Renewable and Sustainable Energy Reviews 52 (2015) 201–208

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Development and experimental investigation of a biodiesel from a nonedible woody plant: The *Neem*

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ARTICLE INFO

Article history:
Received 17 March 2014
Received in revised form
30 June 2014
Accepted 8 July 2015
Available online 11 August 2015

Keywords:
Biodiesel
Esterification
Neem Methyl Ester
LCV
Performance
Emission characteristic
NME

ABSTRACT

The escalation of oil prices is irremediably accompanied by the rise of the prices of products of broad consummation and commodities. This results in a dramatic impoverishment of the neediest populations. This situation makes renewable energies like biodiesel a very attractive alternative to overcome the lack of fossil energy, because they respect the notion of sustainability and because of their ease of extraction. Because of its slight impact on food safety, Neem can be regarded as an adequate raw material to produce esters via an esterification process. The goal of this study is to extract oil from Neem fruits and to esterify it in order to obtain a biofuel. Then, the obtained product is tested within Direct Injection DI diesel conditions. The Neem Methyl Ester (NME) produced in the laboratory is then characterized according to different standards. It turns out that its chemical and physical characteristics, are close to that of classical esters of vegetable oils with acceptable lowest values. The output of the oil extraction is estimated at 27.5% and the Low Calorific Value (LCV) found is estimated to be 38.7 MJ/kg. The measure of opacity shows that chloride and potassium account respectively for 61.00 and 2.19 mol^{-1} (thresholds values: 74.00 per mol). The principal pollutants such as CO, CO_2 and unburned hydrocarbons are found to be at the lowest acceptable values. The biofuel elaborated has been tested thanks to a single cylinder (DI) diesel engine under the same burning conditions than those of petroleum based fuels. It has been observed that the performances of NME are acceptable compared to diesel fuel. The highest level of CO found for NME engine combustion mode is 698 mg/kg which is 18.83% less than mineral diesel. The Neem's NO_x emission is 5.64% higher than that of diesel fuel at the same load condition.

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http://dx.doi.org/10.1016/j.rser.2015.07.027
1364-0321/

1. Introduction

The use of fossil fuels as combustible has showed their predisposition as energy source in reason of their calorific energy supplied. The combustion of these fuels in all their forms releases toxic gases at dangerous concentration levels for humans and this despite the restrictive requirements in term of emission rates of substances known to be unsafe for the ecosystem when released [1]. The substances released by the combustion of these types of fuels are responsible for the climatic warming of the planet in reason of the well known greenhouse effect. In the coming years this will have a dramatic impact on the equilibrium of the ecosystem of the planet. This is the reason why most of the researches are focused on alternative energies sources combining development and durability like biofuel. Some raw materials used for biofuel are edible foods, their intensive exploitation to produce fuel generate famine and leads hungry populations to riot because of the lack of foods [1,2,6,7]. This is the reason why non-edible raw materials such as Jatropha [3], algae are increasingly used [3,5]. Several studies showed the use of vegetable oils as fuel, in their state or modified [17–20]. High viscosity as well as weak volatilization capacity of raw vegetable oils affects atomization as well as spraying during injection [3,6,10]. This predisposition affects the quality of combustion causing a carbon deposit as well as the filling of the mobile components of the engine.

Cross esterification, among all the processes used to reduce the viscosity of raw vegetable, presents the best result from an economical and an environmental point of view [4,11]. The process of esterification integrates chemical reactions and an external contribution of heat [12].

The aim of this research is to work out and characterize a biofuel that can be used as fuel in the motorization by using a local non-edible plant: Neem fruits. Neem is a non-edible oilseeds fruit scientifically known as *Azadirachta indica*, or *Neem tree*, generic name used through the world. Present in Africa, Neem tree seems to be a non-edible raw material used to obtain vegetable Methyl Ester oil (VME) by an esterification process. The Neem Methyl Ester of NME *as another biodiesel* can be used like alternative to petro-diesel in motorizations [3,9,10].

