# Potential Of Linseed Oil Biodiesel As Fuel For CI-Engines In India

**Avinash Kumar Namdeo, Dr. Rajesh Gupta**

**Abstract:** The advances in industrial and transport sectors with modernization of the world demand huge amount of energy. Therefore, fossil fuels are being consumed in enormous amounts. The limited reserves of these fuels have motivated numerous researchers to look for substitute fuels and renewable sources of energy. In recent time, biodiesel fuels have gained the attention of numerous researchers, as they are derivatives of renewable feedstock and for their environmental and economic benefits. Four methods namely pyrolysis, transesterification, micro-emulsion and blending have been developed to transform vegetable oils and fats into CI Engine fuel (Biodiesels). Linseed oil is selected for this study because it is an inedible oil, which could be cultivated in wastelands of India. This paper evaluates the scope of biodiesel fuel from various vegetable oils primarily of linseed oil, its current production around the world and possibilities of cultivating Linseed crop in India. Finally, this review addresses the consequences of using linseed oil biodiesel in CI engines. It is concluded that linseed oil biodiesel is suitable for substituting conventional diesel in India.

**Index Terms**: Biodiesel, combustion, diesel engine, emissions, Linseed oil, NOx emissions, transesterification.

## 1. INTRODUCTION

THE global energy requirements for growing industrial and transport sectors are fulfilled by oil, natural gas and coal [1-4]. Meanwhile, the toxic emissions produced from petroleum driven automobile engines are causing severe health disorders in humans, plants and animals [3]. The governments of different countries including Indian government are considering this problem very seriously. They have enforced very strict emissions regulation guidelines for emission of NOx (nitrogen oxide) and PM (particulate matter) from diesel engines. Fossil based fuels will be completely consumed faster than we expect. Therefore, researchers are exploring for sustainable, efficient and eco-friendly alternative fuels. Biodiesels are the alternative fuels produced from vegetable oils [5, 6]. Linseed oil is an inedible oil, which is generally utilized by varnish and paint industry. It could be easily transformed into biodiesel fuel for use in CI engines.

## 2 LITERATURE REVIEW

### 2.1 Biodiesel Fuels

Biodiesels are generally esterified vegetable oils and fats, which can be directly used to run CI engines without alterations [2, 7-16]. These fuels are renewable and offer improved engine performance too [13, 17, 18]. Biodiesels can be produced from a variety of oils and fats. [12, 19, 20].

### 2.2 Biodiesel in India

The Petroleum and Natural Gas Ministry of India started the first phase of using biodiesel blended fuel in 2003 in which, nine states and four union territories used 5% ethanol blended petrol. Biodiesel production of India primarily focuses on extracting vegetable oils from non-edible sources like Jatropha, Neem, Karanja, Mahua, etc... This phase targeted to reach 20% (B20) by year 2012. Therefore, Government of India has planted Jatropha over an area of 11.2 million hectares by 2012 [21, 22]. Recently, government has planned to blend ethanol up to 20% in petrol and biodiesel upto 5% in diesel by 2030 [62].

### 2.3 Linseed Oil

Linseed is one of the most primitive field crops cultivated in North America. Linseed crop is mainly grown for its fibre (linen), oil and animal feeding. Linseed oil is inedible but it is a very important industrial oil due to its quick drying tendency [23]. The oil content of seed is based on climate and varies from 35-47% [24-26, 47].

### 2.4 Linseed in Human Diet

Linseed oil is composed of about 57-58% of omega-3 rich alpha-linolenic acid, 18% of oleic acid, 16% of linoleic acid, 5% of palmitic acid and 4% of stearic acid. Both alpha-linolenic and linoleic acids are the vital for humans and cannot be prepared in human body by itself. But consumption of linseed for humans in limited to 30 or 40 grams per day as it contains cyanogenic glucosides and linatine which are considered to be anti-nutritional components [27, 28]. Linseed is also served to poultry for yielding omega-3 rich eggs.

