Review and prospects of bitter apricot oil as an alternative feedstock for biodiesel production – an Indian perspective

Virender Singh Gurau and Sarbjoit Singh Sandhu*
Department of Mechanical Engineering, Dr. B R Ambedkar NIT Jalandhar, Punjab, India
Email: virendergurau@gmail.com
Email: sandhuss@nitj.ac.in
*Corresponding author

Anil Kumar Sarma
SSS National Institute of Renewable Energy, Kapurthala, Punjab, India
Email: draksarma@gmail.com

Abstract: The increasing energy demands along with the gradual depletion of fossil fuels have prompted to search for alternative fuels that can be obtained from renewable energy resource. Biodiesel as a renewable energy resource has drawn the attention of many researchers and scientists because it has immense potential to be part of a sustainable energy mix in near future. This paper explores the feasibility of converting wild/bitter apricot (Prunus armeniaca Linn.) oil into biodiesel and its prospects in India and reviews the history of wild apricot, its origin, distribution, oil extraction, biodiesel processing and engine testing. The positive attributes and limitations of the bitter apricot utilisation are also discussed. It was unveiled that the production of biodiesel from wild apricot oil offers many social, economical and environmental benefits for the country and can play a great role to solve the problem of energy crisis in high altitude areas of India. The prospects of wild apricot biodiesel and its expansion for setting up biodiesel industry in the mountainous regions have also been emphasised. [Received: March 4, 2015; Accepted: June 13, 2015]

Keywords: apricot; Prunus armeniaca Linn.; vegetable oil; biodiesel; alternative fuel; diesel engine; emission; transesterification; blends; energy.


Biographical notes: Virender Singh Gurau obtained his BTech in Mechanical Engineering from Institution of Mechanical Engineers, India, Mumbai and MTech in Mechanical Engineering from Al Falah School of Engineering and Technology, Faridabad, Haryana. He worked as a Project Scientist in Center of Advance Studies and Research in Automotive Engineering at Delhi
1 Introduction

Energy is one of the most significant inputs for the growth of all sectors including agricultural, industrial service and transport sectors. Energy has been at the centre stage of national and global economic development for several decades. The demand for energy, around the world is increasing exponentially, specifically the demand for petroleum-based energy. There is a realisation throughout the world that the petroleum resources which are non-renewable, are limited and are being consumed at an alarming rate. The growing demand for energy and gradual extinction of fossil fuels has led to an energy crisis. Most of the energy in industries and transportation is derived from oil and coal. Special mention is needed for automobiles where almost all of the fuels for combustion engine today are derived from petroleum, a non-renewable source of energy, which is nearing its end at an unprecedented pace. Another, major global concern is environmental degradation or climate change such as global warming. Global warming is related to the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. To solve the dual problems of fossil fuel depletion and environmental degradation, the renewable fuels with lower environmental impact are necessary. The purpose of this paper is to provide information about the review and future prospects of bitter apricot biodiesel in high altitude areas of India.

1.1 Energy scenario: Indian context

India is a developing country and world’s second most populous country after China. The primary energy resources in India are coal, oil, hydropower and natural gas. India is both a major energy producer and consumer. India currently ranks as world’s 11th greatest energy producer accounting for about 2.4% of worlds total annual energy production, and as world’s sixth greatest energy consumer accounting for about 3.3% of world’s total annual energy. India’s energy consumption has been increasing at a very fast rate due to increase in population and economic development. The highest demand for energy comes
from industry, followed by the transportation sector. The consumption of crude oil in India was about 211.42 MT for the year 2011–2012, and 81.4% of this demand was met by import (Petstat, 2014). The share of high-speed diesel (HSD) was about 39.6% out of total petroleum products in 2011–2012. The rate of energy consumption is increasing at the rate of 4.2% per annum while reserves for petroleum oil are decreasing day by day. India’s share of crude oil production is about 1% of total world crude oil production while in consumption; its share is about 5.2% of total world consumption (Petstat, 2014). The import of crude oil has increased from 75.2% in 2004–2005 to 81.4% in 2011–2012 (Petstat, 2014). The above figures indicate that India imports large amount of crude oils for its domestic consumption and consequently pay huge foreign exchange for it. Indian economy is a diesel driven economy. The demand for diesel and petrol in India is very much skewed. India consumes 5 times more diesel as compared to petrol. The demand of HSD grew from 39.65 MT in 2004–2005 to 64.74 MT in 2011–2012 at the rate of average 8% per annum (Petstat, 2014). The recoverable crude oil reserves of India are estimated to be around 757.4MT. According to an estimate, if India does not import crude oil and all the demand for oil is met by 100% indigenousl y explored Indian crude oil, then the crude oil reserves of India will last for only 3.6 years.

