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Review Article

A REVIEW ON BIODIESEL AS EFFICIENT ALTERNATIVE FUEL ENERGY: CURRENT STATUS AND FUTURE PERSPECTIVES

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ABSTRACT

The world needs an alternative for transportation, although other automobile technologies like natural gas, hydrogen, and plug-in- electric are available, but not effective for long term uses. Further, climate change, volatile oil prices, depleting oil resources and an increasing demand of energy lead researcher to search for an alternative fuel, which would be economically efficient, socially equable and environment friendly. Biodiesel can be a suitable alternative for next generation fuel, as it does not contain any aromatic compound and a result of either transesterification of triglyseride or esterification of free fatty acids (FFAs). It is, whether pure or blended, produces low exhaust pH emissions, SO_2, hydro carbons, CO, toxin, compare too petrodiesel. In a developing country, like India, where vehicle emission standards are less stringent and where old polluting cars are more common, biodiesel are the best solution as they are nontoxic, biodegradable and an oxygenated fuel. Currently biodiesel cost 1.5-3 times than conventional diesel. The high cost of feedstock raw material is the main hurdle in commercialization of biodiesel production. To reduce its cost new alternatives like waste oil from food non-edible oils such as Jatropha, algal oil have been studied for the biodiesel production. Present paper is an attempt to review, how biodiesel have high potential in present scenario, and its future perspectives.

INTRODUCTION

Depleting fossil fuels and their contribution in climate change by emitting green house gases (GHGs) into the atmosphere, lead researcher to search for an alternative, which would be economically efficient, socially equable and environment friendly. Biodiesel appears as an effective alternative, which is, renewable, sustainable and could replace petroleum fuel. In 1895, Rudolf Diesel developed a new engine that could use a variety of fuels, including vegetable oil and start a new era in the field of fuels.

Biodiesel is defined by ASTM International as a fuel composed of monoalkyl esters of long chain fatty acid derived from renewable vegetable oils or animal fats meeting the requirement of ASTM D6751. Biodiesel is a liquid biofuel made from natural fats such as vegetable oils, algae or animal fats, through a process of esterification and transesterification. The environmental advantages in using biodiesel are: it is easy to use, as well as being biodegradable, non-toxic, reduces emissions of particulate, reduces emissions of carbon dioxide, its emissions causes 50% less ozone than conventional diesel fuel, and it is essentially free of sulfur and aromatics (Ragauskas *et al*., 2006). In addition, biodiesel can be a total or partial substitute for petroleum diesel to diesel engines through preparation of blends diesel/ biodiesel with different proportions. Thus, petrodiesel blended with 2%, 5%, 10% and 20% of biodiesel are known as B2, B5, B10 and B20, respectively, up to pure biodiesel (B100). The Major disadvantages of biodiesel are higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector coking, engine compatibility, high price, and higher engine wear (Khendewal, S. and Chahuan, R.Y., 2012).

Biodiesel Standards

Biodiesel holds promise as replacement fuels for modern diesel engines. However, their use in restricted by some unfavorable physical properties, like viscosity, which is about 10-20 times higher than that of diesel fuel .Consequently , vegetable oil causes poor fuel atomization, incomplete combustion, and carbon deposition. Many countries have established standards for biofuel to ensure that only high quality biodiesel reaches to the market. The two most important fuel standards ASTM (D6751-08) in the united states and EN-14214-2003 in the European union ((European committee for standardization, CEN). The Bureau of Indian Standards (BIS) has too evolved a standard (IS-15607) for Bio-diesel (B 100), which is the Indian adaptation of the American Standard ASTM D-6751 and European Standard EN-14214.and published as IS: 15601-05.

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ASTM (D6751-08), CEN-14214-03 and IS-15601-05 are summarized in table-1, 2 and 3 respectively. The petrodiesel standards ASTM D975 (ASTM-2003c) and EN 590(CEN2004) and IS:15601-05 allow up to 5% biodiesel (B5) as a blend component for biodiesel. Further, ASTM D7467 (ASTM 2008b) allows 6-20% biodiesel blend in petrodiesel and is summarized in table4.

Table 1 ASTM standards of biodiesel and petro diesel fuels

Property	ASTMD975 (petrodiesel)	ASTMD6751(biodiesel,B100)	
		Limits	Test Method
Composition	Hydrocarbans (C10-C21)	FAME(C12-C22)	NA
Specific Gravity(g/ml)	0.85	0.88	
Flash point (K min)	325	403 K	ASTM D93
Water and sediment	0.05 max %vol	0.05 max %vol	ASTM D2709
Kinematic viscosity (at 313K)	1.3-4.1mm^2/s	1.9-6.0 mm^2/s	ASTM D445
Sulfated ash	-	0.02 max %wt	ASTM D874
Ash	0.01 max %wt	-	
Sulfur (max %wt)	0.05	0.0015 (S15), 0.05(S500)	ASTM D5453
Oxidation stability h	-	3.0min	EN14112
Copper strip corrosion	No.3 max	No. 3max	ASTM D130
Cetane number	40 min	47 min	ASTM D613
Aromaticity	35 max %vol	-	
Total Glycerin (%mass)		0.240	ASTM D6584
Free Glycerin(%mass)		0.020	ASTM D6584
Carbon residue	0.35 max %mass	0.05 max %mass	ASTM D4530
Acid Value		0.50maxmgKOH/g	ASTM D664
Distillation temp (90% volume recycle)	555 K min-611 K max	360max	ASTM D1160
Pour Point (^{0}C)	-35-15	-15-16	
Hydrogen (wt%)	13	12	
Cloud Point (^{0}C)	-15-5	-3-12	ASTM D2500
Methanol		0.2 max	EN14110
Sodium and Potassium (ppm)		5max	EN14538
Calcium and Magnesium (ppm)		5Max	EN14538
Phosphorus		360 max	ASTM D1160
HFRR(µm)	685	384	
BOCLE scuff (g)	3600	>7000	

FAME- Fatty acid methyl ester, HFRR- High frequency reciprocating, BOCLE- Ball-on-cylinder

Table 2 European committee for standardization EN 14214 biodiesel fuel standard

Property	Test Method	Limits
Ester content (%mol/mol)	EN14103	96.5
Density, 15^{0}C(kg/m^3)	EN ISO 3675,EN ISO 12185	860-900
Kinematic Viscosity,40^{0}Cmm^2/s	EN ISO 3104, ISO3105	3.5-5.0
Flash point ^{o}C	EN ISO 3679	120 min
Sulfur Content mg/kg	EN ISO 20846, EN ISO 20884	10.0 max
Carbon residue (10% distillation residue)	EN ISO 10370	0.30 max
Cetane number	EN ISO 5165	51min
Sulfated ash (%mol/mol)	ISO 3987	0.02max
Water content(mg/kg)	EN ISO 12937	500max
Total contamination (mg/kg)	EN ISO 12662	24 max
Copper Strip Corrosion(3h, 50^{0}C) Degree of Corrosion	EN ISO 2160	1
Oxidation stability,110^{0}C h	EN 14112	6.0 min
Acid Value(mg KOH/g)	EN 14104	0.50 max
Iodine value (g I_2/100g)	EN 14111	120 max
Linolenic acid content (%mol/mol)	EN 14103	12.0 max
Polyunsaturated (>4double bond)Methyl esters (%mol/mol)	EN 14103	1 max
Methanol content(%mol/mol)	EN 14110	0.20 max
MAG content(%mol/mol)	EN 14105	0.80 max
DAG content(%mol/mol)	EN 14105	0.20 max
TAG content(%mol/mol)	EN 14105	0.20 max
Free Glycerol(%mol/mol)	EN 14105 EN 14106	0.020 max
Total Glycerol (%mol/mol)	EN 14105	0.25 max
Group I metals (Na, K) (mg/kg)	EN 14108, EN 14109	5.0 max
Group II metals (Ca, Mg) (mg/kg)	EN 14538	5.0 max
Phosphorus Content (mg/kg)	EN 14107	10.0max