### 2.5 Production of Linseed and Linseed Oil

Linseed requires cold temperatures and grows on wide range of soil and climatic conditions where annual rainfall ranges from 45–75 cm. In temperate climates of Canada, Russia and other countries, linseed is a summer crop. In tropical or sub-tropical areas like India, Bangladesh, Pakistan, Brazil, etc… linseed is grown in winters. Linseed is cultivated in moist but firm soil with a seeding rate of about 3–4.5 kg/m2. After sowing of seeds in rows of about 15-20 cm the crop has a vegetative period, a flowering period and a seed maturation period that completes in 90–150 days. Flowers color may vary from white to blue or pink due to genetic diversity but on maturity, slightly or completely closed capsules are formed


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which contain oilseeds as shown in Fig. 1.

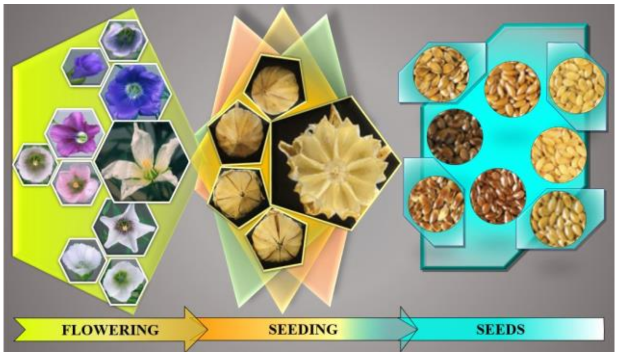


***Fig. 1.*** *Genetic diversity in Linseed [25].*

About ten seeds are present in each capsule. The colour of seed coat may also vary ( in the colour shades of yellow to olive to brown). The yields of linseed is about 0.14 kg/$m^2$ for countries like Canada and North America, while it is less than 0.1 kg/$m^2$ for rest of the world. Cultivation of linseed all over the world was around $4x10^9$ kgs in past 50 years with Canada, Russian Federation Belgium, and Kazakhstan as the largest producers. The cultivation of linseed gradually declined since the 1980s with a peak in 1999 of almost $3x10^9$ kgs and again declined during 2005 ($2.8x10^9$ kgs) to 2012 ($2.1x10^9$ kgs) with a lowest of $1.7x10^9$ kgs in 2007. Canada has also decreased production from $1.0x10^9$ kgs in 2005 to $0.5x10^9$ kgs in 2012 [28-31].

### 2.6 Potential of producing Linseed Oil in India

The climatic and soil conditions of India are favourable for the cultivation of linseed crop. In India it is sown as a cold-crop during October or November and harvested during March or April. The annual yields of Linseed in India are shown in Fig2. [17, 32, 33]. It is observed that, the yield of Linseed is decreased from $0.197x10^9$ kgs in 2003-04 to $0.132x10^9$ kgs in 2015-16. Meanwhile, the annual production of Linseed oil is also dropped by $0.016x10^9$ kgs. But, the total production of oil from other oilseed crops is raised from $5.484x10^9$ kgs to $10.79x10^9$ kgs. The annual yields of linseed crop may vary due to reduction of harvested area or due to climatic conditions in different regions of India. According to Ministry of Agriculture (India), only about 0.15% of land of gross cropped area is used for cultivation of linseed crop in India. From Fig. 2, it is very clear that about $1.25x10^5$ $km^2$ of cultivable land is unutilized. These cultivable wastelands can be utilized in growing linseed.