The recent increase of oil prices, energy security fears, increasing foreign exchange outflow due to massive petroleum import and international environmental regulations give cause for a more serious consideration of renewable energy in India.

To keep pace with its rapidly expanding economy and energy demand with environmental sustainability, Indian Government has been setting targets and developing strategies, policies, and investment plans in biofuels to enhance energy security and explore alternative energy sources. According to National Policy of Biofuels in India formulated by Ministry of New and Renewable Energy (MNRE), a target of blending 20% biodiesel has been fixed by 2017 (MNRE, 2012). It has been decided to encourage the biodiesel production from non-edible oilseeds on waste, degraded and marginal lands.

In India, the production of biodiesel is expected to grow significantly in the years to come due to the availability of various non-edible oils.

### 2 Biodiesel

The term biodiesel is referred to the fatty acid methyl ester that can be produced from vegetable oils or animal fats by transesterification treatment (Atabani et al., 2012, 2013; Silitonga et al., 2011; Singh and Singh, 2010). Biodiesel is biodegradable, non-flammable, renewable, non-toxic as well as environment friendly (Atadashi et al., 2010, 2012; Basha and Gopal, 2012; Jayed et al., 2011). Biodiesel has almost similar properties (such as cetane number, energy content, viscosity and phase changes) as compared to mineral diesel fuel (Jayed et al., 2009; Lin et al., 2011) and it can be blended with diesel fuel at any proportion and thus can be used in CI engine without carrying out any major modification in engine with comparable performance and improved emission characteristics as petroleum diesel fuelled engine (Shahabuddin et al., 2012; Jain and Sharma, 2011). Moreover, it does not contain any harmful substances like sulphur or aromatics and produce less harmful emissions to the environment. One of the advantages of this fuel is that the raw materials used to produce it are natural and renewable. All these types of oils come from vegetables or animal fat, making it biodegradable and non-toxic.
2.1 Current biodiesel feedstock

The choice of feedstock for biodiesel production is country and region specific. In mid 60’s India was self-sufficient in edible oil and oil seeds and was a substantial exporter of oilseeds and extracted oil. With stagnation in production as well as rise in population, oilseed production fell far short of its demand in the early 70s. The green revolution which occurred in late 60s and early 70’s remained insulated from oil seeds sector. Currently, India is a big importer of edible oils.

India’s edible oil imports surged to 10.38 million tonnes in 2012–2013 and it is predicted that the edible oil import in 2020 would be 14 million tonnes. The use of edible oils as feedstock for biodiesel in India does not make any sense.

There are more than 350 oil-bearing crops recognised worldwide as potential sources for biodiesel production (Mofijur et al., 2013). India has vast potential of unexploited non-edible oil bearing plants. The main commodity sources for biodiesel production from the non-edible oil bearing plants are Jatropha curcas (ratanjyot), Pongamia pinnata (karanja), Calophyllum inophyllum (nagchampa), Ricinus communis (castor), Argemone mexicana (Mexican prickly poppy), Cerbera odollam (sea mango), Putranjiva roxburghii (Lucky bean tree), Sapindus mukorossi (soapnut), Hevea brasiliensis (rubber tree), Melia azedarach (syringa), Simmondsia chinensis (jojoba), Madhuca indica (mahua), Schleicheria triguga (kusum), Thevetia peruviana (yellow oleander), Mesua ferrea L etc (Kumar and Sharma, 2011). In India, Pongamia Pinnata and Jatropha Curcas have been extensively studied in the last 15 years. In order to achieve the target of 20% biodiesel blending by 2017, 18.13 MT of biodiesel is required. Apart from conventional biofuels, there is a huge untapped potential for biodiesel production from unconventional non-edible oils. Bitter Apricot oil is one such oil which is found in high altitude area and need to be explored for biodiesel production.

2.2 Biodiesel production

There are different ways of using vegetable oil in diesel engine. Vegetable oil is made compatible by dilution with mineral diesel, emulsification and transesterification to be used in diesel engine. Transesterification is the most commonly used method to produce biodiesel from vegetable oil.

