable to treat sediments, sludges, and soils contaminated by heavy metals. Bio-oil produced from solvent extraction method is highly dense and viscous liquid oil has the following properties. The density, viscosity, and higher calorific value (HCV) are 912–1250 kg/m^3, 25–1000 cp, 16–40 MJ/kg, respectively. Bio-oil has the application in vehicle and power plant sectors. It is potential to replace up to 60% of transportation fuels. In coal-fired power stations, bio-oil and charcoal can be cocombusted representing an 85% biomass-to-fuel energy efficiency. For natural-gas-fired power stations pure bio-oil can be cofired which results in a 70% biomass-to-fuel energy efficiency. In 2003, 15 tonnes of oil were successfully combusted in an existing 350 MWe power station (Harculo, the Netherlands). In the Netherlands, the engineering of a 50 ton/day bio-oil production plant is well under way [12]. About 3.9% of total households used kerosene for cooking and lighting where bio-oil can be used as effective replacement of kerosene.

2. Material

Normally, kerosene is used in stove for cooking purpose. In this work, *Pongamia pinnata* (karanj) oil is used in gravity stove for cooking as the replacement of kerosene. *Pongamia Pinnata* trees are normally planted along the highways, roads, and canals to stop soil erosion. *Pongamia pinnata* is called as Koroch in Bangladesh. *Pongamia pinnata* is a medium-sized evergreen tree of 15–25 m height. In Bangladesh, karanj oil is used as medicine and not cultivated commercially. In India, billions of karanj trees exist where karanj trees are cultivated commercially. The recommended spacing for *Pongamia pinnata* plantation is 5 × 4 m and 80–100 plants per hector in India. Amount of seeds found from each tree is 10–90 kgs, which contains 30–40% oil. *Pongamia pinnata* trees reach adult height in 4 or 5 years. Seed collection season in India is from December to April. One person can collect 180 kgs of seeds in 8 hours of a day. Seed collection cost is Rs. 4 per kg [13, 14].

3. Production of Bio-Oil

The Karanj seeds were collected from Bangladesh Council of Scientific & Industrial Research (BCSIR), Rajshahi, Bangladesh. Solvent extraction method is used for oil extraction where, hexen (C_6H_6) is used as solvent. The seeds were grinded into fine particles and 200 gms of the grinded seeds were taken and a thimble was made from thick filter paper. 400 ml of hexane was added to thimble from above. The Soxhlet extractor apparatus was used for oil extraction as shown in Figure 1. The thimble was placed into the main chamber of the Soxhlet extractor. The Soxhlet extractor was placed onto a flask containing the extraction solvent and equipped with a condenser. The solvent was then heated to reflux. The solvent vapour travels up a distillation arm and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapour cools and drips back down into the chamber housing the solid material. The chamber was slowly filled with warm solvent which extracts oil. When Soxhlet chamber was almost full, the chamber was automatically emptied by a siphon side arm, with the solvent running back down to the distillation flask. This cycle was allowed to repeat several times within 8 hrs of extraction. After many cycles the desired compound was concentrated in the distillation flask. After extraction the solvent was removed, typically by means of a rotary evaporator at 40–50°C, yielding the extracted oil as shown in Figure 1. The nonsoluble portion solid remains in the thimble.

Though, small scale production of oil by solvent extraction method is costly; however, this method is used due to lack of expeller. The density, viscosity, and higher calorific value (HCV) of sample karanj oil were 912 kg/m^3 at 30°C, 29.65 cSt at 30°C and 40.756 MJ/kg, respectively.

4. Experimental Setup

The gravity stove in this work refers to that type of stove in which fuel tank is separated from stove and the fuel is fed under gravity force. The purpose of this type stove is to burn

(a) (b)

FIGURE 1: Soxhlet extractor and rotary evaporator.

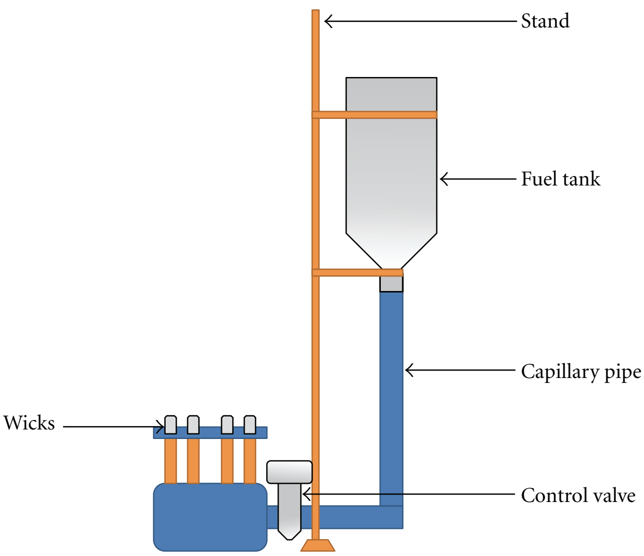

FIGURE 2: Schematic diagram of gravity stove.

