Journal of Petroleum Technology and Alternative Fuels Vol. 4(1), pp. 1-6, January 2013
Available online at http://www.academicjournals.org/JPTAF
DOI:10.5897/JPTAF12.022

Review

Evaluation of different algal species for the higher production of biodiesel

Gulab Chand Shah*, Mahavir Yadav and Archana Tiwari

School of Biotechnology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, Madhya Pradesh (University of Technology of Madhya Pradesh), Airport Bypass Road, Gandhi Nagar, Bhopal-462 033, India.

Accepted 18 December, 2012

Algae are a potential resource for biodiesel production. *Scandasmus algae* displayed faster growth at a wide temperature range of 4 to 32°C compared to *Chlorella vulgaris*. As the Conventional fuels are depleting day by day, there is a need to find out an alternative fuels to fulfill the energy demand of the world. Biofuels is one of the best available resources that have come to the forefront recently. In this paper, a detailed review has been conducted to highlight different related aspects to biodiesel industry. These aspects include: biodiesel feedstocks, extraction and production methods, properties and qualities of biodiesel, problems and potential solutions of using vegetable oil, advantages and disadvantages of biodiesel, the economical viability and finally the future of biodiesel. The literature reviewed is selective and critical. Based on the overview presented, it is clear that the search for beneficial biodiesel sources should focus on feedstocks that do not compete with food crops, do not lead to land-clearing and provide greenhouse-gas reductions. These feedstocks include non-edible oils such as *Jatropha curcas* and *Calophyllum inophyllum*, and more recently microalgae and genetically engineered plants such as poplar and switchgrass have emerged to be very promising feedstocks for biodiesel production.

Key words: Biodiesel feedstock, extraction, production, properties and qualities, problems.

INTRODUCTION

Renewable energy plays a critical role in addressing issues of energy security and climate change at global and national scales. In the US, the Federal Government passed the energy independence and security act (EISA) in 2007 which requires a gradual increase in the production of renewable fuels to reach 36 billion gallons per year by 2022. Furthermore, 28 States have passed their own mandatory renewable energy legislation (Energy Information Administration (EIA), (2009). Energy has become a crucial factor for humanity to continue the economic growth and maintain high standard of living especially after the inauguration of the industrial revolution in the late 18th and early 19th century. According to the International Energy Agency (IEA) report (International Energy Agency (IEA) (2007) and Shahid and Jamal (2011), the world will need 50% more energy in 2030 than today, of which 45% will be accounted for by China and India.

The development of biofuels as an substitute fuel to supplement or replace conventional diesel is receiving great attention among researchers and policy makers for its numerous advantages such as renewability, biodegradability and lower gaseous emission profile. Also, concerns over increasing energy demand, continuous global warming effects, declining petroleum reserves, petroleum price hike and scarcities have raised the need to search for alternative renewable fuels (Sahoo et al., 2007; Basha et al., 2009; Refaat, 2010; Demirbas, 2009; Yang et al., 2012). The annual rate of the global

*Corresponding author. E-mail: gulab777@gmail.com. Tel: 0755- 2678803. Fax: 0755- 2742002-3.