In this work, the methyl ester of Neem biodiesel and diesel were investigated in the same conditions for their performances and compared. A single cylinder diesel engine was used to study performances and exhaust emission of diesel engine fuel. Performance parameter like brake thermal efficiency, specific fuel consumption, brakes power was determined. Exhaust emission like smoke, CO_2, NO_x and CO have been evaluated. For comparison purposes experiments were carried out on 100% esterified Neem and diesel fuel.

2. Experimental setup

2.1. Description of the vegetable material

Known as *Azadirachta indica*, *Neem tree* or *Neem* (English generic name used throughout the world), belongs to "*méliacées: fr*" family of plant from which the name *Melia azedarach* is derived. Neem is a tree which can reach 30 m and live 2 centuries, it is in general smaller (5–10 m), its persistent foliage is imparipenne (5–8 pairs of sickle-shaped leaflets with very unequal base), its panicles-shaped flowers are white or yellowish [8]. Its fruits are a drupe of 1–2 cm, which turn yellow when it is mature. It is a plant of tropical origin precisely in the South of the Himalayas in India but the climatic conditions of the Mediterranean are appropriate for it also. Neem grows very well in the tropical and subtropical areas even in severe dry season (semi-arid and semi-wet climate). It can cope with climates lower than 500 mm of rains because it possesses a system of very deep roots but it does not support long lasting cold. It is widespread in India and in the south east of Asia. Also, it was introduced in Australia, western India and the tropical America [8,9]. In the northern part of the USA and Europe one was able to acclimatize frost resistant species from northern India. Present in Africa, the Neem has different names in the west as well as in the center of the continent: *Dému tubab* in *Wolof a* language spoken in Senegal; *Ngu Nimma in Massa,* a language spoken by the natives of Yagoua in Mayo Danaï (far North Cameroon).

Neem plant can do well with stony soil as well as sandy ones. This is the reason why it is wide spread in the northern part of Cameroun. The current number of Neem plant of the northern Cameroon can be estimated at 25–30 millions. They have been obtained during the "green Sahel" campaign since 1972. Neem is very widespread in northern Cameroon; many plants are also found in the littoral region [9]. The vegetable material is made of Neem oil from fruit represented in Fig. 1.

2.2. Experimental procedure

1. The Neem Methyl Ester production procedure
   The Neem oil has been made by processing almond powder. Once the oil is obtained, the biodiesel used in this study is produced. The esterification of raw Neem oil with methanol (CH_3OH) catalyzed by potassium hydroxide (KOH) is then carried out. A titration was performing to determine the amount of KOH needed to neutralize the free fatty acids in raw Neem oil. The amount of KOH was added for every 200 g of raw Neem oil was determined as 2 g. For trans-esterification, 43 g (CH_3OH) plus the required amount of KOH were added for every 200 g of raw Neem oil and the reaction were carried out at 60 °C (Fig. 2). The water wash process was performed by using a sprinkler which slowly sprinkled water into the biodiesel container until there was an equal amount of water and biodiesel in the container. The water biodiesel mixture was then agitated gently for 25 min, allowing the water to settle out of the biodiesel. The water was drained out after the mixture had settled. Fig. 3 shows the production procedure of NME [3].
2. Mechanism of trans-esterification reaction
   Mass of NME estimation after transesterification process
   Oleic acid (50.4%); Palmitic acid (18.1%);Stearic acid (14.2%); Linoleic acid); Arachidonic acid (1.4%); Linolineic acid (0.5%); palmitoleic acid (0.2%);
   Mass of Neem fatty acid: 200 g; mass of NME: 200 g.

2.3. Characterization method of the Neem Methyl Ester (NME)

The first time NME obtained has been tested in laboratory conditions (HYDRAC, analysis laboratory of hydrocarbons in Cameroon), in order to characterize its physicals properties and its components. The second time, it has been tested by means of a DI diesel engine.