Renewable and Sustainable Energy Reviews 61 (2016) 302–318

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia

A.K. Azad *, M.G. Rasul, M.M.K. Khan, Subhash C. Sharma, M. Mofijur, M.M.K. Bhuiya

School of Engineering and Technology, Central Queensland University Rockhampton, QLD 4702, Australia

ARTICLE INFO

Article history:
Received 5 March 2015
Received in revised form
16 October 2015
Accepted 6 April 2016
Available online 21 April 2016

Keywords:
Non-edible oil
Biodiesel
Calophyllum inophyllum
Ricinus communis
Transesterification
Bio-lubricant

ABSTRACT

This study critically reviewed the prospects, feedstocks and challenges of biodiesel production from two non-edible oil sources, namely Beauty leaf oil (BLT) (*Calophyllum inophyllum*) and Castor oil (*Ricinus communis*). The recent developments and the lifecycle assessment (LCA) of these species such as their habitat, growth, oil content, free fatty acid profile and biodiesel characteristics are briefly discussed. Different oil extraction techniques and biodiesel conversion methods are also presented. The properties of the pure biodiesel and their blends are compared with petroleum diesel under different ASTM and European standards. Furthermore, the literatures on engine performance and emission studies using these biodiesels are reviewed and presented in tabular form. The review found that BLT oil can be catalytically transesterified to produce biodiesel as a potential alternative transport fuel in Australia. The review concludes that castor oil is not only an alternate fuel resource, but it also holds good lubricating properties and hence is a potential bio-lubricant source for internal combustion engines. Further research is needed on combustion, corrosion, tribo-corrosion, long term engine durability tests and tribological performance tests before recommending commercial scale biodiesel production from BLT oil and Castor oil.

Contents

1. Introduction

Biodiesel obtained from energy resources which are non-edible, biodegradable and ecofriendly are known as second generation (2G) biodiesel. The biodiesel production from non-edible

* Corresponding author. Tel.: +61 4 6923 5722; fax: +61 7 4930 9382.
E-mail addresses: a.k.azad@cqu.edu.au, azad.cqu@gmail.com (A.K. Azad).

http://dx.doi.org/10.1016/j.rser.2016.04.013
1364-0321/

oil sources has become an important research topic now-a-days. The sources of non-edible vegetable oil, animal fat, wood and wood waste have been investigated in the literature for 2G biodiesel production [1]. The 2G biodiesels can overcome the shortcomings of first generation (1G) biodiesels (which are derived from edible sources) in addressing social, economic and environmental challenges without hampering our food cost and creating pressure on land use [2–4]. Though 2G biodiesels have a large array of sources, they are not being produced commercially yet because this requires more sophisticated processing equipment, more investment per unit fuel production and large scale facilities [5]. There are many 2G biodiesel feedstocks which are readily available; some of them are Karanja (*Pongamia pinnata*), Jatropha (*Jatropha curcas*), Polanga or Beauty leaf (*Calophyllum inophyllum*), Rubber tree (*Hevea brasiliensis*), Desert date (*Balanites aegyptiaca*), Castor oil plant (*Ricinus communis*), Sea mango (*Cerbara odollam*), Terminalia belerica, Neem (*Azadirachta indica*), Koroch seed (*Pongamia glabra*), Mahua (*Madhuca indica*), Tobacco seed (*Nicotiana tabacum*), Soapnut (*Sapindus mukorossi*), *Sterculia foetida*, Chinese tallow (Sapium sebiferum Roxb.), Silk cotton tree (*Ceiba pentandra*) and Jojoba (*Simmondsia chinensis*) [6–8]. During the Second World War, 2G biodiesel was employed as a petro-diesel fuel alternative blended with diesel [6,9]. BLT and Castor oil have high oil content, around 46.51 ± 4.5% and 45–50% respectively, therefore both have been selected in this study for their lifecycle assessment (LCA) as potential biodiesel production species.

1.1. Beauty leaf oil (Calophyllum inophyllum)

The scientific name of "*Calophyllum*" comes from the Greek word for "beautiful leaf" and "*inophyllum*" refers to the straight lines made by the veins in the leaves [10]. It is a native plant widely grown in Australia and commonly known as Beauty Leaf Tree (BLT). The BLT is also known as a perennial plant that usually grows in coastal areas of Queensland and the Northern Territory [11]. The distribution map for BLT is presented in Fig. 1(a). It is also widespread in South East Asia, India, Sri Lanka and the South Pacific. Different countries know the species by different vernacular names, some of which are presented in Table 1.