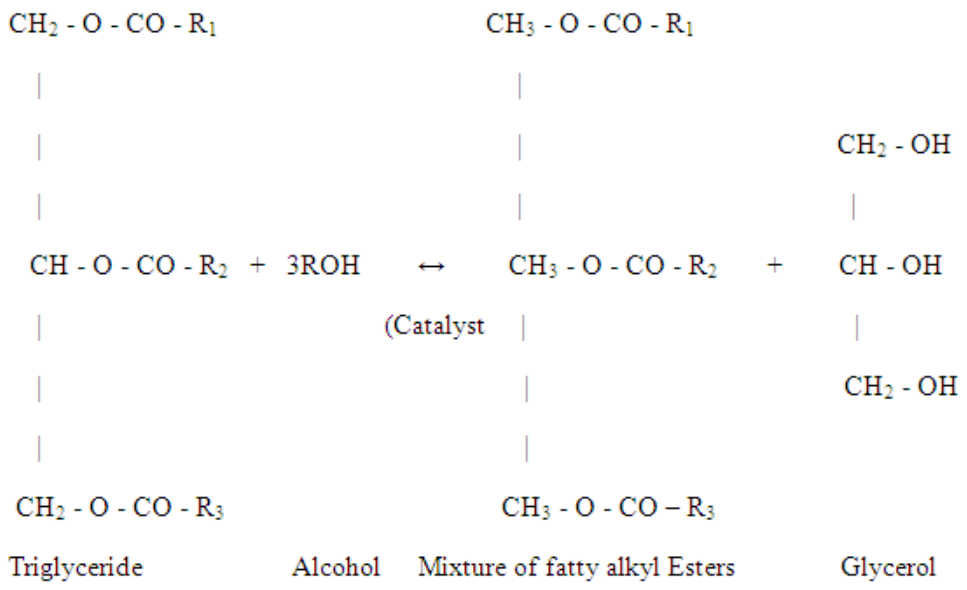

Figure 1. Transesterification of triglycerides to alkyl esters (biodiesel).

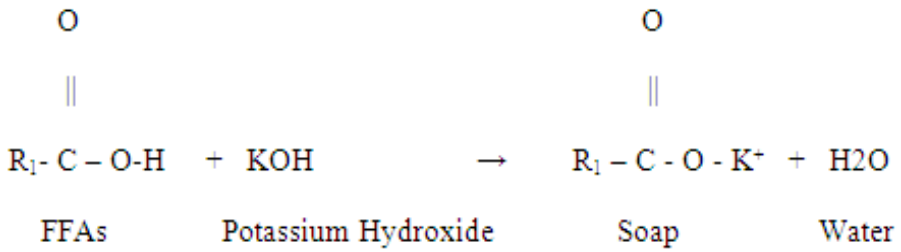

Figure 2. Formation of saponified product (soap).

primary power demand is estimated to increase to a value of 1.7% and reach a value of 16,487 from 2002 to 2030 (Pandey et al., 2012).

Thus, use of renewable power is expected to get better the energy availability. Besides, renewable force is one of the most efficient routes to achieve sustainable development (Demirbas, 2009; Demirbas, 2011; Ramadhas et al., 2004; Saeid et al., 2008; Antolin et al., 2002; Bari et al., 2002; Demirbas, 2009; Kapilan et al., 2009). Transesterification is the reaction of triglycerides to fatty acid alkyl esters (FAAE) and low molecular weight alcohols such as methanol and ethanol in the presence of catalyst (Demirbas, 2011; Sharma and Singh, 2009; Demirbas et al., 2009) as shown in Figure 1. Methanol is the most favored alcohol because it is less costly and easily obtainable (Leung et al., 2010). The formed FFAs favor the formation of soap as shown in Figure 2. Saponification reaction is usually referred to as a side reaction that occurred during transesterification of fats and oils to biodiesel escalating soaps formation (Haas, 2005; Zadra, 2006).

Soap formation increases loss of methyl ester to glycerol phase, resulting to high purification costs and less biodiesel yield (Zadra, 2006). For this reason, processing low quality feedstocks containing considerable amount of water and FFAs using alkali catalyzed route requires the feedstocks to undergo pretreatment via esterification reaction using acid catalyst (H_2SO_4) as shown in Figure 3. The product (refined feedstocks) obtained with less FFAs content (≤3 wt.%) and water content (<0.06 wt.%) is then used for alkali-catalyzed transesterification to produce biodiesel (Velasquez-Orta et al., 2012).

RAW MATERIALS FOR BIODIESEL PRODUCTION

Animal fats and vegetable oils are the main raw materials usually employed to produce biofuels. Also, oils from algae have shown some promise as raw materials for biofuels production. Fats and oils are primarily water-insoluble, hydrophobic substances in the plant and