high dense and viscous fuel (Bio-oil). The setup consists of a conventional burner set along with well-heighted fuel tank arrangement as shown in Figure 2. The burner set consists of 10 cylindrical wicks made of cotton. The wicks consume fuel by capillary action. In gravity stove high dense and viscous fuel is fed under gravity force which accelerates the capillary action. The tin made fuel burner having another fuel tank works as diffuser. The main fuel tank situated on a certain height is made of transparent pipe for proper observation of fuel consumption. This main fuel tank is attached to the burner with capillary pipe. As for the fluid property to smooth flow it is obligatory to place the main fuel tank at least at height of upper wick. Consequently, this height produces required force to overcome the resistance of encountered by fuel during flow through wicks as well as lift it. To fulfill the purpose of fuel flow control a control valve is placed at the junction of capillary pipe and burner tank. This gravity stove was then investigated for numerous observations to determine its efficiency and effectiveness in comparison with conventional stove.

5. Result and Discussion

The performance parameter of the gravity stove is its efficiency, heating capacity, and discharge. The efficiency of the gravity stove means the percentage of heat that can be utilized for heating. The efficiency can be measured by heating up some known quantity of water to a certain temperature by burning some known quantity of fuel whose calorific value is known

$$\therefore \text{ Efficiency } = \frac{\left[m_w \times S \times \left(t_f - t_i\right)\right]}{m_f \times \text{CV}}, \qquad (1)$$

where m_f = mass of fuel burnt (kg), CV = calorific value of fuel (kJ/kg), m_w = weight of water initially taken in container (kg), t_f = final temperature of water (°C), t_i = initial temperature of water (°C), S = specific heat of water (kJ/kg°C).

Discharge is the amount of fuel consumed by the stove per unit time

$$\therefore \text{ Discharge } = \frac{m_{f1}}{t} \text{ (ml/s)}, \qquad (2)$$

where m_{f1} = volume of fuel burnt (ml), t = time required to burn the fuel(s).

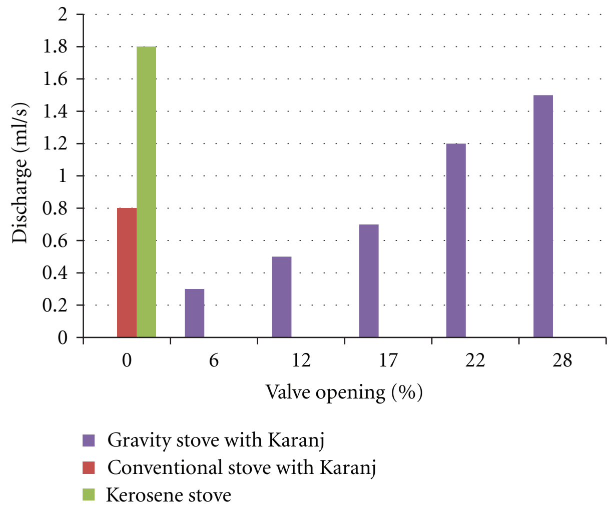

FIGURE 3: Discharge through kerosene and gravity stove.

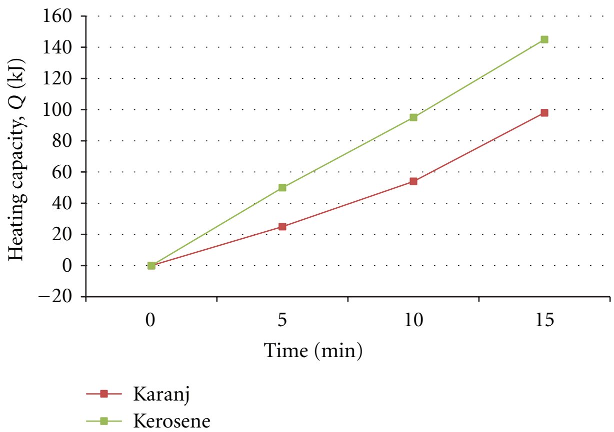

FIGURE 4: Heating rate of kerosene and karanj.