The BLT is a medium and large-sized evergreen sub-maritime tree with mature height of 8–20 m (25–65 ft) and is broadly spreading with a crown of irregular branches. The life time of the tree is more than 200 years [18]. The bark is grey with flat ridges and sap is milky white and sticky. It flowers twice a year and produces up to 8000 fruits per adult plant annually [19,20]. According to Ashwath [21], kernels of BLT contain about 46% non-edible vegetable oil. Some literature reported that oil content of the kernels is about 75% and it is mostly 71% unsaturated oleic and linoleic acid [6,10,22,23]. When ripe, the fruit is wrinkled and the colour varies from yellow to brownish-red. It requires medium

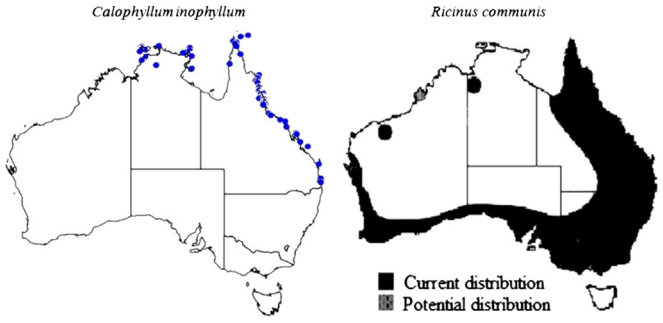

Fig. 1. Distribution maps for (a) beauty leaf tree. Source: Atlas of Living Australia [27] and (b) castor oil plant in Australia. Source: Weed Identification & Information database [28].

Table 1
BLT (*Calophyllum inophyllum*) dialectal names in different countries of the world [6,10,12–17].

Country	Common names	Country	Common names
Australia	Beauty leaf tree (BLT)	Marshall Islands	Lueg
Bangladesh	Punnang	Myanmar	Ponnyet
Cook Island	Tamanu	Northern Marinas	Da'ok, Da'og
Cambodia	Kchyong, Khtung	Nauru	Tomano
Chuuk	Rakich	Palau	Btaches
English	Beach mahogany, Alexandrian laurel, Ball nut.	Papua New Guinea	Beach calophyllum
Fiji	Dilo	Philippines	Bitaog, Butalau, Palomaria
Guam	Da'ok, Da'og	Phonpei	Isou
Hawaii	Kamanu, Kamani	Samoa	Fetau
India	Poon, Polanga, Undi, Sultan champa.	Solomon Islands	Dalo
Indonesia	Bintangur, Nyamplung	Society Islands	Tamanu
Kiribati	Te itai	Tahiti	Tamanu
Kosrae	Eet	Thailand	Naowakan, Krathing
Malaysia	Bintangor, Penang laut	Tonga	Feta'u
Marquesas	Tamanu	Yap	Biyuch

temperatures in wet or moderate weather conditions, with 1000–5000 mm mean annual rainfall and mean annual temperatures of 18–33 °C (64–91 °F) for neutral to acid soil (pH 7.4–4.0) in its growth [16]. Initially, BLT grows at a rate of up to 1 m (3.3 ft) in height per year at good sites, though much more slowly than castor oil plants. It is a hardy tree of tropical coastal areas that tolerates wind, salt spray, drought and brief periods of waterlogged soil, but the plants are sensitive to frost and fire. Plantations can be cultivated at a density of 400 tree/ha [24]. The average oil yield is 11.7 kg-oil/tree or 4680 kg-oil/ha [25]. Due to the presence of resins in the kernels, it changes colour by undergoing chemical changes. The oil is of golden colour with a species-specific odour.

There are some significant advantages of BLT, such as it is a native species in Australia which can grow in marginal land and has low plantation cost due to longer life time (more than 200 years) and tolerant to different weather conditions with salty water condition, has high oil yield (about 75%) of non-edible vegetable oil. It is one of the important sources of oleic acid (42.3%) and linoleic acid (29.2%). It can be converted into biodiesel using a modified transesterification method. The diesel engine performance and emission characteristics are similar to other biodiesels. The BLT has other traditional uses as a source of medicine (Domba oil), such as it has unique capacity to promote the formation of new tissue, thereby accelerating wound healing and the growth of healthy skin [26]. Finally, its timber can be used for construction purposes.

1.2. Castor oil plant (Ricinus communis)

The scientific name "*Ricinus*" comes from the name of the European sheep tick Ixodes ricinus or sheep tick and "*communis*" is from the Latin for common because it is the only species in the genus [29]. *Ricinus communis* is commonly known as castor oil plant. Other common and dialectal names are listed in Table 2. It is indigenous to north-eastern Africa and Eurasia. It has been found in the ancient Egyptian tombs dating back to 4000 BC and the oil was used thousands of years ago in the Middle East and India in wick lamps for lighting [30]. It is now widely cultivated in dry areas of the tropics and subtropics and in different temperature areas with a hot summer. Global castor oil production is around 1.8 million tons per year [31]. Leading production countries are India, China and Brazil. It is commercially produced in California