Table 2 European committee for standardization EN 14214 biodiesel fuel standard

Table-3 ASTD7467 biodiesel-petrodiesel blend (B6-B20) fuel standards

Property	Test Method	Limits
Biodiesel Content (% Volume)	ASTM D 7371	6-20
Flash Point (Closed Cup)^{0}C	ASTM D 93	52min
Cetane Index	ASTM D 976	40 min
Aromaticity(% Volume)	ASTM D 1319	35 max
Water and sediment (% Volume)	ASTM D 2709	0.050 max
Kinematic viscosity, mm^2/s	ASTM D 445	1.9-4.1
Sulfur Content40^{0}C (ppm)	ASTM D 5453, ASTM D 2622	15 max (S15) 500 max
Copper Strip corrosion	ASTM D130	No3 max
Cetane number	ASTM D 613	40 min
Ramsbottom carbon residue(% mass)	ASTM D 524	0.35 max
Acid value(mg KOH/g)	ASTM D 664	0.30 max
Oxidation stability(h)	EN 14112	6.0 min
Ash contant(%mass)	ASTM D 482	0.01 max
Lubricity, HFRR, 60^{0}C(µm)	ASTM D 6079	520 max
Cloud point or LTFT/CFPP(^{0}C)	ASTM D 2500, D4539, D6371	Only guidance provided
Distillation temperature,90%recovered(^{0}C)	ASTM D 86	343 max

Table-4 Biodiesel Standards in India

Property	Test Method	Limit Min	Max
Density at 15^{O}C (Kg/m^3)	ISO 3675/P32	860	900
Kinematic viscosity at 40ºC (mm^2/s)	ISO3104/P25	2.5	6.0
Flash point (closed cup) ºC	P21	120	-
Sulphur mg/kg	D5443/P83	-	50
Carbon resiue (Ramsbottom) (m/m)	D4530	-	0.05%
Sulfated ash (m/m)	ISO6245/P4	-	0.02%
Water content (mg/kg)	D2709/P40	-	500
Total contamination (mg/kg)	EN12662	-	24
Copper corrosion 3 hr at 50ºC	ISO 2160/P15	-	1
Cetane number	ISO5156/P9	51	-
Acid value (mg KOH/g)	P1	-	0.50
Methanol EN 14110 – 0.20 % (m/m)	EN14110	-	20%
Ethanol (m/m)		-	0.20%
Ester content (m/m)	EN141.03	-	96.5%
Free glycerol, max (m/m)	D6584	-	0.02%
Total glycerol, max (m/m)m	D6584	-	0.25%
Phosphorous(mg/kg)	D4951	-	10.0
Sodium and potassium mg/kg	EN14108		5*
Calcium and Magnesiummg/kg	EN14538		5*
Iodine value	EN14104	To Report	
Oxidation stability at 110ºC hours	EN14112	6	-

***being included through amendment**

Biodiesel composition

The chemical composition (carbon – C, hydrogen – H and oxygen – O), the C/H ratio and the most significant difference between biodiesel and diesel fuel composition is their oxygen content, which is between 10 and 13%. The composition of biodiesel varies slightly depending on the feedstock it is produced from, as vegetable oil and animal fats of differing origin have dissimilar fatty acid composition. Many Scientist have studied the fatty acid composition derived from various sources are shown in table-5 (Gunstone and Harwood, 2007; Apple white, 1980).

High viscosity causes poor flow of fuel in the engine combustion chamber during intake stroke and takes a long time to mix with air. Therefore, it results in delayed combustion.

Table 5 Chemical composition of diesel fuel and biodiesel (wt. %)

	Oil/fat	Fatty acid Composition (wt. %)							
		C12:0	C 14:0	C 16:0	C 18:0	C 18:1	C 18:2	C 18:3	C 22:1
1	Babassu	44:45	15-17						
2	Canola			4	2	61	22	10	1-2
3	Coconut	44-51	13-18.5	7.7-10.5	1-3	5-8.2	1.0-2.6		
4	Corn (maize)			11	2	28	58	1	
5	Cottonseed	47	18	9	3	6	2		
6	Linseed			6	3.2-4	13-37	5-23	26-60	
7	Olive		1.3						
8	Palm		1	45	4	39	11		
9	Peanut		0.5	6-125	2.5-6	37-61	13-41		1
10	Rapeseed		1.5	1-4.7	1-3.5	13-38	9.5-22	1-10	40-64
11	Safflower			6.4-7	2.4-29	9.7-13.8	75-80		
12	Safflower (high oleic)			4.8	2.3-8	73-79	11-19		
13	Sesame			7-9	5-7	35-46	35-48		
14	Soybean			11	4	23	54	8	
15	Sunflower			6	5	29	58	1	1
16	Tallow(beef)	1	4	26	20	4	8	23	
17	Chicken fat		1	25	6	41	18	1	

C12:0= Methyl Laurate, C14:0= Methyl Myristrate, C16:0= Methyl Palmitate, C18:0= Methyl Stearate, C18:1= Methyl Oleate, C18:2= Methyl Linoleate, C18:3= Methyl Linolenate,C20:0= Methyl Arachidate, C22:0= Methyl Behenate

Biodiesel and its properties

Biodiesel is almost similar to petroleum diesel in many aspects and can be blended with petrodiesel in different proportion to make a suitable biodiesel blend. Density, viscosity, flash point, cetane number, cloud and pour point, and calorific value, among others are the most important fuel properties considered in the application of biodiesels in petrodiesel engines. Bauaid *et al* (2007), investigated used frying oils to study the effect on biodiesel quality during storage. They stored these oils in white and amber glass containers at room temperature for a period of 30-months. After regular intervals, they measured some physicochemical parameters such as acid value, peroxide value, viscosity, iodine value and insoluble impurities and found that the iodine value decreased with increasing storage time, but the other parameters increased through the storage. Therefore, all kinds of biodiesel were very stable because the increase of the three parameters was not fast. However, there is deterioration of the biodiesel after 12 months of storage and the specification limits of the parameters studied was exceeded after this period. The results obtained suggested that it is necessary to limit access to oxygen and exposure to light and moisture in order to obtain a highly stable biodiesel. (A. Bouaid, M. Martinez, J. Aracil, Fuel 86 2007).

Kinematic viscosity

Viscosity of any fuel is related to its chemical structure. Viscosity increases with the increase in the chain length and decreases with the increase in the number of double bonds (unsaturation level) [Goering, *et al*, 1982; Gorboski, 1998; Konthe, 2005)]. In addition, viscosity and heat content of the feedstocks and biodiesel fuels tend to increase together [Demirbas, 2003, Goering, *et al*, 1982].Viscosity is the most important property of fuel that must be considered to maintain engine performance and to monitor the fuel quality.

Density

The molecular weight of biodiesel is one of the factors that contribute in the increase in biodiesel density [Alptekin and Canakci, 2008]. Diesel has a density range of 816–840 kg/m3 (Phuan, *et.al*, 2009). All biodiesel fuels regardless of produced from vegetable oils or from fats are denser and less compressible than the diesel fuel. Hence, When a fuel with lower density and viscosity is injected, improved atomization and better mixture formation can be attained [Canakci and Gerpen.2003; Konthe, 2005;Graboski and Mccormick,1998; Tat, *et al*, 2000].

Cetane number (CN)

The cetane number is the prime indicator of fuel ignition quality. It can be defined as the measure of knock tendency of a diesel fuel. Higher CN implies shorter ignition delay. The CN of pure diesel fuel is lower than that of biodiesel [Pinzi, *et al*, 2009, Krishn a and Mallikarjuna, 2009]. The CN of biodiesel is higher because of its longer fatty acid carbon chains and the presence of saturation in molecules. Cetane number can also influence the cold engine starting and subsequent white smoke and noise emissions.

Flash point

The flash point is the temperature at which the fuel will start to burn when it comes to contact with fire (Ali *et al*, 1995). It is an important temperature from the safety point of view during storage and transportation At this temperature, vapor stops burning if the source of ignition is removed. Each biodiesel has its own flash point. Many factors affect the change in biodiesel flash point, with residual alcohol content being one of them [Todd, *et al*, 2007]. Moreover, flash point is influenced by the chemical compositions of the biodiesel, including the number of double bonds, number of carbon atoms, and so on. [Fang *et al*, 2005] flash point strictly corresponds to the amount of methanol. A fuel with high flash point may cause carbon deposits in the combustion chamber.

