Chapter 1

A Review of Selected Non-Edible Biomass Sources as Feedstock for Biodiesel Production

Emad A. Shalaby

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/59178

1. Introduction

Biofuels are being given serious consideration as potential sources of energy in the future. Due to recent petroleum crisis and unavailability of petroleum diesel, the need for petroleum diesel is increasing day by day hence there is a need to find out an appropriate solution. The use of renewable resources for energy production is a strategic focus of governmental institutions to restructure the national energy economies, and many efforts are undertaken to increase the share of renewable energies within the nation; biodiesel is presently the most widely accepted alternative fuel for diesel engines due to its technical, environmental and strategic advantages. Biodiesel is known as a carbon neutral fuel because the carbon present in the exhaust is originally fixed in the atmosphere. Moreover, different vegetable oils can be used for biodiesel production like soybean oil, jatropha oil, rapeseed oil, palm seed oil, sunflower oil, corn oil, peanut oil and cottonseed oil in addition to the possibility for use of waste cooking oil, and algal species (micro and macroalgae). Compared to fossil-based diesel fuels, biodiesel possesses many advantages such as cleaner engine emissions, biodegradable, renewable and superior lubricating property. However, until now biodiesel is not yet commercialized all over the world. And this may be due to the high cost of the raw material. Biodiesel Free on Board (FOB) costs between 0.65 and 1 U.S. dollars (USD/L). The biodiesel production cost is nearly 1.5–2 times more than petroleum-based diesel depending upon feedstock oils. It is reported that nearly 70%–95% of the total cost of biodiesel production arises from the cost of raw material; i.e., vegetable oil or animal fats. The cost of biodiesel can be reduced if we use available, non-coasted, unused biomass such as non-edible oils as frying oils, acid oils and agriculture waste oils instead of edible oils.

2. Non-edible biomass sources

2.1. Date palm seeds

The date (*Phoenix dactylifera*) has always played an important role in the economy and social life of the people of arid and semiarid regions of the world. *Phoenix dactylifera* (date or date palm), a flowering plant species in the palm family Arecaceae, is one of the member of the genus *Phoenix*, widely cultivated for its edible fruit. Dates have been a staple diet in the Middle East for thousands of years. Date seeds, considered as waste product, are either discarded or used as fodder for domestic farm animals. Egypt is considered the first rank in the production of date as shown in Table 1. The total world production of date fruits was about 6.64 million tons in 2007 [1], with Egypt, Iran, Kingdom of Saudi Arabia, UAE and Pakistan being the main producing countries. Habib and Ibrahim [2] found that, the relative percentage of date seeds to the date fruits ranges 6.10%–11.47%. The same author also estimated the annual world production of date seeds at about 697,000 tons in 2007. Date seeds are commonly considered as a waste product (Figure 1) that is either discarded or used in animal feed. However, date seeds have been shown to possess extractable high value added components [3]. Date seeds, which are low cost agriculture by-products, can be used for production of activated carbon.

Figure 1. Date palm seeds pictures.

In an attempt to make use of this costless date seeds for biodiesel production, Shanab et al [4] found that the oil content (extracted with petroleum ether) in the four date seed cultivars ranged between 3.31% and 4.48% as recorded in Table 2.

Ramly showed the highest oil content (4.48%) followed in descending order by Amhat (3.88%) then Sewy (3.34%) and Haiany (3.31%).

It is evident from these results and previous investigations that, date seeds do not provide high yield of oil [2], but the oil may serve as a potential source of some important phytochemicals [3].

Transesterification of the extracted date seed oils by Methanol/KOH mixture led to the production of fatty acid methyl esters (biodiesel).

2.1.1. Physico-chemical properties of produced biodiesel from date palm seeds

Iodine value (IV) is a measure of unsaturation degree. The obtained results revealed that date seed cultivars showed different iodine values (mg I_2/g), which ranged between 90.4 mg/g in Sewy, 88.5 in Amhat, 86.3 in Haiany and 75.3 mg/g in Ramly (Table 3).

These variable contents may be due to high content of saturated fatty acids in their oils, which was confirmed by the GC analysis of the four date seed cultivars.

Shalaby and El-Gendy [5] reported that waste cooking oil and its methyl esters have low iodine values (~ 62, 60 mg I_2/100g oil). Also, JUS [6] illustrated that, methyl esters used as biodiesel fuel must have an iodine value less than 120 mg I_2/100g of the oil sample (JUS EN 14214). This means that the iodine values of the produced biodiesel from date seed oils in this study (75.3–90.4 mg I_2/g) as well as from *Phoenix canariensis* seed oil (76.66 mg I_2/g) were due to the high contents of saturated fatty acids leading to low or even no oxidation tendency in these oils [7].