Heating capacity of fuel is the total amount of heat utilized by the stove to a certain time period.

$$\therefore \text{ Heating capacity} = m_w \times S \times \left(t_f - t_i\right) \text{ (kJ)}. \quad (3)$$

5.1. Flow Characteristics through Gravity Stove. Discharge of a stove is a parameter that indicates the effectiveness. The discharge of karanj fuel through conventional stove is very low due to its high density and viscosity. The gravity stove is investigated for numerous observations of discharge for several valve openings.

Figure 3 indicates that biofuel (Karanj) flow rate in conventional stove is not sufficient for continuous burning. An optimum discharge is obtained at 25% valve opening competitive to the discharge of kerosene stove. However, above 25% valve opening the discharge is so high that it overflows and hence not shown in Figure 3.

5.2. Heating Performance of Bio-Oil. The prime objective of this work is to test the feasibility of biofuel in heating purpose as the performance of the stove largely depends on the heating performance of fuel. For this purpose same weighted amount of water is heated in gravity stove up to a certain temperature in case of kerosene and karanj oil. The heating capacity of kerosene and karanj is calculated to plot against time.

Figure 4 indicates that the heating rate of kerosene is higher than biofuel (karanj) due to its higher heating value. Thus, the efficiency of stove with kerosene is high. Considerably good efficiency is obtained with karanj fuel competitive to kerosene. Thus biofuel (karanj) can be an effective replacement of kerosene for domestic purposes.

6. Conclusion

A gravity stove is designed to use high dense and viscous biofuel. The discharge of karanj oil through gravity stove is 1.43 ml/s competitive to the discharge of kerosene stove as 1.8 ml/s for continuous burning. The efficiency of gravity stove with karanj is 11.81% but in conventional stove is 5.65%. The efficiency of the gravity stove with karanj is 11.81/5.65 = 2.09 times as compared to conventional stove. The efficiency of gravity stove with karanj is 11.81% competitive to kerosene stove as 17.80%. Further investigation can be conducted to design more fuel efficient stove.

References

[1] "Titas Gas Transmission and Distribution Company," 2011, http://www.titasgas.org.bd/annualreport.htm.

[2] "Barapukuria Coal Mining Company Limited (BCMCL)," Bangladesh, 2011, http://www.bcmcl.org.bd/.

[3] "Bangladesh Petroleum Corporation (BPC)," 2011, http://www.mof.gov.bd/.

[4] ADB Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement (PREGA) Operating Procedures, "Country Study Report of Bangladesh," Asian Development Bank, p. 73, 2003.

[5] D. Mohan, C. U. Pittman, and P. H. Steele, "Pyrolysis of wood/biomass for bio-oil: a critical review," *Energy & Fuels*, vol. 20, no. 3, pp. 848–889, 2006.

[6] J. A. Caballero, R. Front, A. Marcilla, and J. A. Conesa, "Characterization of sewage sludges by primary and secondary pyrolysis," *Journal of Analytical and Applied Pyrolysis*, vol. 40-41, pp. 433–450, 1997.

[7] M. Asadullah, M. A. Rahman, M. M. Ali et al., "Production of bio-oil from fixed bed pyrolysis of bagasse," *Fuel*, vol. 86, no. 16, pp. 2514–2520, 2007.

[8] F. Ateş, E. Pütün, and A. E. Pütün, "Fast pyrolysis of sesame stalk: yields and structural analysis of bio-oil," *Journal of Analytical and Applied Pyrolysis*, vol. 71, no. 2, pp. 779–790, 2004.

[9] A. E. Pütün, A. Özean, and E. Pütün, "Pyrolysis of hazelnut shells in a fixed-bed tubular reactor: yields and structural analysis of bio-oil," *Journal of Analytical and Applied Pyrolysis*, vol. 52, no. 1, pp. 33–49, 1999.

[10] M. F. Parihar, M. Kamil, H. B. Goyal, A. K. Gupta, and A. K. Bhatnagar, "An experimental study on pyrolysis of biomass," *Process Safety and Environmental Protection*, vol. 85, no. 5, pp. 458–465, 2007.

[11] http://www.wisegeek.com/what-is-solvent-extraction.htm.
[12] http://www.btgworld.com/uploads/documents/BTG%20Paper%20Harculo.pdf.
[13] *Journal of the American Oil Chemists' Society*, vol. 23, no. 11, Springer Link, 1946.
[14] http://www.svlele.com/karanj.htm.