Cloud point and pour point

The cloud point is the temperature at which a cloud of wax crystals first appears in a liquid when cooled [Ali, *et al*, 1995]. The pour point is the lowest temperature at which the fuel will still flow and can be pumped [Lee *et al*, 1995]. All Biodiesel regardless of its source have higher cloud and pour points than conventional diesel fuel [Fernando, *et al* 2007, Sanford, *et al*, 2011]. This property is one of the most critical obstacles against the widespread use of biodiesel.

Biodiesel oxidation

This property shows the fuel's resistance to oxidation during extended storage. The presence of light, high temperature, metal, the material of the container, and other extraneous materials can affect the quality of biodiesel. Biodiesel oxidation leads to a variety of species including shorter-chain fatty acids, aldehydes as well as higher-molecular-weight species through oxidative polymerization. Besides that, the fatty acid profile of some feedstocks for biodiesel production can also affect the oxidative stability of this fuel. Oxidation eventually deteriorates the fuel properties because of gum formation. This formed gum does not combust completely, resulting in carbon deposits in the combustion chamber and lubrication oil thickening (Ma and Hanna, 199). Therefore, this parameter is one of the major issues affecting the use of biodiesel (Konthe, 2006(1); Konthe, 2006(2)). In fact, (Bouaid, *et al*, 2007) is an essential issue for the successful development and viability biodiesel.

Water content

Water can present in two forms, either as dissolved water or as suspended water droplets. Though biodiesel is generally considered to be insoluble in water, it actually takes up considerably more water than diesel fuel. Higher content of water in biodiesel might reduce the storage ability, promote microbial growth, lead to tank corrosion, participate in the formation of emulsions, and cause hydrolysis of FAME (Konthe *et al*, 2005). Therefore, the content of water is limited to 0.05% (w/w) according to EN 14214 and ASTM D 6751 standards (Table 1).

Methanol content

The residual methanol in biodiesel can cause corrosion of metals, mainly of aluminium, and decrease the biodiesel flash point. Besides, it is responsible for cetane number and lubricity decreasing of fuel. ASTM D 6751 limits indirectly the methanol content through the flash point minimum value. However, the EN 14214 standard, beside the flash point, establishes 0.2% (w/w) as the maximum content of methanol (Table 1). (Monteiroa, *et al*, 2008). Methnol contaminantion is usually results from insufficient purification of biodiesel following the transesterification reaction.

Metals and metalloids content

Metals and metalloids are also important issues in biodiesel quality control, since high contents can cause environmental problems or damage the engines. ASTM D 6751 and EN 14214 standards of biodiesel limit to 5.0mgkg 1 the amount of Na and K. Indirectly, these contents are also restricted through the sulphated ash value. On the other hand, the quantity of phosphorous is limited to 10.0mgkg 1, Ca and Mg to 5.0mgkg 1, and S to 10.0mgkg 1, according to EN 14214 (Table 1). (Monteiroa, *et al*, 2008)

Iodine number

Iodine number describes the content of unsaturated fatty acids and is only dependent on the origin of the vegetable oil. A limitation of unsaturated fatty acids may be necessary, due to the fact that heating higher unsaturated fatty acids results in polymerization of glycerides. This can lead to the formation of deposits or to deterioration of the lubricating oil. This effect increases with the number of double bonds in the fatty acid chain.

Calorific value

Calorific value is the measure of heat energy content of a fuel. Higher calorific value of fuel is desired because it releases higher heat and consequently improves engine performance during combustion (http://www.mnre.gov.in/list/oil-plants.pdfS, 2004, Yusuf *et al*, 2010, Nwafor,O, 2003). Biofuel usually has lower calorific value than diesel fuel because of its higher oxygen content [Ramadhas(1) *et al*,2005; Ramadhas(2) *et al*, 2005; Puhan *et al*, 2005]

The ash content of biodiesel

Sodium and potassium ash may be present due to the contamination from the catalyst used in transesterification. According to Mittelbach [Mittelbach,1996], the carbon residue is the most important indicator for the quality of biodiesel since it corresponds strictly to the content of glycerides, free fatty acids, soaps, remaining catalysts, and other impurities. However, Mahajan *et al*. [Mahajan *et al*, 2006] state that one of the most important features of biodiesel is the acid number, which represents almost exclusively the fatty acid content.

Lubricity

Lubricity, measures the extent to which a liquid diminishes friction. Two primary tests are used to measure lubricity: the Ball On Cylinder Lubricity Evaluator (BOCLE) and the high-frequency reciprocating rig (HFRR) test. A BOCLE test involves pressing a ball bearing against a rotating ring immersed in the diesel fuel. Weight is applied on the bearing until the diesel fuel fails, leaving a scuff mark on the rotating cylinder. The HFRR test consists of a ball that is placed on a flat surface and then rapidly vibrated back and forth with a stroke distance of one millimeter while 200 grams of weight is applied. The vibratory motion closely models engine vibration. After a given time, the flat spot that has been worn into the ball is measured (http://fiss.com/rm/firm0015.htm, http://www.pfs-pros.com/page14.html).

Biodiesel feed stocks

The continued demand of fuel, and to get rid from dependency on gulf countries for petrofuel, government mandates for alternative fuel usage and to increase global production there is a need for alternative sources for fuel. Globally, there are more than 350 oil-bearing crops identified as potential sources for biodiesel production. As much as possible the oil seed feedstock should fulfill majority of the significant requirements given below.

1. Adaptable to local growing condition (rainfall, soil type, latitude, regional climate etc.)
2. Regional adaptability and compatibility with existing farm infrastructure.
3. Low Agricultural inputs (water, fertilizer and pesticides) and defineable growth seasons.l
4. Ability to grow in agriculturally undesirable lands or off season from conventional commodity crops.
5. High oil content and favorable fatty acid composition
6. Contribution to biodiversity and effect on environment
7. Could create employment and large production sale

Generally, there are four major biodiesel feedstock: algae, oil seeds (edible and non-edible), animal fats and various low value material such as used cooking oil and can be broadly classified in to first, second and third generation fuels. Table- 6 Showing estimated oil content and yields of different biodiesel feed stocks [Ahmed *et al*, 2011, Janaun and Ellis, 2010; Balat and Balat 2010, Karmakar *et al*, 2010, Kkbazohi and Sangwan, 2011; Kumar and Sharma, 2011; Kumar *et al*, 2010; Balat, 2011; Chisti 2007; Demirbas, 2011; Lui, 2008; Mata *et al*, 2008; Yusuf *et al*, 2011; Wang *et al*, 2011; Hathurusingha *et al*, 2011].

Edible/Virgin Oil

Edible vegetable oils are called first generation of biodiesel feedstock because they were the first crops to be used for biodiesel production. Edible oils from crops such as soybean, peanut, sun flower, rapeseed, canola, coconut, palm, and mustard, have been evaluated in many parts of the world. Their plantations have been well established in many countries around the world such as Malaysia, USA and Germany. Currently, more than 95% of the world biodiesel is produced from edible oils such as rapeseed (84%), sunflower oil (13%), palm oil (1%), soybean oil and others (2%).

But use of such edible oil is not feasible in India, due to insufficient land and over increasing population, which may produce food vs fuel crisis. Moreover, in the last 10 years the prices of vegetable oil plants have increased dramatically which will affect the economical viability of biodiesel industry [Balat and Balat, 2010, Balat, M, 2011; Dex, *et al*, 2011]. Further, large scale production may affect environment and biodiversity.

Non-edible Oil

Non-edible oils are regarded as the second generation of biodiesel feedstocks. The main sources for biodiesel production from non-edible oils are jatropha, karanja, Almond, rubber seed, Desert date, Rice bran, Sea mango, neem, Koroch seed oil, mahua, Tobacco seed, Chinese tallow, silk cotton tree, jojoba, Sesame, Karang, babassu tree and Salmon oil. The use of non-edible oils for biodiesel production solves the food-versus-fuel concern and other issues (Gui, *et al*, 2008). Moreover, unproductive lands, degraded forests, cultivators' fallow lands, irrigation canals, and boundaries of roads and fields can be used for the plantation of non-edible oil crops. (Syers, *et al*, 2007; Ong, *et al*, 2013; Mustafa, 2011; Vedharaj *et al*, 2013).

