Chapter 1

Introduction

1.1 General

Energy is an essential input to agricultural production, industrial growth, transportation and domestic development. Energy consumption and development of a country are interrelated. The sustenance of modern economy is highly energy intensive and needs a long standing availability of energy from reasonable, reachable and environmental friendly sources. India ranks sixth in the world in total energy consumption, accounting for about 3.5% of the world commercial energy demand (Ghose and Paul, 2007). It is becoming more and more dependent on fossil fuels such as coal, oil and natural gas to meet its ever increasing energy demand. Crude oil is the second highly consumed primary commercial energy source which shared 33.22% of the total commercial energy as compared to 53.54% and 9.34% from coal and natural gas, respectively in the year 2007–08 (Anon., 2010a). In India, the consumption of crude oil was 148.5 million metric tons in the year 2009–2010 and 70–80% of this consumption was met by import (Borah, 2010). The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources and is also largely responsible for energy supply shortages.

Consumption of high speed diesel (HSD) is mainly influenced by transport, agriculture, industry, and power generating units. Total HSD consumption during the year 2009–10 was 56.24 million metric tons (Anon., 2010b), which was about 36% of the fossil fuel consumption. The demand for HSD has been estimated to be 66.9 million metric tons for the year 2011–12. Further, energy consumption is increasing at the rate of 6.5% per annum while reserves for petroleum oil are decreasing day by day (Jain and Sharma, 2010). The continuous use of fossil fuels not only increases the burden on the oil import bills, but also it greatly enhances the environmental pollutions. Beside these facts, these sources are exhaustible in nature and cannot be restored due to their much faster exploitation. Due to the ever increasing demand for fossil fuels, uncertainty in their availability along with growing emissions due to their combustion generated pollutants, it is important on the part of researchers and energy planners to search for renewable and non-polluting alternative energy sources.

Renewable energy generated from solar radiation, wind, hydropower and biomass are becoming widely popular because these are thought to be inexhaustible and environmentally benign sources of power. These sources are abundant in India and many of these resources have a great potential to exploit.

A number of feasible technologies have been developed, tested and perfected to harness the energy from solar radiation, wind movement, biomass etc., and have been successfully implemented. Biogas, producer gas and vegetable oils are found to be reliable and alternative sources for HSD. Among these, biogas and producer gas have low energy content per unit mass and their gaseous nature creates problems for their storage. But vegetable oils are strongly advocated because of certain advantages offered by them. Firstly, the ratio of fuel yield to energy input for vegetable oils is the highest. Secondly, vegetable oil crops can be grown on marginal lands, their processing is simple and it can be easily done in rural areas. Further, these vegetable oils have the potential to make the farming communities self-sufficient with regard to the fuel requirement for running the day-to-day farm activities.

Several systematic efforts have been made by the researchers to use vegetable oils as fuel in compression ignition (CI) engines (Takeda, 1982; Masjuki and Sohif, 1991; Peterson *et al.*, 1993; Nag and Bhattacharya, 1995; Piyaporn *et al.*, 1996). Though vegetable oils, in general, have acceptable cetane number and calorific value, operation of CI engines with these oils is associated with some problems such as troubles in pumping, combustion and atomization with the injection system of the CI engines, gum formation, injector deposits, ring sticking as well as incompatibility with conventional lubricating oils (Pryde, 1983; Ziejewski and Kaufman, 1983; Ryan *et al.*, 1984; Korus *et al.*, 1985; Rewolinski and Shaffer, 1985). These problems are mainly due to the higher viscosity of vegetable oils (Roger and Jaiduk, 1985; Sinha and Misra, 1997; Agrawal, 1998; Demirbas and Demirbas, 2007). The higher viscosity is due to the large molecular mass and chemical structure of vegetable oils and it can be reduced through many processes such as preheating of oil, blending or dilution with other fuels, transesterification and thermal cracking or pyrolysis.