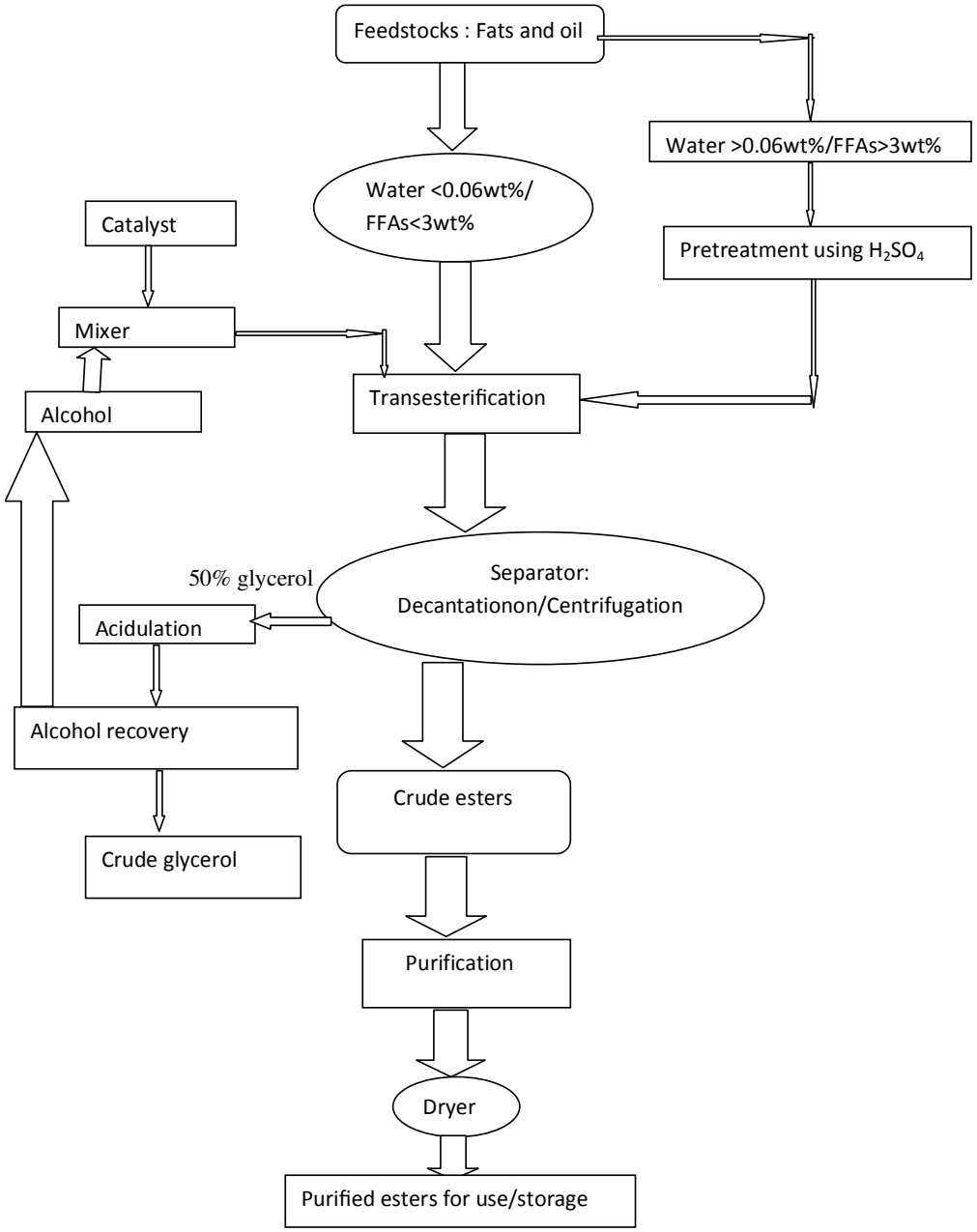

Figure 3. Schematic diagram of alkali-catalyzed transesterification for alkyl esters production.

animal kingdoms that are made up of one molecule of glycerol and three molecules of fatty acids are commonly referred to as triglycerides (Agarwal, 2007). Transesterification of triglycerides for biofuels production has been extensively studied in recent years. The raw materials being exploited commercially by the Constitute, the edible oils derived from rapeseed, soybean, palm, sunflower, coconut, and linseed (Mohibbe Azam et al. (2005). The use of refined raw materials could yield high-purity and quality biofuels with physicochemical properties comparable to diesel fuels. The major economic factor to be considered as input costs for biodiesel production is the cost of feedstocks (Demirbas, 2010).

Algae are classified into four categories: diatoms, green algae, blue-green algae and golden algae. Microalgae are microscopic photosynthetic organisms that are found in both marine and freshwater environments (Demirbas, 2010). Oleaginous microorganisms like microalgae, bacillus, fungi and yeast are all available for biodiesel production (Meng et al., 2009). Microalgae have been recommended as good sources for biofuels production

because of their advantages of superior photosynthetic efficiency, higher biomass production and faster growth rates compared to other energy yielding crops (Miao and Wu, 2006).

FACTOR EFFECTING ETHYL ESTER YIELD

Most of the points discussed here in after concern homogeneous alkaline catalysis unless specified otherwise. According to many studies focusing on the influence of reaction parameters on the ethanolysis, the main independent variables that affect ethyl ester production are (Cernoch et al., 2010):

i. The ethanol: vegetable oil molar ratio, MR,
ii. The reaction temperature, T,
iii. The amount of catalyst (weight ratio of catalyst to vegetable oil wt%), C,
iv. The purity of reactants (free fatty acid and water contents).