Waste/ used cooking oil

Limited availability of vegetable oil feed stocks are always critical issues for the biodiesel production. The high cost of vegetable oils, which could be up to 75% of the total manufacturing cost, has led to the production costs of biodiesel becoming approximately 1.5 times higher than that for diesel (Ma and Hanna, 1999; Zhang, *et al*, 2003). The food processing industries and restaurants all over the world produce large amount of waste oil left after frying food items. Their disposal is always a great problem before world. Biodiesel from waste cooking oil solved their disposal problem easily. Since the cost of used oil is 5-10 time cheaper than the virgin oil, the total manufacturing cost of biodiesel can be significantly reduced (Zhang, *et al*, 2003). A similarity in the quality of biodiesel derived from used oil and from vegetable oils could be achieved at an optimum operating condition (Cetinkaya, *et al*, 2004).

Table-6 estimated oil content and oil yield in different feed stocks

S.No.	Feedstock	Oil content (%)	Oil yield (La/Ha/year)
1	Castor	53	1413
2	Jotropha	Seed: 35-40 Kernal: 50-60	1892
3	Linseed	40-44	-
4	Neem	20-30	-
5	Karanja	27-39	225-2250a
6	Soybean	15-20	446
7	Sunflower	25-35	952
8	Calophyllum inophyllum L.	65	4680
9	Moringa oleifera	40	-
10	Euphorbia lathyris L.	48	1500-2500a
11	Sapium sebiferum L. Kernel	12-29	-
12	Rapeseed	38-46	1190
13	Tung	16-18	940
14	Pachira glabra	40-50	-
15	Palm oil	30-60	5950
16	Peanut oil	45-55	1059
17	Olive oil	45-70	1212
18	Corn (germ)	48	172
19	Coconut	63-65	2689
20	Cottonseed	18-25	325
21	Ricebran	15-23	828
22	Sesame	-	696
23	Jojoba	45-50	1818
24	Rubberseed	40-50	80-120a
25	Seamango	54	-
26	Microalgae(Low oil content)	30	58,700
27	Microalgae(Medium oil content)	50	97,800
28	Microalgae(High oil content)	70	136,900a

A=kg oil/ha

Animal Fat and Grease:- Animal fat such as beef tallow, chicken fat, lamb meat and pork lard are Low value feed stocks for as a biodiesel Production. Animal fats are triacylglycerols, which are generally solid, but liquid at room temperature Thus, cannot be use directly as biodiesel. In animal fat, saturated fatty acid component accounts for almost 50% of the total fatty acids. Table- 7 illustrates fatty acid profile of biodiesel fuel obtained from animal fat and other low value feed stocks. Chakraworti *et al*., 2014, used animal fat and concluded that slaughter house animal fat and poultry fat can be used as biodiesel after transesterication process, However, direct transesterification may lead to formation of soap due to high acid number. Thus, a pretreatment with alcohol could reduce the FFA content of feed stock. Further, higher values of iodine number and kinematic viscosity offered a measure resistance to flow and shear. Table 8 shows the various properties of animal fat feed stock.

Rendered animal fats and restaurant waste oil are known as yellow grease, only when the FFA level is less than 15 wt% and brown greases if the FFA content is excess of 15%. (Canakei and Van Gerpen, 2001)

bioremediation (Pitman,*et al*, 2011; Mulbry *et al*,2008; Rawat, *et al*, 2010; www.wikipedia.org). Microalgae sequester CO_2 from fuel gases emitted from fossil fuel, fired power plants and other sources, thereby reducing emission of a major GHG. Microalgae can be harvested daily23. Biodiesel from algae is a new technology and immense research is required for its improvement.

Table -7 Fatty acid profile (wt %) of biodiesel fuels prepared from animal fats and other low value alternative feedstocks

Feedstock	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	24:0	ref
Salmon	6.8	14.9	6.1	3.2	15.6	2.1	11.5				1
Melon Bug		30.9	10.7	3.5	46.6	3.9					2
Sorghum Bug		12.2	1.0	7.3	40.9	34.5					2
Pork Lard		26.4		12.1	44.7	12.7	1.0				3
Beef Tallow	3.1	23.8	4.7	12.7	47.2	2.6	0.8				4
Chicken Fat	0.7	20.9	5.4	5.6	40.9	20.5					4
Waste frying oil	1.0	30.7	0.6	5.7	40.5	19.1	0.2	0.6	0.3	0.4	5
Waste cooking oil	16.3	10.6		3.3	8.2	2.0					6
Waste cooking oil		16.0		5.2	34.3	40.8					7
Used cooking oil	0.9	20.4	4.6	4.8	52.9	13.5	0.8	0.1			8
Used frying oil	0.2	11.9	0.2	3.8	31.3	50.8		0.3	0.5	0.2	9
Waste frying oil		8.4	0.2	3.7	34.6	50.5	0.6	0.4	0.8	0.3	10
Soybean soap stock		17.2		4.4	15.7	55.6	7.1				11
Yellow grease	2.4	23.2	3.8	13.0	44.3	7.0	0.7				12
Brown grease	1.7	22.8	3.1	12.5	42.4	12.1	0.8				12

1Chiou, *et al*, 2008, 2 Mariod *et al*, 2006; 3 Jeong *et al*, 2009; 4 Wyatt *et al*, 2005; 5 Predojevic 2008;6 Phan and Phan 2008; 7Meng *et al*, 2008;8 Leung and Guo, 2006; 9 Cetinkaya and Karaosmanoglu 2004; 10 Dias *et al*,2008;11 Haas 2005;12 Canakei and Van gerpen 2001

Table 8 Characteristics of slaughter house animal feed stocks viz. pork lard, tallow and fleshing oil. (Chaokraborty, *et al*, 2014)

Parameter	Pork lard	Beef tallow	Fleshing oil
Acid number (mg KOH/g of fat)	0.63	1.07	24.30
Iodine number (g/100g of fat)	77.9	46.37	75
Kinematic viscosity at 40^0 C(mm^2/s)	39.53	46.37	43.33
Higher heating point (Mj/kg of fat)	39.5	38.9	39.572

Algae

These are called third generation fuel. Algae are aquatic plants that lack the leaves, stem, roots, vascular systems, and sexual organs of the higher plants. They range in size from microscopic phytoplankton to gain kelp 200 feet long. They live in temperatures ranging from hot spring to arctic snows, and they come in various colors mostly green, brown and red. There are two types of algae; Macro algae and microalgae. It can produce upto 250 times the amount of oil per acre as soybeans and 7-31 time greater oil than palm oil. but the best algae for biodiesel would be microalgae. Microalgae are prokaryotic or eukaryotic photosynthetic microorganisms that can grow rapidly and live in harsh conditions due to their unicellular or simple multicellular structure. Examples of prokaryotic microorganisms are Cyanobacteria (Cyanophyceae) and eukaryotic microalgae are for example green algae (Chlorophyta) and diatoms (Bacillariophyta) [Richmond, 2004].

Microalgae transform the solar energy into the carbon storage products, leads to lipid accumulation, including TAG (triacylglycerols), which then can be transformed into biodiesel, bioethanol and biomethanol. It utilizes nitrogen and phosphorus from variety of waste water sources and providing the additional benefit of domestic and industrial waste water

Table shows the various microalgae which could use for biodiesel production along with their corresponding lipid content.