The low Acid values (AV) recorded in the four cultivars of date seed oils ranged 0.5–0.92 mgKOH/g, and these results indicated that these oils can be stored for longer periods without deterioration, which seems in conformity with the results reported by Ojeh [8].

Acid value of biodiesel was shown to be higher than that of standard petrodiesel, but it meets the standard limits of EN 14215 and D-6751, indicating that the free fatty acids content will not cause operational problems such as corrosion and pump plugging caused by corrosion and deposit formation.

Variable saponification values (SV) in the studied four date seed cultivars (185.4–202.3 mgKOH/g) of the *P. canariensis* seed oil (191.28) indicated the presence of low molecular weight triacylglycerols, which are in conformity with those reported by Eskin *et al.*, [9] and Oomah *et al.*, [10] who declared that their saponification values are similar to values of canola oil and raspberry seed oil.

More or less similar higher heating values (HHV, Table 4) of the produced fatty acid methyl esters (39.84 kg/g–40.50 kg/g) indicated that they have nearly similar stability values due to their low polyunsaturated fatty acids contents in their oils, which were clearly observed in the GC analysis of fatty acid methyl esters (Table 5).

Infrared spectrum (IR) of the produced biodiesel showed the presence of ester group (-C-O-) at bands 1027, 1165 and 1745, as well as the absence of the hydroxyl peak, which can be correlated to the transesterification process of date seed oil (Figure 2).

These results were concomitant with those reported by Shalaby and El-Gendy (2012) on waste cooking oil methyl ester.

Fatty acid composition of the esterified products using gas chromatography (GC) revealed the presence of eight saturated fatty acids ($C_{8:0}$–$C_{18:0}$) in the three date seed cultivars: Amhat, Ramly and Haiany, while cultivar Sewy has only seven saturated fatty acids as recorded in Table 5.

The highest percentage of saturated fatty acids was shown in Amhat cultivar (79.517%) followed in descending order by those of Haiany (68.135%), Sewy (45.764%) and Ramly (20.986%).

The fatty acids caprylic ($C_{8:0}$) and capric ($C_{10:0}$) constituted the largest percentage of saturated fatty acids in the studied date seeds. Ramly cultivar was the only date seed containing Arachidic fatty acid ($C_{20:0}$) of 0.441%.

The recorded unsaturated fatty acids were oleic ($C_{18:1}$) and Linoleic ($C_{18:2}$), which were present in variable relative percentages in only three of the four date seed cultivars (24.64% in Ramly to 0.573% in Sewy), while linoleic acid was absent in Amhat cultivar (Oleic represented by 1.88%).

Ramly recorded the most pronounced content of unsaturated fatty acids (20.99% Oleic + 3.65% Linoleic), and the least percentage of saturated fatty acids (20.986%).

Our results go parallel with those published by Nehdi *et al*. [11] on date palm seeds and seed oils.

Yong and Salimon [12] reported that liquid oils with high oleic fatty acid content (as Ramly oil) normally have good flavor and frying stability.

Oleic acid is important in nervous cell construction and can be changed in the organism into a set of compounds close to prostaglandin, which have an important role at the vessel level and for blood coagulation [13]. So, Ramly can be of importance in this concern.