Out of these processes, transesterification is popularly followed to produce oil with fuel properties similar to those of diesel. The major product after transesterification of vegetable oils is called biodiesel. It is generally a mixture of mono alkali esters of fatty acids. Biodiesel can be produced from both edible and non-edible oils as well as animal fats. However, in India, the non-edible oils will be the major source of feedstock for biodiesel production as our country is not self sufficient in edible oil production. In recent years biodiesel obtained from oils of *Jatropha curcas* (Tiwari *et al.*, 2007; Rao *et al.*, 2008), *Pongamia pinnata* (Raheman and Phadatare, 2004; Rao *et al.*, 2008), *Madhuca indica* (Puhan *et al.*, 2005a & 2005b; Ghadge and Raheman, 2006), *Azadirachta indica* (Rao *et al.*, 2008) etc. have been successfully proven as potential feedstocks under India conditions. The performance of engine when operated with biodiesel and its blend with HSD was reported to be at par with that when it is operated with HSD and there was reduction in harmful exhaust emissions as well (Ali *et al.*, 1995a, 1995b & 1995c; Schumacher et el., 1996; Clark and Lyons, 1999; Monyem and Gerpen 2001; Schumacher *et al.*, 2001; Canacki and Gerpen 2003; Raheman and Phadatare, 2004; Usta, 2005; Rakopoulos *et al.*, 2006; Ghadge 2006; Kumar, 2009). Beside these studies, carbon deposits on the engine components and wear metal addition in lubricating oil were reported to be less when operated with biodiesel and their blends as compared to HSD (Masjuki *et al.*, 1993; Schumacher *et al.*, 1995; Agarwal *et al.*, 2003; Kalam and Masjuki, 2005; Schumacher *et al.*, 2005a & 2005b; Ramaprabhu *et al.*, 2008; Jadhav, 2009). Considering the positive effects on using biodiesel, Government of India has formulated a biofuel policy for production and commercialization of biodiesel. According to this policy, it is expected to use 5% blend of biodiesel with HSD fuel by the end of 2011–12, which will be raised to 10% by 2016–17 (Neogi, 2007). To meet this policy, ultimately the requirement of biodiesel will increase from 3.35 million metric tons in 2011–12 to 8.35 million metric tons in 2016–17 (Malik, 2007). Hence, to meet this huge requirement, only jatropha (*Jatropha curcas*) or mahua (*Madhuca indica*) oil will not be sufficient. More and more feedstocks or mixtures of feedstocks need to be explored.

The availability of vegetable oil has to be sufficient enough to support the current rate of demand. The vegetable oils which have received prominent attention for biodiesel production in India are region specific. Therefore, it is not possible to have sufficient amount of particular oil at one place to produce biodiesel to cope with the steady increasing demand for HSD fuel. Further, production cost of biodiesel has been found to be dependent on type of oil, particularly its free fatty acid (FFA) content. Cost of production of biodiesel can be reduced, if oils from less important feedstocks with lower FFAs, used frying oils, acid oils or their mixtures are tried.

A few studies were carried out on production of biodiesel from the mixture of virgin oils either with fried vegetable oils or animal fats in order to improve their fuel properties. It was reported that a minimum ratio of virgin to animal fat or fried vegetable oil is necessary to produce good quality biodiesel (Meneghetti *et al.*, 2007; Dias *et al.*, 2008; Issariyakul *et al.*, 2008; Barbosa *et al.*, 2010). Further, most of the oils studied were of edible type and not suitable to be used as a source for biodiesel production in India. The growing concern on producing biodiesel from mixture of oils in order to modify the fuel properties to fulfill the feedstock demand for biodiesel production, and unavailability of much literature on the engine performance when run with biodiesel obtained from mixture of oils are the main reasons for carrying out the present investigation on mixture of Mahua oil with higher FFAs and Simarouba (*Simarouba glauca*) oil with lower FFAs.

Mahua oil, which is obtained from the seeds of *Madhuca indica* tree, commonly found in deciduous forests. Its seed contains about 35–40% oil. Each tree yields about 20–40 kg of seed per year and the total oil yield per ha is 2–4 metric tons per ha per year. This tree has an estimated annual oil production potential of 0.181 million metric tons in India (Ghasias, 2006). Simarouba oil, which is obtained from the seeds of *Simarouba glauca* tree, is commonly known as paradise tree. It is a multipurpose tree capable of growing on the degraded soils and can be adapted to a wide range of temperatures (10–45°C) and altitudes up to 1000 m above sea level. Its seeds contain 50–65% oil that can be extracted by conventional methods. Each well grown tree yields 15–30 kg nutlets per year equivalent to 2.5–5 kg oil. This amounts to 1–2 metric tons oil per ha per year and about the same quantity of oil cake (Kaul *et al.*, 2003).

Considering the oil contents of seeds and availability potential of simarouba and mahua oils, the present investigations on biodiesel production from their mixture; engine performance; emissions with this biodiesel and its blends with HSD were undertaken with the following specific objectives:

1.2 Objectives

1. To select a suitable mixture of mahua and simarouba oils and to produce biodiesel from this mixture of oils.
2. To determine the fuel properties of biodiesel obtained from the selected mixture of mahua and simarouba oils.
3. To evaluate the performance and exhaust emissions of diesel engine fueled with biodiesel obtained from selected mixture of oils and its blend with HSD.
4. To investigate carbon deposits on in-cylinder engine components and wear metal addition in lubricating oil of engine when operated with selected blend of biodiesel and HSD.