2.3 Transesterification of vegetable oils

In the transesterification process, triglycerides react with an alcohol, generally methanol or ethanol, to produce esters and glycerine (Miguel et al., 2001). Transesterification can be achieved by using a catalyst or without using catalyst in a supercritical process. The use of methanol in transesterification is more common because of its low cost and because the base-catalysed formation of methyl ester is simple compared to the formation of ethyl esters. In catalytic transesterification, the catalyst used may be alkaline, acidic or enzymes. Figure 1 shows the basics of transesterification reaction.
Table 1 shows the comparison of different technologies to produce biodiesel (Marchetti et al., 2007).

### Table 1  Comparison of the different technologies to produce biodiesel

<table>
<thead>
<tr>
<th>Variable</th>
<th>Alkali catalysis</th>
<th>Acid catalysis</th>
<th>Lipase catalysis</th>
<th>Supercritical alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction temperature (°C)</td>
<td>25–120</td>
<td>55–80</td>
<td>30–40</td>
<td>239–385</td>
</tr>
<tr>
<td>Free fatty acid in raw</td>
<td>Saponified</td>
<td>Esters</td>
<td>Esters</td>
<td>Esters</td>
</tr>
<tr>
<td>materials</td>
<td>products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water in raw material</td>
<td>Interference with reaction</td>
<td>Interference with reaction</td>
<td>No influence</td>
<td>No influence</td>
</tr>
<tr>
<td>Yield of methyl esters</td>
<td>Normal</td>
<td>Normal</td>
<td>Higher</td>
<td>Good</td>
</tr>
<tr>
<td>Recovery of glycerol</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Easy</td>
<td>-</td>
</tr>
<tr>
<td>Purification of methyl esters</td>
<td>Repeated</td>
<td>Repeated</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>Production cost of catalyst</td>
<td>Cheap</td>
<td>Cheap</td>
<td>Relatively</td>
<td>No catalyst</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>expensive</td>
<td></td>
</tr>
</tbody>
</table>

3  Wild/bitter apricot (*Prunus armeniaca* Linn.)

3.1 History of apricot

The wild apricot (*Prunus armeniaca* Linn.) is an important tree borne oilseed of mid hills and dry temperate regions of the country. Wild apricot belongs to the family *Rosaceae* and sub-family *Prunoidea*. In the Himalayan region of India, local communities call it by different vernacular names viz. ‘Chulli’, ‘Shara’, ‘Khurmani’, ‘Chulu’, Zardhi, Khubani, Chuari, Kashmiaru, Chola and Giradlu. In Punjabi, it is called as Hari, Sari and Chuli (Kureel et al., 2007). Figure 2(a) and (b) shows the wild apricot tree, fruit kernel and seeds (sunwarrior & acenutrients, 2013).
3.2 Origin and distribution

The cultivated apricot has its origin in North-Eastern China, whereas, wild apricot appears to be indigenous to India. Wild apricot locally called Chullu is found in the dry temperate regions of North-Western Himalayas particularly in the valleys of Jammu and Kashmir (especially Ladakh), Chenab; Kullu and Shimla regions of Himachal Pradesh and Garhwal hills of Uttrakhand at altitudes up to 3000 m. In Kumaon region, wild apricot is found in all the three districts of Nainital, Almora and Pithoragarh. Pithoragarh district has maximum density of wild apricot tree in the Kumaon region (Kureel et al., 2007). Estimated harvested area of apricot in India is about 5000 ha with an average yield of 36000 hectogram/ hectare in 2012 (Faostat, 2012).

3.3 Morphology

The wild apricot tree is about 10–15 m tall with a reddish brown bark. Leaves are ovate to round, approximately 5–9 cm long. Its somatic chromosome number is (2 n) 16 and basic chromosome number (X), is 8. Flowers are solitary, white or pinkish, about 2.5 cm across, borne singly and appearing much in advance of the foliage. Fruits are around 1.5–4.0 cm across or more and hairy when young but nearly smooth skinned at maturity. The appearances of the fruits are yellowish with light red cheek and nearly glabrous. The flesh is yellow or yellowish orange to firm and sweet. Stone is smooth with a thickened furrowed edge.
Wild apricot thrives best in mid hills at elevations of 1,200–3,000 m above mean sea level. The long cool winter (800 chilling hours below 7°C), and frost free and warm spring are favourable for fruiting. Average summer temperature (16.6°C–32.3°C) is suitable for better growth and quality fruit production. The sites located in north-eastern India at lower elevations and on south-western at higher elevations are also suitable for its cultivations. Spring frost causes extensive damage to the blossoms, which are killed when temperature falls below 4°C. An annual rainfall of about 100 cm well distributed throughout the season is good for its normal growth and fruiting (Kureel et al., 2007).