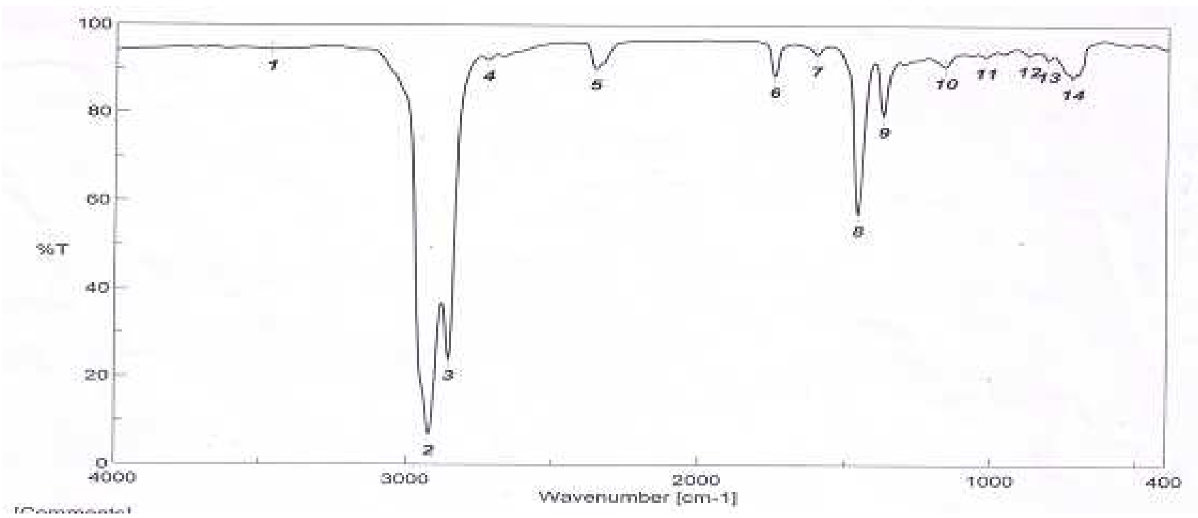


Figure 2. Infrared spectrum of Fatty acid methyl ester (FAME) of date palm seed.

Country	Production (tons)	% World
Egypt	1,352,950	17.2
Saudi Arabia	1,078,300	13.7
Iran	1,023,130	13.0
United Arab of Emirrate	775,000	9.8
Pakistan	759,200	9.6
Algeria	710,000	9.0
Iraq	566,829	7.2
Sudan	431,000	5.4
Oman	276,400	3.5
Libya	161,000	2.0
Arab countries	5,351,479	68.11
Asia	4,804,126	61.1
Africa	3,011,205	38.3
America	26,003	0.3
Europe	16,121	0.2
World	7,857,455	100

Table 1. Total date production by different countries and continents [1].

Species	Oil (%)	Biodiesel %	Glycerol %
Amhat	3.88	2.05	1.26
Ramly	4.48	2.43	1.43
Siwy	3.34	1.90	1.33
Haiany	3.31	1.84	1.34

Table 2. Oil contents, Biodiesel and glycerol (%) in different date seed cultivars [4].

Species	Acid value (mg KOH/g)	Iodine value (mg I_2/g)	Saponification value (mg KOH/g)
Amhat	0.92	88.5	185.4
Ramly	0.50	75.3	199.0
Siwy	0.67	90.4	192.5
Haiany	0.72	86.3	202.3

Table 3. Some chemical properties of methyl esters of date seed [4].

Species	HHV (Kj/g)	CN
Amhat	40.50	60.52
Ramly	40.14	55.42
Siwy	40.18	57.03
Haiany	39.84	54.61

Table 4. Higher heating value (HHV) and cetane number (CN) of fatty acid methyl esters of date seed cultivars [4].

Fatty acids	RT	Relative % of Fatty acids in different Date seeds			
		Amhat	Ramly	Sewy	Haiany
C8:0	**7.3**	50.77	-	-	47.35
C10: 0	**11.16**	28.37	-	57.06	26.88
C11:0	**13.36**	5.44	1.07	-	8.9
C12:0	**15.51**	2.77	1.55	9.69	4.82
C13:0	**17.51**	5.93	22.9	14.9	5.9
C14:0	**19.61**	2.62	4.52	10.38	4.72
C15:0	**21.45**	0.97	4.61	3.08	2.7
C16:0	**23.27**	0.79	7.63	2.48	0.39
C17:0	**24.9**	-	1.50	1.10	-
C18:0	**26.63**	-	0.85	-	0.37
C18:1	**27.16**	2.31	45.9	1.04	1.22
C18:2	**28.06**	-	7.98	0.19	0.48
C18:3	**29.28**	-	-	-	-
C20:0	**29.76**	-	0.96	-	-
SFA		97.69	46.12	98.77	98.3
USFA		2.31	53.88	1.23	1.7
SFA/USFA ratio		42.3/1	0.85/1	80.3/1	57.8/1

*R_t: Retention time; SFA: Saturated fatty acids; USFA: Unsaturated fatty acids

Table 5. Fatty acids content in different commercial date seeds cultivars [4].

2.2. Non-edible plants (e.g., Jatropha)

Jatropha is a genus of flowering plants in the spurge family, Euphorbiaceae. Jatropha is a drought-resistant perennial, growing well in marginal/poor soil and considered as one of the best candidates for future biodiesel production. Jatropha the wonder plant produces seeds (Figure 3) with an oil content of around 27%–40%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. Oil contains also insecticide. It can also be used as a bio-pesticide and for medicinal purposes. It is found to be growing in many parts of the country, is rugged in nature, can survive with minimum inputs, and is easy to propagate, and these growth conditions give this plant the big chance for selection as biofuel sources.