Table-9 Lipid content of different microalgae Organisms Lipid Content (% by dry weight)

Micro-algae	Lipid Content	references
Botryococcus braunii	25–75	Patil,*et al*, 2008, Tran, *et al*,2012
Chatoceros muelleri	33.6	Xue *et al*,2010
Chlorella sp	29	Natrah *et al*,2007
Cyclotella DI-35	42	Tran *et al*,2012
Ankistrodesmus TR-87	28–40	Barupal,*et al*,2010
Chlorella protothecoides (autotrophic/ heterothrophic)	15–55	Leduc, *et al*,2009
Chlorella emersonii	25-63	Xue *et al*,2010
Chlorella vulgaris	25-63	Xue *et al*,2010
Schiochytrium sp	50–77	Chisti,2007, Patil,*et al*,2008
Euglinagracilis	14-20	Xue *et al*,2010
Neochloris oleoabundans	35–54	Leduc, *et al*,2009, Chisti,2007,Rodolfi,*et al*,2009
Monallanthus salina	20	Leduc, *et al*,2009
Schizochytrium sp	50-77	Chisti,2007, Patil,*et al*,2008
Crypthecodinium cohnii	20-56	Swaff *et al*,2003
Scenedesmus sp	45-47	Patil,*et al*,2008
Phaeodactylum tricornutum	31	Fajardo et l,2007
Nitzschia TR-114	28–50	Meng, *et al*,2008
Nannochloropsis	31–68	Chisti,2007, Patil,*et al*,2008
Dunaliella tertiolecta	36–42	Shimizu,2003, www.wikipedia.com
Nannochloris	20-35	Patil,*et al*,2008

Worldwide production of biodiesel

Worldwide production of fats and oils was estimated in 174.6 million tons for the season 2010/2011. From that, 86% represent vegetable oils with soybean, palm, rapeseed, and sunflower seed as the major resources. Biodiesel has been in use in many countries such as United States of America, Malaysia, Indonesia, Brazil, Germany, France, Italy and other European countries. However, the potential for its production and application is much more. [Sharma and Singh, *et. al* 2009, Balat M, and Balat H, 2010; Johnston Mand Holloway T, 2007; Atadashi, *et al*, 2011]. Table 10 describe world oil crop distribution [FAO, USA, 2010; http://lipidlibrary.aocs.org/, 2011]. The annual world primary energy supply in 2009 has been estimated at 12,150 million tonnes of oil equivalent (Mtoe1). Just over one-third (36%) of the energy supply comes from oil. World annual final energy use (accounting for losses during conversion) in 2009 was 8,353 Mtoe, of which transport accounted for about 25% (IEA World Energy Statistics, 2011).

increase more than 14% per annum. Shrinking crude oil reserves and limited refining capacity, India will have to depend heavily on imports of crude. Hence, to secure a long-term supply of energy sources, to prioritize development, and to ensure the country's future energy, Government of India is promoting biofuels as an alternative energy source. Production of vegetable oil during 2003-04 in India illustrate below in table-7.

In December 2009, the Government came out with a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE), calling for blending at least 20% biofuels with diesel and petrol by 2017.

Table-10 World oil crop Distribution

Fats and oil	World Production (million tons)	Five major producer
Animal fat	24.4	USA, China, Brazil, Germany and France
Coconut oil	3.7	Philippines, Indonesia, India, Vietnam, and Mexico
Cottonseed oil	4.8	China, India, Pakistan, Uzbekistan, and USA
Groundnut oil	5.3	China, India, Myanmar, Nigeria and Sudan
Linseed oil	0.6	China, Belgium, USA, and Ethiopia and India
Maize oil	2.3	USA, China, Japan, Brazil and south Africa
Olive oil	2.9	Spain, Italy, Greece, Syrian Arab Republic, and Tunisia
Palm kernel oil	5.6	Indonesia, Malaysia, Nigeria, Thailand and colombia
Palm oil	23.9	Malaysia, Nigeria, Thailand, Colombia, and Cˆote d'Ivoire
Rapeseed oil	21.2	China, Germany, India, Canada, and France
Safflower oil	0.1	India, USA, and Argentina
Sesame oil	0.9	Myanmar, China, India, Sudan, and Japan
Soybean oil	36.0	USA, China, Brazil, Argentine and India
Sunflower oil	13.0	Russian Federation, Ukraine, Argentine, Turkey, and France

Although oil is expected to remain the largest source of energy, the oil share of world marketed energy consumption is expected to decline from 35% in 2007 to 30% in 2035 (http://www.eia.doe.gov/oiaf/ieo/pdf/0484%282010%29.pdf; 2010). The World Energy Forum has predicted that reserves will be exhausted in less than another 10 decades. Other believes that it will be depleted in fewer than 45 years if consumed at an increasing rate of 3% per annum (http://www.bp.com/productlanding.do?categoryId=6929&contentId= 7044622; 2010; Sharma and Singh, 2009; Ahmed at al, 2011; Kafuku and Mbarawa,2010). Hence, to fight energy crisis, many developed countries like United States spent around US $ 5.5 billion to 7.3 billion a year to accelerate the biofuel production (Thurmond, 2008). It is interesting to know that 75 % of total biodiesel production comes from European countries (TBW, 2008).

Current scenario of biodiesel in India

Currently, India's biofuel production accounts for only 1 per cent of its global production. As per an estimate, India consumed about 40.34 million tons of diesels in 2000–2001, which was 43.2% of the total consumption of petroleum products, and two-thirds of the demand was met by import costing about Rs. 200 billion. According to an estimate, Transportation sector consumed about 16.9% (36.5 m of oil equivalent) of the total energy (217 million t) in 2005-06 (TERI 2007). Within the transportation sector, the consumption of motor spirit (gasoline) grew by 6.64%, from 7.01 million t in 2001-02 to 11.26 million t in 2008-09 and that of high speed diesel (HSD) by 4.1%, from 36.55 million t to 51.67 million t (GOI 2009). This growth will only escalate over the next several years since India's vehicular population is expected to grow by 10-12% per annum. Hence, diesel consumption will

Indian biofuel policy's sailent features are given below

- An indicative target of 20% blending of biofuels both for biodiesel by 2017
- Biodiesel production from non-edible oilseeds on waste, degraded and marginal lands to be encouraged
- A Minimum Support Price (MSP) to be announced for farmers producing non-edible oilseeds used to produce biodiesel
- Financial incentives for new and second generation biofuels, including a National Biofuel Fund
- Biodiesel and bioethanol are likely to be brought under the ambit of "declared goods" by the Government to ensure the unrestricted movement of biofuels within and outside the states.

A National Biofuel Coordination Committee (NBCC) headed by the Prime Minister was set up to provide high-level coordination and policy guidance/review on different aspects of biofuel development.

In April 2010, the government decided to raise the minimum purchase price (MPP) of ethanol to Rs. 27.00 per litre from the previous level of Rs. 21.50 per litre so as to increase its availability for blending. With the increased price and the expected surplus production of sugar cane in 2010-11, the government hopes to meet the targets this year. Large-scale blending of biodiesel with conventional diesel has not yet started in India. Around 20 biodiesel plants annually produce 140- 300 million litres of biodiesel which is mostly utilized by the informal sector locally for irrigation and electricity generation and by the automobile and transportation companies for running their experimental projects (USDA, 2010). Demand projections for diesel suggest that nearly 3.21 million tonnes of biodiesel required for 5 per cent blending by the year 2011-12 (Table 12).(Shilong, *et al*. 2011)

Table 11 Production of oilseeds in 2002–2003 in India

Oilseed	Production (million tons)		Total oil availability (million tons)	% Recovery	Oil cost (Rs. per ton)
	World	India			
Soybean	123.2	4.30	0.63	17	4300
Cottonseed	34.3	4.60	0.39	11	3200
Groundnut	19.3	4.60	0.73	40	6200
Sunflower	25.2	1.32	0.46	35	5360
Rapeseed	34.7	4.30	137	33	5167
Sesame	2.5	0.62	-	-	6800
Palm krnals	4.8	-	-	-	-
Copra	4.9	0.65	0.42	65	3035
Linseed	2.6	0.20	0.09	43	-
Castor	1.3	0.51	0.21	42	-
Niger	0.8	0.08	0.02	30	-
Rice Bran	-	-	0.60	15	2000
Total	25	3.6	21.18	4.92	-

Table-12 Biodiesel Demand in India

Year	Diesel Demand	Biodiesel demand (% blending)		
		5%	10%	20%
2010-12	64.19	3.21	6.42	12.84
2016-17	92.15	4.61	9.21	18.43
2020-2021	123.06	6.15	12.31	24.61