Apricot is cultivated worldwide including Greece, China, Japan, Iran, Spain, Pakistan and some parts of Australia etc.

3.4 Harvesting and yield

Wild apricot fruits generally start maturing from last week of May and continue up to August end depending upon altitude and location. They are harvested manually by shaking the tree branches and no mechanical harvesting is practiced. Change of surface colour, days from full bloom to harvesting and fruit total sugar solids (TSS) are considered as the best indices of maturity. For fresh marketing, fruits should be plucked when they change their surface colour from green to yellow. Fully ripened fruits are harvested for freezing, canning and drying. The fruits should be harvested in morning hours and direct exposure of fruits to sun should be avoided during grading and packaging. Tree starts bearing at the age of 4–5 years and continues to bear well for 50–60 years. The full bearing occurs at about 10–15 years when it yields about 85–100 kg fruits per tree. The stone yield varies from 12-17% of fruits and the kernel yield ranges 3.14–4.81 kg/tree. The yield of a full-bearing well maintained tree varies from 120–150 kg (Kureel et al., 2007).

3.5 Utilisation

The wild apricot is unfit for table purpose due to high acids and low sugars. It is not processed for any commercial product at present although studies for preparation of sauces and chutney from this fruit have given quite encouraging results. The seed cake of the bitter apricot yields 1.6% of the oil. The cake from which the oil has been removed is free of hydrocyanic acid and can be used as a feed stuff for livestock (Kureel et al., 2007).

4 Apricot oil an alternate feedstock for biodiesel

The wild apricot fruits yield 22–38% kernels, which may be sweet or bitter depending on the type. Sweet kernels resemble almonds in taste and are used as its substitute in pastes and confectionery and can be added to apricot jams. The characteristics of oil depend upon the geographical area where it is grown. The kernel contains water (4.3 %), protein (31.4 %), oil (53.4 %), fibre (4.8 %), ash (2.6 %), sugar direct (8.1 %) and as dextrose after conversion (11.6 %) (Kureel et al., 2007). Siberian apricot seed kernels were found to contain 50.18 ± 3.92% (w/w) oil after extraction (Wang and Yu, 2012), which is in agreement with previous literature (Zhang, 2003; Luo and Liu, 2007; Ozcan, 2000). Figure 3 shows the comparison of oil content of different biodiesel stock in India, it is
clearly seen from the figure that wild apricot oil content is more than the commonly used biodiesel in India which makes it a promising feed stock for biodiesel production in high altitude areas.

Figure 3  Comparison of oil content of different biodiesel feed stocks in India (see online version for colours)

Utilisation of biodiesel in transport sector is the solution to reduce the dependence of India on imported crude oil and thus achieve the target gross domestic product (GDP) growth rate of 8-9%. The price of feedstock alone represents 75–80% of biodiesel cost. In order to keep biodiesel production economically viable and have the contribution of every region of India towards energy security and sustainability, diversification of biodiesel feedstock is required. Apart from energy security, biodiesel production from bitter apricot oil will provide a livelihood and revenue generation for many families living in high altitude areas of India who otherwise find little use for bitter apricot oil.

4.1 Method of oil extraction

For the extraction of oil, the seeds are manually broken to avoid shooting of the seeds, cords made of *Bhimal* are made into a loop, the seeds are kept inside it and broken manually by small round stones found in the river bed. The kernels thus extracted are dried in the sun. They are then crushed to a fine paste in a mortar, known as the ‘Okhali’ locally. The paste is then kneaded by dipping hands in warm water under the sun. With this process, the paste exudes the oil. This paste is then put in a wooden vessel made especially for the extraction of oil (Kureel et al., 2007). The kernels of Siberian apricot seeds were dried and crushed using a domestic grinder giving a mean particle size of the milled kernels of 0.8 mm. Fat components were extracted with petroleum ether using a Soxhlet apparatus at 45–50°C for 6–8 h until the extraction was completed (Wang and Yu, 2012; Zhang, 2003; Luo and Liu, 2007; Ozcan, 2000; Karmakar et al., 2010; Ullah et al., 2009).
4.2 Fatty acid composition

The fatty acids composition in the seed kernels of the Siberian apricot analysed were determined as myristic acid (C14:0), palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), \(\alpha\)-linolenic acid (C18:3) and arachidic acid (C20:0). The percentage of fatty acid composition from different researchers (Wang and Yu, 2012; Sun et al., 1994; Esengun et al., 2007) is shown in Table 2.