FEEDSTOCK'S FOR BIODIESEL

Since last few years many biodiesel production plants have been identified in India. These plants are operational as per the availability of feedstock, price of crude vegetable oils. The common feedstock for the production of biodiesel in India is palm oil, which is being imported from Malaysia and Indonesia. As palm oil is being used for edible purposes, the price of the crude palm oil fluctuates in the international market. Even though the consumption of edible oils in some countries like India is high, the availability of used cooking oil is very small. Hence, focus needs to be shifted to non-edible oilseed plants available in India and the details of such potential oilseed plant. Among these non-traditional oilseeds plants huge scope exists for the oilseeds such as *Pongamia piñnata* and *Jatropha cardus* as biodiesel feedstock. The oil from algal biomass has also attracted the attention as the future feedstock for biodiesel (Zadra, 2006).

OIL EXTRACTION METHODS

There are three main methods that have been identified for extraction of the oil: (i) Mechanical extraction, (ii) solvent extraction and (iii) enzymatic extraction. Before the oil extraction takes place, seeds have to be dried. Seed can be either dried in the oven (105°C) or sun dried. Mechanical expellers or presses can be fed with either whole seeds or kernels or a mix of both, but common practice is to use whole seeds. However, for chemical extraction only kernels are used as feed (Achten et al., 2008).

BIODIESEL PRODUCTION TECHNOLOGIES

Globally, there are many efforts to develop and improve vegetable oil properties in order to approximate the properties of diesel fuels. It has been remarked that high viscosity, low volatility and polyunsaturated characters are the mostly associated problems with crude vegetable oils. These problems can be overcome by pyrolysis, dilution with hydrocarbons blending, microemulsion, and transesterification (Canakci and Sanli, 2010; Pandey, 2008; Demirbas and Demirbas, 2007; Chauhan et al., 2010).

PROPERTIES AND QUALITIES OF BIOFUELS

Since biofuels are produced from quite differently scaled plants of varying origins and qualities, it is necessary to install a standardization of fuel quality to guarantee an engine performance without any dificulties (Pinto et al., 2005). Austria was the first country in the world to define and approve the standards for rapeseed oil methyl esters as a biofuels. The guidelines for standards and the quality of biodiesel have also been defined in other countries such as in Germany, Italy, France, the Czech Republic and the United States (Meher et al., 2010).

PROBLEMS ASSOCIATED WITH BIODIESEL PRODUCTION

The direct use of vegetable oils or blends has generally been considered to be impractical for both direct and indirect diesel engines. The high viscosity, low volatility, acid composition, free fatty acid and moisture content, gum formation due to oxidation and polymerization during storage and combustion, poor cold engine start-up, misfire, ignition delay, incomplete combustion, carbon deposition around the nozzle orifice, ring sticking, injector choking in engine and lubricating oil thickening are the major problems of using vegetable oils. In general, the problems associated with using straight vegetable oil in diesel engines are classified into short and long term probable causes and the potential solutions (Chauhan et al., 2010; Agarwal, 2007).

ADVANTAGES OF BIODIESEL

Biodiesel has 10–11% of oxygen; this makes biodiesel a fuel with high combustion characteristics (Miao and Wu, 2006; Chauhan et al., 2010). Biodiesel reduces net carbon-dioxide emissions by 78% on a lifecycle basis when compared to conventional diesel fuel and reduces smoke due to free soot (Chauhan et al., 2010; Saeid et al., 2008; Bari et al., 2002). Biodiesel is renewable, non-toxic, non-flammable, portable, readily available, biodegradable, sustainable, ecofriendly and free from sulfur and aromatic content, this makes it an ideal fuel for

heavily polluted cities. Biodiesel also reduces particular matter content in the ambient air and hence reduces air toxicity. It provides a 90% reduction in cancer risks and neonatal defects due to its less polluting combustion (International Energy Agency (IEA), 2007; Demirbas, 2009; Demirbas, 2010; Miao and Wu, 2006; Chauhan et al., 2010). Biodiesel serves as climatic neutral in view of the climatic change that is presently an important element of energy use and development (Miao and Wu, 2006; Chauhan et al., 2010). Biodiesel has higher cetane number (about 60 to 65 depending on the vegetable oil) than petroleum diesel (53) which reduces the ignition delay (International Energy Agency (IEA), 2007; Demirbas, 2010; Miao and Wu, 2006; Chauhan et al., 2010).