Advantages and disadvantages of Biodiesel

Advantages of Biodiesel

1. **Easy to use: -** Biodiesel can be used directly or by blending with petroleum fuel to the engines without any modification in the motor engines. Further, it can be stored anywhere because not so inflammable like petrofuel (Shreena and Thangarey, 2009)
2. **CO_2 Mitigation and green House gases: -** Biodiesel does not emit any aromatic compounds and produces low PM (Particulate Matter), CO_2, SO_2, and lower aromatic Hydrocarbon emission. Biodiesel is a carbon neutral fuel, as the amount of CO_2 absorb during plant production emitted on combustion of oil.
3. **Biodegradability, and recycling:-** biodiesel is a cleaner fuel which is produced from 100% natural and renewable, biomasses, hence, it, creates favourable effects on the environment such as easy biodegradable, reduce in CO_2, So_X emissions during combustion.
4. **Employmemt and Economic feasibility:-**As sources of fossil fuels are continuously degrading resulted hike in price, further distillation process make s it more costlier. If this is the situation ,in near future biodiesel will be in demand, Hence a well planned structure of crops will provide a way of employment in rural and economically deprived areas.
5. **Other uses:-**Besides transportation fuel, biodiesel can be used as an aviation fuels to low-altitude aircraft (Dunn, 2000). According to Hashimoto et al, 2008, biodiesel may used for electricity production in turbines.

    1. Easy to use:
    2. Power and performance:
    3. CO_2 Mitigation and green House gases
    4. Toxic Emissions
    5. Biodegradability, safety and recycling
    6. Safe and stable fuel
    7. Other uses
    8. Economic feasibility

Disadvantages of biodiesel

Competition for fresh water and land: - Pressure on water resources increasing day by day due to population growth, trans-boundary mitigations, climate change, poverty, agricultural practices and natural calamities. Using irrigation to grow biofuel crops will aggravate for other uses and further impacting fresh water system**.** The water requirements of biofuel derived energy are 70 to 400 times larger than other energy sources such as fossil fuels, wind or solar. Roughly 45 billion cubic meters of irrigation water were used for biofuel production in the 2007, or some 6 times more water than people drink globally**.**

Biofuel crops require land, water, nutrients, and other inputs, and therefore compete with food crop for these resources. This competition contributes to conversion of grasslands, to deforestation, to and other land-use changes, with the associated adverse environmental effects. Land limits have a very strong social-economic component, sometimes more important than biophysical constraints, and in this sense local and regional contexts are critical. Land limits have a very strong social-economic component, sometimes more important than biophysical constraints, and in this sense local and regional contexts are critical

Impacts on food prices and poor

In 2007 and 08, price increases of food products reached alarming proportion triggering concern of a global food crisis that has been widely reported in the media (The economist, 2008). During this period, prices of wheat, rice and corn increased. By this most gravely affected are the poor, who spend 50-60% of their income on food (Brauan, V V, 2008)). As many as 1.2 million Asians are at great risks of malnutrition and food deprivation, because of the inflation in food prices. The factors that are responsible for food crisis are population, natural calamities, rising energy costs (electricity, fuel), crop productivity, lack of fertile land, policy inadequacy. Production of plants for fuel creates a fuel vs food controversy.

Biodiversity

Increased biofuel production will have negative impacts on biodiversity due to habitat loss, enhanced dispersion of invasive species, and agrochemical pollution. The consequences are likely to be very heterogeneous depending on the biodiversity characteristics and impact history of the region and the type of biofuel production Land conversions are perhaps the greatest threat to biodiversity, particularly deforestation and conversion of grasslands and savannas to biofuel crops**.**

Environmental effects

Biofuels are often promoted as a way to reduce global warming. However, some biofuel systems can increase the release of greenhouse gases relative to the fossil fuels they replace, thus aggravating global warming. Greenhouse gas emissions from biofuels occur from farming practices, refining operations, and the conversion of ecosystems to cropland for biofuel production. The details of how and where crops are grown, how crops are transported before being processed into fuels, and how fuels are made are all important in determining the net effect on greenhouse gas emissions.

Combustion of biodiesel emitted N_2O nitrous oxide from biofuel production N_2O is not so abudent ike CO_2 but it is the third most important gas in coming years**.**

Cold flow properties

Specific com pounds in diesel fuel and biodiesel tend to crystallize at low temperatures. This can cause filter plugging and even tu ally the fuel will become a solid mass. Certain varieties of algae, yeast, and fungi can also grow in the diesel fuel tanks. (Singaram L. 2009)

Future of Biodiesel

Biodiesel generated a new interest in searching of new feed stocks for biodiesel as it has potential to reduce pollution, and can solve the energy crisis. Though biodiesel has many significance, there remain several advantage in terms of development like in feed stock selection and production technologies.

In order to reduce the use of edible oil and to save biodiversity scientists are concentrating their attention towards perennial grasses, Algae, Forestry, Municipal waste, agricultural waste, wood and biotechnology for production of transport oil.

The major focus of researcher is to develop a fourth generation fuel which would be produced from genetically engineered microorganisms and plants. These plants and microorganism would produce high yield of oil, consume more carbon from atmosphere and release less carbon during combustion, and have a shorter life cycle, and won't require much land**.** Further these species may also be genetically engineered to be more resistant to pest, diseases and natural calamities (like drought**).** Crag Venter's company's "synthetic Genomics" is genetically engineering microorganisms to produce fuel directly from CO_2 on an industrial scale. (Marica PV, 2009)

Alage is a new candidate in the field of biodiesel. Today many strains of algae are recognized as a feedstock for biodiesel, but more research has been left.

Transesetrification process is based on uses of acid and base catalyst which enhances the total cost of fuel oil. Biochemical research has also focused on the use of enzyme produced by bacteria and fungi in producing biodiesel and to search new strain of bacteria, yeast and fungi that could perform this function efficiently.

CONCLUSION

Only tax exemption is not sufficient, if governments of India aggressively want to promote biodiesel, he has to continue to invest in research and development of biodiesel, than only biofuels could be capable in fulfilling the energy demands of country. The main challenge for biofuel production in India is the establishment of biofuel production system which is not steady, low-cost, and lack of highly efficient biofuel production technologies. Though, Bioethanol production from non food based feedstocks and biodiesel production from non-edible oil plants will be very promising developments. But India is now in the developing stage of large scale feedstock production bases and it has to measure a long way in establishing modern biofuel factories.

References

1. Ali Y, Hanna MA, Cuppett SL (1995) Fuel properties of tallow and soybean oil esters. J Am Oil Chem Soc 72:1557–1564
2. Ahmad AL, Mat Yasin NH, Derek CJC, Lim JK. Microalgae as a sustainable energy source for biodiesel production: a review. Renew Sustain Energy Rev 2011; 15(1):584–93.
3. Alptekin E, Canakci M. Determination of the density and the viscosities of biodiesel–diesel fuel blends. Renew Energy 2008; 33:2623–30.
4. Apple white, H.T., 1980. In Kirk –Orthmer, Encyclopedia of Chemical Technology,3rd edn, John Wiley and Sons, New York, NY, vol-.9,795-811
5. Atadashi IM, Aroua MK, Abdul Aziz A. Biodiesel separation and purification: a review. Renew Energy 2011; 36(2):437–43.
6. Balat M, Balat H. Progress in biodiesel processing. Appl Energy 2010; 87(6):1815–35.
7. Balat M. Potential alternatives to edible oils for biodiesel production – a review of current work. Energy Convers Manage 2011;52(2): 1479–92.
8. Botanic Garden of Indian Republic (BGIR). Data base of oil yielding plants. <http://www.mnre.gov.in /list/oil-plants.pdfS> (2004).
9. Bouaid A, Martinez M, Aracil J, 2007. Long storage stability of biodiesel from vegetable and used frying oils. Fuel 86, 2596-2602
10. Balat M, Balat H. Progress in biodiesel processing. Appl Energy 2010; 87(6):1815–35.
11. Balat M. Potential alternatives to edible oils for biodiesel production – a review of current work. Energy Convers Manage 2011;
12. Brauun, V. Van, 2008. Rising Food rises: What should be done? International food policy Research institute Washington DC, USA.
13. Barupal D.K., Kind T., Kothari S.L., Lee D.Y. and Fiehn O., Hydrocarbon phenotyping of algal species using pyrolysis-gas chromatography mass spectrometry, *BMC Biotechnology*, **10,** 1472-6750 **(2010)**
14. Chisti Y., Biodiesel from microalgae: A Review, *Biotechnology Advances,* **25,** 294-306 **(2007)**
15. Canakci M, Gerpen JV (2001).Biodiesel production from oils and fats with high free fatty acids.Trans. ASAE 44: 1429-1436.
16. Canakci M, Gerpen JV (2003) Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel and soybean oil biodiesel. Trans ASAE 46:937–944
17. Chaokraborty, R., Gupta, A.K., Chowdury, R, 2014. Conversion of slaughterhouse and poultry farm animal fats and wastes to biodiesel : Parametric sensitivity and fuel quality assessment. Renewable and sustainable energy reviews 29, 120-134.
18. Canakci M,Van Gerpen J., 2001. Biodiesel production from oils and fats with high free fatty acids. Trans ASAE 42:1429-1436.
19. Cetinkaya, M, Karaosmanoglu, F., 2004. Optimization of base-catalyzed transesterification reaction of used cooking oil. Energ.Fuel18:1888-1895.