Table 2  Fatty acid composition of apricot oil

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Structure</th>
<th>Composition, % (Wang and Yu, 2012)</th>
<th>Composition, % (Esengun et al. 2007; Gumus and Kasifoglu, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic acid</td>
<td>C 14: 0</td>
<td>0.03</td>
<td>-</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>C 16: 0</td>
<td>3.79</td>
<td>5.62</td>
</tr>
<tr>
<td>Palmitoleic acid</td>
<td>C 16: 1</td>
<td>0.67</td>
<td>0.72</td>
</tr>
<tr>
<td>Steric acid</td>
<td>C 18: 0</td>
<td>1.01</td>
<td>1.27</td>
</tr>
<tr>
<td>Oleic acid</td>
<td>C 18: 1</td>
<td>65.23</td>
<td>67.31</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>C 18: 2</td>
<td>28.92</td>
<td>24.68</td>
</tr>
<tr>
<td>Linolenic</td>
<td>C 18: 3</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>Arachidic</td>
<td>C 20: 1</td>
<td>0.009</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 4  Fatty acid composition of various biodiesel feed stocks used in India (see online version for colours)

Figure 4 shows the comparison of fatty acid composition of various biodiesel feedstock used in India. From the figure it is seen that wild apricot oil has greater monounsaturated
content so biodiesel from wild apricot oil has the global better physico-chemical properties. The presence of these monounsaturated compounds gave a high cetane number, improve stability and good CFPP (cold filter plugging point) property to the biodiesel (Ramos et al., 2009).

4.3 Apricot biodiesel production

The very low acid value and water content of the Siberian apricot seed kernels oil enabled direct base-catalysed transesterification for biodiesel production without acid pretreatment and the yield of biodiesel was obtained at 88.7% (Wang and Yu, 2012). Apricot seed kernel oil methyl ester (ASKOME) has been produced as an alternative fuel by transesterification method. The optimum transesterification conditions in terms of viscosity, density and ester transformation rate were determined by transesterification in 18 different reaction conditions which is combination of temperature (50°C, 60°C, and 70°C), volumetric ratios of oil to methanol (1:4, 1:5, and 1:6) and catalysts (NaOH and KOH) (Gumus and Kasifoglu, 2010). Biodiesel was produced through base (NaOH) catalysed transesterification (Meher et al., 2006), with some modification such that methoxide prepared by dissolving NaOH pellets into methanol was treated with molecular sieve (size A3) for 10 h to remove any of the chemical water produced during reaction of methanol with sodium hydroxide prior to transesterification. The ratio of oil to methanol was 1:6 (Ullah et al., 2009).

4.4 Apricot methyl ester fuel properties

Table 3 shows the important physico-chemical properties of apricot methyl ester found by various researchers and its comparison to diesel fuel.

Table 3 Fuel properties of apricot biodiesel

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/ m³) @ 15°C</td>
<td>ASTM D 4052</td>
<td>830</td>
<td>878.2</td>
<td>855</td>
<td>884.3</td>
</tr>
<tr>
<td>Kinematic viscosity (cSt) @ 40°C</td>
<td>ASTM D 445</td>
<td>2.4</td>
<td>4.341</td>
<td>4.26</td>
<td>4.92</td>
</tr>
<tr>
<td>Calorific value (MJ/ kg)</td>
<td>ASTM D 240</td>
<td>43.15</td>
<td>-</td>
<td>-</td>
<td>39.95</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>ASTM D 93</td>
<td>59</td>
<td>173</td>
<td>105</td>
<td>111</td>
</tr>
<tr>
<td>CFPP (°C)</td>
<td>EN 116</td>
<td>-10</td>
<td>-14</td>
<td>-12</td>
<td>-17</td>
</tr>
</tbody>
</table>

5 Engine testing

Only one research work has been reported on the performance and emission analysis of diesel engine using bitter apricot biodiesel (Gumus and Kasifoglu, 2010) and the authors
Review and prospects of bitter apricot oil

did not find any study related to the combustion characteristics of diesel engine fuelled with wild apricot fuel and thus it needs to be explored.