DISADVANTAGES OF BIODIESEL

Biodiesel has 12% lower energy content than diesel, this leads to an increase in fuel consumption of about 2 to 10%. Moreover, biodiesel has higher cloud point and pour point, higher nitrogen oxide emissions than diesel. It has lower volatilities that cause the formation of deposits in engines due to incomplete combustion characteristics (International Energy Agency (IEA), 2007; Miao and Wu, 2006). Biodiesel causes excessive carbon deposition and gum formation (polymerization) in engines and the oil gets contaminated and suffers from flow problem. It has relatively higher viscosity (11 to 18 times diesel) and lower volatility than diesel and thus needs higher injector pressure (Achten et al., 2008). It can be oxidized into fatty acids in the presence of air and causes corrosion of fuel tank, pipe and injector (Demirbas, 2009; Kapilan et al., 2009).

Due to the high oxygen content in biodiesel, advance in fuel injection and timing and earlier start of combustion, biodiesel produces relatively higher NO_2 levels than diesel in the range of 10 to 14% during combustion (Demirbas, 2010). Economical viability of biodiesel is an attractive renewable energy resource. However, there are some challenges that face this vital resource (Pandey et al., 2012). These challenges include the high cost and limited availability of biodiesel feedstock beside the cheaper prices of crude petroleum. There are various factors contributing to the cost of biodiesel. These factors include feedstock prices, plant's capacity, feedstock quality, processing technology, net energy balance nature of purification and its storage, etc (Haas, 2005). However, the two main factors are the costs of feedstocks and the cost of processing into biodiesel. It has been found that the cost of feedstocks accounts for 75% of the total cost of biofuels (Miao and Wu, 2006).

FUTURE OF BIODIESEL

Biodiesel production is expanding rapidly around the world, driven by energy security and other environmental concerns. Given geographic disparities between demand and supply potential, and supply cost, expanded trade in biodiesel appears to make sense. Global potential in biodiesel production is very unclear, but in the long run it could be a substantia percentage of transport fuel demand. Currently, biodiesel can bemore effective if used as a complement to other energy sources (Kapilan et al., 2009).

CONCLUSION

Energy is an indispensable factor for human to preserve economic growth and maintain standard of living. Globally, the transportation sector is the second largest energy consuming sector after the industrial sector and accounts for 30% of the world's total delivered energy. This sector has experienced a steady growth in the past 30 years. It has been estimated that the global transportation energy use is expected to increase by an average of 1.8% per year from 2005 to 2035. Nearly all fossil fuel energy consumption in the transportation sector is from oil (97.6%). However, the expected depletion of fossil fuels and the environmental problems associated with burning them has encouraged many researchers to investigate the possibility of using alternative fuels. Among them, biodiesel seems a very promising resource.

REFERENCES

Achten WMJ, Verchit L, Mathijs Franken YJ, Singh E, Aerts VP, Muys RB(2008). Jatropha bio-diesel production and use. Biomass Bioenergy 32(12):1063-1084.

Agarwal AK (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Prog. Energy Combust. Sci. 3(33):233-271.

Agarwal AK (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progr Energy Combust. Sci. 33:233-271.

Antolin G, Tinaut FV, Briceno Y, Castano V, Perez C, Ramirez AI (2002). Optimisation of biodiesel production by sunflower oil transesterification. Bioresour. Technol. 83:111-114.

Bari S, Lim TH, Yu CW (2002). Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Renew Energy. 27:339-351.

Basha SA, Raja Gopal K, Jebaraj S (2009). A review on biodiesel production, combustion, emissions and performance. Renew. Sustain. Energy Rev. 13:1628-1634.

Canakci M, Sanli H (2010). Biodiesel production from various feedstocks and their effects on the fuel properties. J. Ind. Microbiol. Biotechnol. 35(5):431-41.

Cernoch M, Hájek M, Skopal F (2010). Ethanolysis of rapeseed oil - distribution of ethyl esters, glycerides and glycerol between ester and glycerol phases. Bioresour. Technol. 01:2071-2075.

Chauhan BS, Kumar N, Jun YD, Lee KB (2010). Performance and emission study of preheated Jatropha oil on medium capacity diesel engine. Energy 35(6):2484-2492.