20. Chiou, BU, EI-Mashad HM, Avena-Bustillos, RJ, Dunn, Ro, Bechtel, PJ, Mchugh, TH, Imam, SH, Glenn GM, Ortz, WJ, and Zhang, R, 2008. Biodiesel from Waste Salmon oil. Trans ASABE 51:797-802.
21. Dias, JM, Alvin-Ferraz, MCM, Almedia, MF, 2008. Comparison of the performance of different homogenous alkali catalysts during transesterification of waste and virgin oils and evaluation of biodiesel quality. Fuel 87:3572-3578
22. Deng X, Fang Z, Liu Y, Yu C. Production of biodiesel from Jatropha oil catalyzed by nanosized solid basic catalyst. Energy 2011; 36(2):777–84.
23. "Diesel Lubrication: Facts and Friction," http://www.pfs-pros.com/page14.html, accessed on September 20, 2003.
24. Demirbas A (2003) Chemical and fuel properties of seventeen vegetable oils. Energy Sources 25:721–728
25. Demirbas A. Biodiesel from oilgae, biofixation of carbon dioxide by microal-gae: a solution to pollution problems. Appl Energy 2011; 88(10):3541–7.
26. Dunn, R.O.2001. Alternative jet fuels from vegetable oils.Trans, ASAE44, 1751-1757.
27. F. Fang, H. Zeng, Jingxi Huagong Zhongjianti 35 (2005) 66.
28. Fernando S, Karra P, Hernandez R, Jha SK. Effect of incompletely converted soybean oil on biodiesel quality. Energy 2007; 32:844–51.
29. Food and Agriculture Organization of The United Nations (FAO), *Food Outlook*, FAO, New York, NY, USA, 2010.
30. GOI (Government of India). 2009. National Policy on Biofuels. New Delhi, India: Ministry of New and Renewable Energy. 18 pp.
31. Gunstone F.D., Harwood J.L. 2007.Occurrence and characterization of oils and fats. In: Gunstone F.D., Harwood J.L.,Dijkstra, A.J.(eds) The Lipid Handbook.3rd ed.CRC, Boca Raton, 37-142.
32. Goering CE, Schwab AW, Daugherty MJ, Pryde EH, Heakin AJ (1982) Fuel properties of eleven vegetable oils. Trans ASAE 25:1472–1477
33. Graboski MS, McCormick RL (1998) Combustion of fat and vegetable oil derived fuels in diesel engines. Prog Energy Combust Sci 24:125–164
34. Gui MM, Lee K, Bhatia S. Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock. Energy 2008; 33:1646–53.
35. Haas, MJ, 2005. Improving the economics of biodiesel production through the use of low value lipids as feedstocks: vegetable o. 1il soapstock. Fuel Process Technol. 86; 1087-1096.Jeong, GW, Yang, HS, Park, DH., Technol, 100, 25-30.
36. Hathurusingha S, Ashwath N, Midmore D. Provenance variations in seed-related characters and oil content of Calophyllum inophyllum L. in northern Australia and Sri Lanka. New Forests 2011;41(1):89–94
37. James WE, Jha S, L. Sumulang, H.H. San, R. Hasan, M.E. Kehan, G.Sugiyarto, and Zhai, F. 2008. Food Prices and inflation in developing Asia: Is Poverty reduction coming to an end? Asian Development Bank, Manila, Philippines.
38. Janaun J, Ellis N. Perspectives on biodiesel as a sustainable fuel. Renew Sustain Energy Rev 2010;14(4):1312–20.
39. Johnston M, Holloway T. A global comparison of national biodiesel production potentials. Environ Sci Technol 2007;41(23):7967–73.
40. Khendewal, S. and Chahuan,R.Y.,2012. Biodiesel production from non edible-oils: a review. Journal of Chemical and Pharmaceutical Research(4) 4219-4230
41. Knothe G (2005) Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters. Fuel Process Technol 86:1059–1070
42. Knothe,G. 2006. Analysing biodiesel : standards and other methods.J. Am. Oil Chem. Soc. 83 822-823.
43. Knothe,G Eur. J. Lipid Sci. Technol. 108 (2006) 493.
44. Krishna BM, Mallikarjuna JM. Properties and performance of cotton seed oil–diesel blends as a fuel for compression ignition engines. J Renew Sustain Energy 2009;1:1–10.
45. Karmakar A, Karmakar S, Mukherjee S. Properties of various plants and animals feedstocks for biodiesel production. Bioresour Technol 2010;101(19):7201–10.
46. Kibazohi O, Sangwan RS. Vegetable oil production potential from Jatropha curcas, Croton megalocarpus, Aleurites moluccana, Moringa oleifera and Pachira glabra: assessment of renewable energy resources for bio-energy production in Africa. Biomass Bioenergy 2011;35(3):1352–6.
47. Kumar A, Sharma S. Potential non-edible oil resources as biodiesel feed-stock: an Indian perspective. Renew Sustain Energy Rev 2011;15(4): 1791–800.
48. Kumar BP, Pohit S, Kumar R. Biodiesel from jatropha: can India meet the 20% blending target? Energy Policy 2010; 38(3):1477–84.
49. Lee I, Johnson LA, Hammond EG (1995) Use of branched-chain esters to reduce the crystallization temperature of biodiesel. J Am Oil Chem Soc 72:1155–1160
50. Leung, DYC, Guo, Y, 2006. Transesterification of neat and used frying oil: optimization for biodiesel Production. Fuel Process Technol, 87, 883-890.
51. Leduc S., Natarajan K., Dotzaue E., McCallum I. and Obersteiner M., Optimizing biodiesel production in India, *Applied Energy,* **86,** 125–131 **(2009)**
52. Ma F, Hanna MA (1999) Biodiesel production: a review. Bioresour Technol 70:1–15
53. Marcos Roberto Monteiroa, Alessandra Regina Pepe Ambrozin, Luciano Morais Liãob, Antonio Gilberto Ferreirac.Critical review on analytical methods for biodiesel characterization.Talanta 77 (2008) 593–605
54. Mahajan S, Konar SK, D.G.B. Boocock, J. Am. Oil Chem. Soc. 83 (2006) 567.
55. Mata TM, Martins AA, Caetano NS. Microalgae for biodiesel production and other applications: a review. Renew Sustain Energy Rev 2010; 14(1):217–32.
56. Mittelbach, M, 1996. Bioresour. Technol. 56, 7.