5.1 Engine power

The power increases with the addition of biodiesel content in the blend until the B20 blend where it reaches a maximum value. When the biodiesel content further continues to increase in the blend, the power will decrease below that of the diesel fuel and reaches minimum value for B100. The results obtained support the previous research on biodiesel (Ramadhas et al., 2004; Kalam et al., 2003; Usta et al., 2005; Wagner et al., 1984; Usta, 2005). Figure 5 shows the maximum brake power obtained by the diesel, apricot biodiesel and its blends.

Figure 5 Maximum brake power obtained by different tested fuels (see online version for colours)

5.2 Brake specific energy consumption

The BSEC initially decreases with increasing of engine load until it reaches a maximum value and then increases slightly with further increasing engine load for all kind of fuels. In the using of blends B5 and B20, the BSEC of the engine is lower than that of diesel for all loads. The BSEC for B5 and B20 was lower than diesel. The BSEC for B50 has similar values with diesel fuel, however in case of B100, the BSEC is found to be higher than that of diesel and support the previous research on biodiesel (Barie and Humke, 1981; Scholl and Sorenson, 1993; Canakci, 2005).

5.3 CO, CO₂, HC and NOₓ emission

The CO emissions are found to be increasing with increase in load since the air-fuel ratio decreases with increase in load such as all typical internal combustion engines. The engine emits less CO using neat biodiesel and its blends with diesel as compared to that
of diesel fuel under all loading conditions and also supports previous research work on biodiesel (Kumar et al., 2003).

The CO$_2$ emission of all fuels has the tendency to increase with increase in output power. The CO$_2$ emission initially increases with the addition of biodiesel content in the blend and reaches a maximum value at the B20 blend and then decreases with more increase of the biodiesel content. More amount of CO$_2$ in exhaust emission is an indication of the complete combustion of fuel. So higher CO$_2$ emission of B20 indicates effective combustion as the biodiesel contains oxygen, which improves combustion of fuel. Higher percentage of biodiesel blends emits low amount of CO$_2$ emissions as a consequence of higher viscosity of biodiesel. Fuel spray cone angle, in which air entrainment depends, decreases with increased fuel viscosity. Decrease in cone angle results in reduction of amount of air entrainment in the spray. Lack of enough air in the fuel spray impedes completion of combustion and decreases formation of CO$_2$ emissions (Nwafor, 2004).

The HC emissions increase with the increase in load. HC emissions decreases with increasing biodiesel percentage in the blend and reaches minimum value when used pure biodiesel as fuel.

The NO$_x$ emission for biodiesel and its blends is higher than that of the diesel oil. The NO$_x$ emission increases with increasing percentage of biodiesel in the blends and reaches maximum value with using pure biodiesel as fuel and support the previous research on biodiesel (Ramadhas et al., 2004; Usta, 2005; Scholl and Sorensen, 1993; Canakci, 2005; Rickeard and Thompson, 1993).

6 Conclusions and future scope

It can be concluded from the wide literature survey, that wild apricot oil can be successfully processed into biodiesel and the biodiesel produced from wild apricot kernel fulfil the fuel properties as required by the ASTM D 6751 and can be successfully utilised in the compression ignition engines. Its use in CI engine results in decrease in emissions of HC and CO but with a penalty of slight increase in NO$_x$. Bitter apricot oil does not compete with food or with nature, reduces greenhouse gases and has positive attributes for the economic development of the high altitude regions of the country. There is huge scope of its cultivation and can fulfil the petroleum diesel crisis in high altitude regions of the country both for civilian and defence applications. Though preliminary investigations carried out worldwide indicate that bitter apricot biodiesel possesses amicable fuel properties, but the study is still in its initial stages and in order to validate the results comprehensive studies need to be undertaken in India particularly for setting up biodiesel refinery in mountainous regions. As oil content of apricot seed is very high amongst all the available Indian biodiesel feed stocks and a substantial area is being cultivated for Apricot in India, but no study has been carried out regarding the performance, emission and combustion analysis for bitter apricot oil of India origin.

As compared to the Indian mineral diesel consumption of 64.74 MT for 2011–2012, the current production of 0.102 MT of biodiesel in 2013 stands very low (GAIN, 2013). Thus bitter apricot biodiesel can play an important role in replacing mineral diesel in the hilly areas where it is grown.

It is expected that apricot biodiesel will increase the energy sustainability and will replace the fossil diesel in the near future in high altitude areas of India.
References


Review and prospects of bitter apricot oil