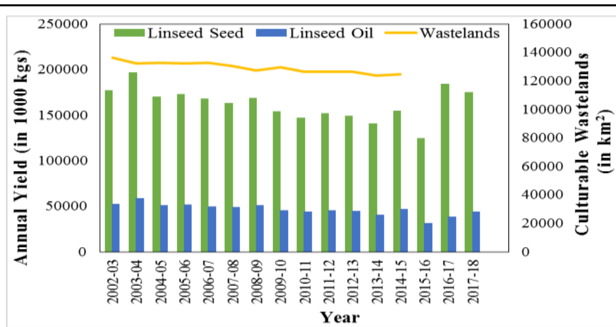


***Fig. 2*** *Annual Production of Linseed and Linseed Oil and Wastelands of India [33]*

3 LINSEED OIL BIODIESEL AND ITS PROPERTIES

It is evident that diesel engines can be operated with straight vegetable oils for short runs only. Problems like coking in fuel injector, piston ring sticking due to gum formation and coagulation of lubricating oil was reported in less than 10 hours of engine test [35]. These problems are attributed to high concentrations of acyl glycerides and glycerine in the fuel and non-volatility of neat vegetable oils [34]. These problems reduce engine life. Hence, straight vegetable oils must be treated before they are used in diesel engines [6, 18, 36-38]. Four methods namely pyrolysis, transesterification, micro-emulsion and blending are developed to produce biodiesel from raw vegetable oil. Out of these methods transesterification is mostly used. [6, 32, 39-46]. The effect curing of linseed oil on its properties are are shown in Table1.

## 3 ENGINE PERFORMANCE AND EMISSIONS

***TABLE 1***

*PROPERTIES OF LINSEED OIL AND LINSEED OIL BIODIESEL [2, 11, 19, 50]*

| Properties | ASTM Test No. | LO | DO | LOME Biodiesel |
|---|---|---|---|---|
| Density | --- | 0.935 | 0.855 | 0.874 |
| API gravity | --- | 19.833 | 33.997 | 30.399 |
| Viscosity at 40°C (cSt) | D445 | 23.93-26 | 2.7-3.06 | 3.59-4.2 |
| Flash point (°C) | D93 | 186-241 | 50 | 161-172 |
| Pour point (°C) | | -15 | -16 | -18 |
| Cetane number | | 47 | 34-50 | 48 |
| Ash Content (%) | D482 | --- | 0.01 | 0.002 |
| Calorific Value (KJ/Kg) | --- | 39307 | 43,800 | 40759-40,374 |

LO = 100% Pure Linseed oil, 100% DO = Pure Diesel Fuel, LOME = 100% Pure Linseed oil Methyl Ester.

Available literature reveals that linseed oil biodiesel could be used as motor fuels in future for the transport sector of India [32, 51, 52]. At present there are no evidences of any investigation conducted on a diesel engine which is fuelled with linseed oil biodiesel prepared by pyrolysis technique or microemulsion or enzyme based process. But many researchers have tested the performance of CI engines with blends of linseed oil based biodiesel. They are discussed below

### 4.1 Brake Thermal Efficiency

Brake thermal efficiency (BTE) points to the conversion of energy released by combustion of fuel to useful shaft power. A higher value of BTE is desirable. Experimental studies revealed that all the blends of linseed biodiesel have higher thermal efficiency than diesel. BTE of the engine is found to be improved by 8 to 11 % when operated with linseed oil biodiesel blends [5, 48, 84, 53, 57, 58, 60, 61, 63, 64, 65, 67, 68]. The engine's highest thermal efficiency was detected for B20 blend of linseed oil biodiesel. Another study reported highest thermal efficiency for emulsion formed by adding 10% methanol and 30% linseed oil in diesel [55].

### 4.2 BSFC

BSFC is the quantity of fuel required by the engine to generate

1kW power. Low BSFC is better. It is found to be about 9% higher when diesel engine was operated with blends of LOME. The calorific value of LOME is less than diesel. Hence, the engine consumes more biodiesel fuel to generate same power. It is observed that, BSFC is least for B20 blend [5, 48, 84, 53, 57, 58, 61, 63, 67, 68].

### 4.3 CO Emissions
Presence of CO in engine exhaust indicates poor combustion of the fuel which is highly undesirable. CO is also considered to be very toxic for all forms of life, hence higher levels of CO is highly undesirable. CO emissions decrease for all LOME blends as compared to standard diesel fuel. As the blend is enriched with linseed oil biodiesel, CO emissions are decreased. This is attributed to better combustion of LOME blends. The oxygen present in the biodiesel's molecular structure causes complete combustion of fuel and so CO emissions are reduced [17, 50, 54, 57, 58, 59, 60, 61, 64, 69, 70]. It is also reported that the percentage of oxygen increases and promotes complete combustion when linseed oil biodiesel is treated with ozone [40].