57. Mustafa B. Potential alternatives to edible oils for biodiesel production – a review of current work. Energy Convers Manage 2011; 52:1479–92.
58. Marica, PV, 2005. A review of the advances in biofuels production. Doct-US, An 1, Nr.1, 77-83.
59. Mariod A, Klupsch, S, Hussian, H, Ondruschka B., 2006.Syntesis of alkyl esters from three unconventional Sudanese oils for their use as biodiesel. Energ.Fuel. 20:2249-2252.
60. Meng, X, Yang, Y, Xa, X, Zhang,L, Nie, Q, Xian, M 2009. Biodiesel production from oleaginous microorganisms. Review energy, 34, 1-5
61. Meng, X, Chen, G, Wang, Y., 2008. Biodiesel Production from waste cooking oil via alkali catalyst and its engine test. Fuel Process ?Techno.89,851-857.
62. Mulbry W., Kondrad S., Pizarro C. and Westhead E.K., Treatment of dairy manure effluent using freshwater algae: Algal productivity and recovery of manure nutrients using pilot-scale algal turf scrubbers, *Bioresource Technology*, 8137–8142 **(2008)**
63. Nwafor O. The effect of elevated fuel inlet temperature on performance of diesel engine running on neat vegetable oil at constant speed conditions. Renew Energy 2003;28:171–81.
64. Ong H, Silitonga A, Masjuki H, Mahlia T, Chong W, Boosroh M. Production and comparative fuel properties of biodiesel from non-edible oils: Jatropha curcas, Sterculia foetida and Ceiba pentandra. Energy Convers Manage 2013;73:245–55.
65. Patil V., Tran K.Q. and Giselrod H. R., Towards Sustainable Production of Biofuels from Microalgae: A Review, *Int. J. Mol. Sci.,* **9,** 1188-1195 **(2008)**
66. Pittman J.K., Dean A.P. and Osundeko O., The potential of sustainable algal biofuel production using wastewater resources, *Bioresource Technology,* **102,** 17–25 **(2011)**
67. Paula- Bianca Marica 2009. A review of the advances in biofuels production. Doct-US, An I,
68. Puhan S, Vedaraman N, Ram BV, Sankarnarayanan G, Jeychandran K. Mahua oil (Madhuca indica seed oil) methyl ester as biodiesel-preparation and emission characteristics. Biomass Bioenergy 2005;28:87–93.
69. Puhan S, Vedaraman N, Ram BV, Sankarnarayanan G, Jeychandran K. . Effect of injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine. Renew Energy 2009;34:1227–33.
70. Pinzi S, Garcia IL, Gimenez FJL, Castro MDL, Dorado G, Dorado MP. The ideal vegetable oil-based biodiesel composition: a review of social. Econ Tech Implic Energy Fuels 2009;23:2325–41.
71. Phan, AN, Phan, TM, 2008. Biodiesel production from waste cooking oil. Fuel 87: 3400-3496.
72. Predojevic, ZJ, 2008. The Production of biodiesel from waste frying oil:a comprasion of different purification steps . Fuel 87: 3522-3528.
73. Ramadhas AS, Jayaraj S, Muraleedharan C(1). Biodiesel production from high FFA rubber seed oil. Fuel 2005;84:335–40.
74. Ramadhas CMuraleedharan, Jayaraj S(2). Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil. Renew Energy 2005;30:1789–800.
75. Ragauskas AJ, Williams CK, Davison BH, Britovsek G, Cairne J, Eckert CK, Frederick WJ, Hallett JP ,Leak DJ, Liotta CL, Mielenz JR, Murphy R, Templer R, Tschaplinski T 2006. The Path Forward for Biofuels and Biomaterials. Science (7) 311- 484.
76. Rodolfi L., Zittelli G.C., Bassi N., Padovani G., Biondi N.,Bonini G. and Tredici M.R., Microalgae for Oil: Strain Selection, Induction of Lipid Synthesis and Outdoor Mass Cultivation in a Low-Cost Photobioreactor, *Biotechnologyand Bioengineering,* **102,** 100-112 **(2009)**
77. Rawat I., Ranjith Kumar R., Mutanda T. and Bux F., Dual role of microalgae: Phycoremediation of domestic wastewater and biomass production for sustainable biofuels production, *Applied Energy*, **88,** 3411-3424 **(2010)**
78. Ranganatham, SV, Narasimha, L, Muthukumar, K. An overview of enzymatic production of biodiesel. Bioresources. Technol.99:3975-3981.
79. Shimizu Y., Microalgal metabolites, *Current Opinion in Microbiology*, **6,** 236–243 **(2003)**
80. Shinoj P, Raju SS, R. Chand,Kumar, P. and S. Msangi,2011.Biofuels in India: Future Challenges.ICAR. Pd.36 PDF.
81. Singaram, L. 2009. BIODIESEL: An Eco-friendly alternate fuel for the future – A review. Thermal Science: Vol. 13 (2009), No. 3, pp. 185-199
82. Shereena, KM, Thangaray, T, 2009. Biodiesel : an alternative fuel Produced from vegetable oils by transesterification. Electronic Journal of Biology, 5(3), 67-74.
83. Sanford S, White J, Shah P, Wee C, Valverde M, Meier G. Feedstock and biodiesel characteristics report. <http://www.regfuel.com/pdfs/FeedstockandBiodiesel Characteristics Report.pdf> (2011).
84. Sharma YC, Singh B. Development of biodiesel: current scenario. Renew Sustain Energy Rev 2009;13(6–7):1646–51.
85. “Stanadyne White Paper on Diesel Fuel,” http://fiss.com/rm/firm0015.htm, Accessed onAugust 26, 2003.
86. Syers JK, Wood D, Thongbai P. The proceedings of the international technical workshop on the feasibility of non-edible oil seed crops for biofuel production. Mae Fah Luang University, chiang Rai, Thailand; 2007.
87. Tat ME, Gerpen JV, Soylu S, Canakci M, Monyem A, Wormley S 2000. The speed of sound and isentropic bulk modulus of biodiesel at 21°C from atmospheric pressure to 35 MPa. J Am Oil Chem Soc 77:285–289.
88. TERI (The Energy and Resources Institute). 2007. TERI energy data directory and yearbook 2006-07. New Delhi, India: TERI. 527 pp.
89. Todd MS, Peters T, LeCaptain DJ, 233rd ACS National Meeting, paper CHED-299, Chicago, March 25–29, 2007.
90. Thurmond, W. biodiesel 2020: global Market Survey, feed stock trends and market forecasts. Emerging

Markets online 2008.Availabl/e at Http:// www.emergingmarkets .com/biodiesel/default.asp
91. TBW.2008.Biofuels: the promise and risks.The world bank.
92. The Economist: The new face of Hungry, 2008.Vol.387.No.8576, 19-25th 30-32, London, U.K., April.
93. USDA (United States Department of Agriculture) (2010) India, Biofuels Annual, 2010. GAIN Report IN 1058. Foreign Agricultural Service, New Delhi.
94. Vedharaj S, Vallinayagam R, Yang W, Chou S, Chua K, Lee P. Experimental investigation of kapok Ceiba pentandra oil biodiesel as an alternate fuel for diesel engine. Energy Convers Manage 2013;75:773–9.
95. Wang R, Hanna MA, Zhou WW, Bhadury PS, Chen Q, Song BA, Yang S. Pro-duction and selected fuel properties of biodiesel from promising non-edible oils: Euphorbia lathyris L.: Sapium sebiferum L. and Jatropha curcas L. Bioresour Technol 2011;102(2):1194–9.
96. Wyatt, VT, Hess, M A, Dunn, RA.,Fogila, TA, Hass, MJ, Marmer WM, 2005. Fuel Properties and nitrogen oxide emission levels of biodiesel produced from animal fats. J. Am. Oil Chem, Soc, 82, 585-591.
97. www.wikipedia.com
98. Xue F., Gao B., Zhu Y., Zhang X., Feng W. and Tan T.,Pilot-scale production of microbial lipid using starch wastewater as raw material, *Bioresource Technology,* **101,** 6092–6095 **(2010)**
99. Yusuf S,KKNNAN, Yaakub Z. Overview on the current trends in biodiesel production. Energy Convers Manage 2010; 52:2741–51.
100. Yusuf NNAN, Kamarudin SK, Yaakub Z. Overview on the current trends in biodiesel production. Energy Convers Manage 2011; 52(7):2741–51.
101. Zhang Y, Dube MA, McLean DD, Kates M. Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. Bioresour Technol 2003; 90:229–40.

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