Chauhan BS, Kumar N, Jun YD, Lee KB (2010). Performance and emission study of preheated Jatropha oil on medium capacity diesel engine. Energy 35(6):2484-2492.

Demirbas A (2009). Biofuels securing the planet's future energy needs. Energy Con. Vers. Manage. 50:2239-2249.

Demirbas A (2009). Biorefineries: current activities and future developments. Energy Convers. Manage. 50:2782-801.
Demirbas A (2009). Progress and recent trends in biodiesel fuels. Energy Convers. Manage. 50:14-34.
Demirbas A (2010). Importance of biodiesel as transportation fuel. Energy Policy 35:4661-4670.
Demirbas A (2010). Use of algae as biofuel sources. Energy Convers. Manage. 51:2738-2749.
Demirbas A (2011). Competitive liquid biofuels from biomass. Appl. Energy 88:17-28.
Demirbas AH, Demirbas I (2007). Importance of rural bioenergy for developing countries. Energy Convers. Manage. 48(8):2386-2398.
Demirbas F, Balat M, Balat H (2009). Potential contribution of biomass to the sustainable energy development. Energy Convers. Manage. 50:1746-1760.
Energy Information Administration (EIA) (2009). State renewable energy requirements and goals: Update through. (2008).
Haas MJ (2005). Improving the economics of biodiesel production through the use of low value lipids as feedstocks: Vegetable oil soapstock. Fuel Process Technol. 86:1087-1096.
International Energy Agency (IEA). World energy outlook 2007. Available from: http://www.iea.org/textbase/nppdf/free/2007/weo 2007.pdf; 2007 [cited 02.02.11].
Kapilan N, Ashok Babu TP, Reddy RP (2009). Technical aspects of biodiesel and its oxidation stability. Int. J. Chem. Tech. Res. 1:278-282.
Leung DYC, Wu X, Leung MKH (2010). A review on biodiesel production using catalyzed transesterification. Appl. Energy 87:1083-1095.
Meher LC, Vidya Sagar D, Naik SN (2010). Technical aspects of biodiesel production by transesterification a review. Renew. Sustain. Energy Rev. 10(3):248-268.
Meng X, Yang J, Xu X, Zhang L, Nie Q, Xian M (2009). Biodiesel production from oleaginous microorganisms. Rev. Enferm. 34:1-5.
Miao X, Wu Q (2006). Biodiesel production from heterotrophic microalgal oil. Bioresour. Technol. 97:841-846.
Mohibbe Azam M, Waris A, Nahar NM (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. Biomass Bioenergy 29:293-302.
Pandey A (2008). Handbook of plant-based biofuels. Taylor and Francis Group. P. 87.
Pandey RK, Rehman A, Sarviya RM (2012). Impact of alternative fuel properties on fuel spray behavior and atomization. Renew. Sustain. Energy Rev. 16:1762-1778.
Pinto AC, Guarieiro LLN, Rezende MJC, Ribeiro NM, Torres EA, Lopes WA (2005). Biodiesel: An overview. J. Br. Chem. Soc. 16(6b):1313-1330.
Ramadhas AS, Jayaraj S, Muraleedharan C (2004). Use of vegetable oils as I.C. engine fuels a review: data bank. Rev. Enferm. 29:727-742.
Refaat AA (2010). Different techniques for the production of biodiesel from waste vegetable oil. Int. J. Environ. Sci. Technol. 7(1):183-213.
Saeid B, Aroua MK, Abdul Raman A, Sulaiman NMN (2008). Density of palm oil-based methyl ester. J. Chem. Eng. Data. 53:877-880.
Sahoo PK, Das LM, Babu MKG, Naik SN (2007). Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine. Fuel 86:448-454.
Shahid EM, Jamal J (2011). Production of biodiesel: a technical review. Renew. Sustain. Energy Rev. 15(9):4732-4745.
Sharma YC, Singh B (2009). Development of biodiesel: current scenario. Renew. Sustain. Energy Rev. 13:1646-1651.
Velasquez-Orta SB, Lee JGM, Harvey A (2012). Alkaline in situ transesterification of Chlorella vulgaris. Fuel 94:544-550.
Yang CY, Li ZFB, Long YF (2012). Review and prospects of Jatropha biodiesel industry in China. Renew. Sustain. Energy Rev. 16:2178-2190.
Zadra R (2006). Improving process efficiency by the usage of alcoholates in the biodiesel production. In: IV forum Brazil-Alemanhasobrebrazil Aracatuba. 16(2012):3456-3470.