### 4.4 HC Emissions
HC emissions also indicate incomplete combustion of the fuel. Just like CO, HC is also considered to be very toxic, hence lower levels of HC is desirable. HC emissions may increase in fuel rich zones where atmospheric oxygen levels are lower and insufficient to cause complete combustion of fuel. HCs may also rise due to poor oxidability of the fuel. The study of different blends of linseed oil biodiesel revealed that when the blend is enriched with linseed oil biodiesel, HC emissions are decreased. Biodiesel fuels burn at higher temperature and the oxygen present in their molecule contributes in complete combustion. Hence, HC emissions are reduced [5, 17, 50, 54, 57, 58, 59, 60, 61, 64, 70]. On the other hand some researches contradict and have reported increase in HC emissions [66, 68].

### 4.5 NOx Emissions
NOx is formed during combustion of fuel in diesel engine. NOx may be formed inside combustion chamber due three possible reasons. They are:

i. Formation of NOx due to high temperature of combustion (2000K or more), is called as "Thermal NOx".
ii. Nitrogen content in the fuel leads to formation of "fuel NOx".
iii. NOx formed when atmospheric nitrogen reacts with fuel in fuel-rich zones during combustion is called as "Prompt NOx".

Biodiesel fuels burn at high temperatures. The higher temperature of combustion leads to formation of thermal NOx. NOx increase when linseed oil biodiesel is used in diesel engines. NOx emissions are highest for pure linseed oil as compared to other blends and standard diesel [5, 48, 50, 53, 54, 58, 60, 61, 63, 64, 65, 66, 68, 69, 70]. NOx emissions are considered to be harmful and undesirable as it is toxic in nature, contributes to depletion of ozone layer and causes acid rain.

### 4.6 Smoke Emissions
Smoke emissions indicate poor combustion of the fuel. It comprises tiny particles of unburnt fuel, released in the atmosphere. These emissions are undesirable as it cause respiratory syndromes to all forms of life. Smoke emissions also increase for all LOME blends. LB100 produced almost 60% more particulate matter (PM) while LB10 produced least PM than other blends. As the blend gets richer in linseed oil biodiesel, smoke emissions are increased. This may be attributed to poor atomization of fuel droplets due to high viscosity of the fuel. [5, 17, 48, 49, 50, 51, 53, 54, 56, 58, 59, 60, 61, 64, 65, 66, 69].

### 4.7 Engine Operation and Wear
Experimental investigations manifested that using linseed oil biodiesel or its blends in CI engines does not require any engine modifications. Macro-emulsions prepared from linseed oil biodiesel and alcohol up to 10% resulted in acceptable engine performance without noise [55]. Substantial reduction in wearing of engine parts is detected when the engine is operated with blends of linseed oil biodiesel. One of the possible reasons suggested for reduced wear was that linseed oil biodiesel has lubricating tendency. Wearing rate of vital engine parts reduced up to 30% for linseed oil biodiesel as compared to petroleum diesel. This concluded that engine life gets improved when biodiesel is used [51, 59].

## 5 CONCLUSION
Biodiesel fuels are very effective in reducing toxic tailpipe emissions. India and other developing countries can reduce their dependency for petroleum on gulf countries by cultivating biodiesel crops. Cultivation of biofuel crops contributes in controlling automotive pollution indirectly since plants absorb carbon dioxide and release oxygen in the atmosphere during their lifecycle. India possess huge amount of cultivable waste lands where linseed crop can be cultivated on a massive large scale. Oil content of linseed varies from 35 to 47% depending on breed harvested and climatic conditions. If all the oil is extracted from these seeds at 40% average yield rate, then also about 2.125 to 10 $x10^9$ kgs of linseed oil will be produced in addition to its current yield of $0.43x10^9$ kgs. Conversion of linseed oil to biodiesel using double TSDP method can be done up to 98% conversion efficiency. This gives an opportunity of producing up to $9.8x10^9$ kgs of linseed oil biodiesel in India. Linseed oil biodiesel is compatible existing diesel engines and do not require any alterations in engine. Therefore conventional diesel fuel could be replaced with linseed oil biodiesel. Experimental investigations have shown higher thermal efficiency, specific fuel consumption and lower CO and HC than standard diesel fuel. Many researchers also found that linseed oil biodiesel causes soot emissions and higher NOx than other biodiesel fuels. So NOx control strategies for linseed oil biodiesel must be applied or developed.

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