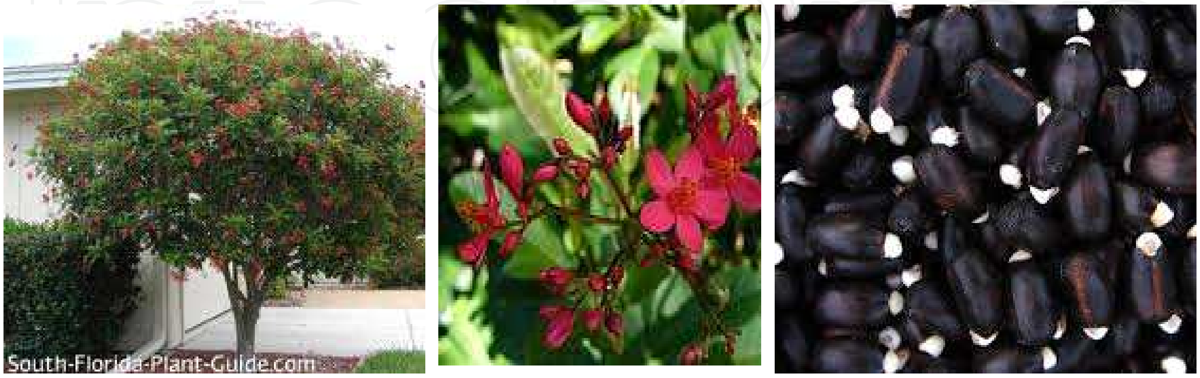


Figure 3. Pictures of Jatropha tree and seeds.

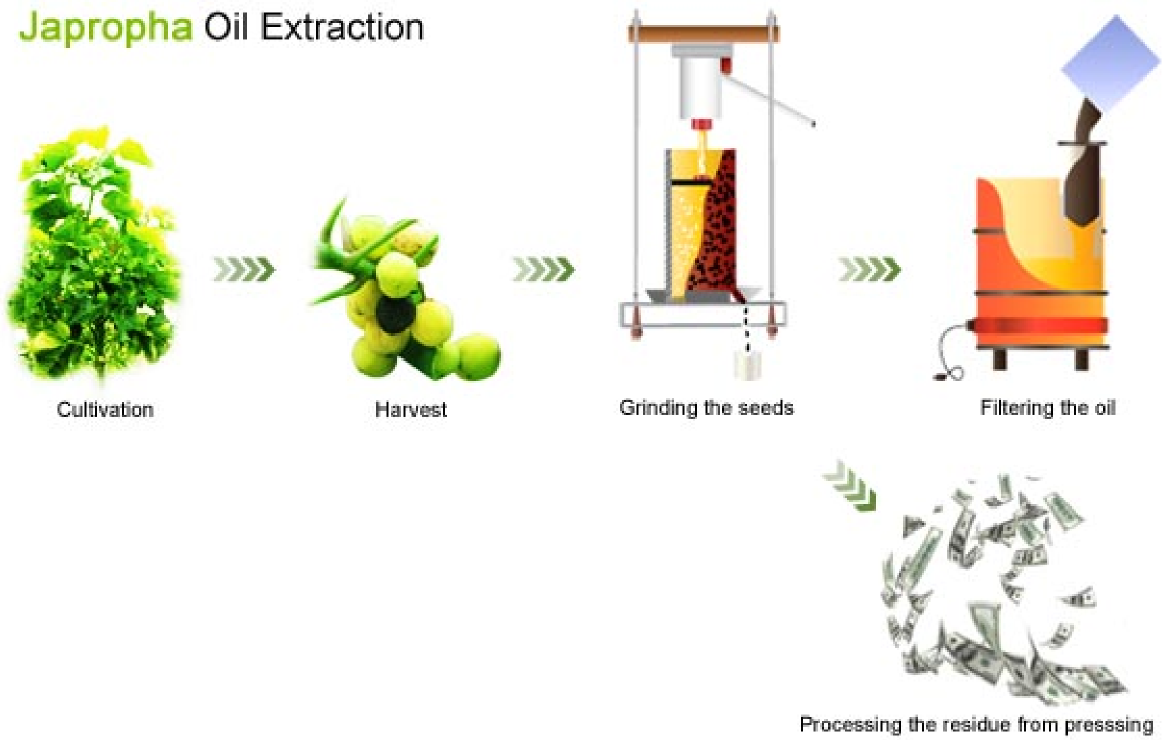


Figure 4. Jatropha oil extraction method. (http://www.aumkiipure.com/oil-extraction.html)

The suitability of a particular oil type from Jatropha species depends on its chemical and physical properties and the plant origin. The fatty acids composition is very important for

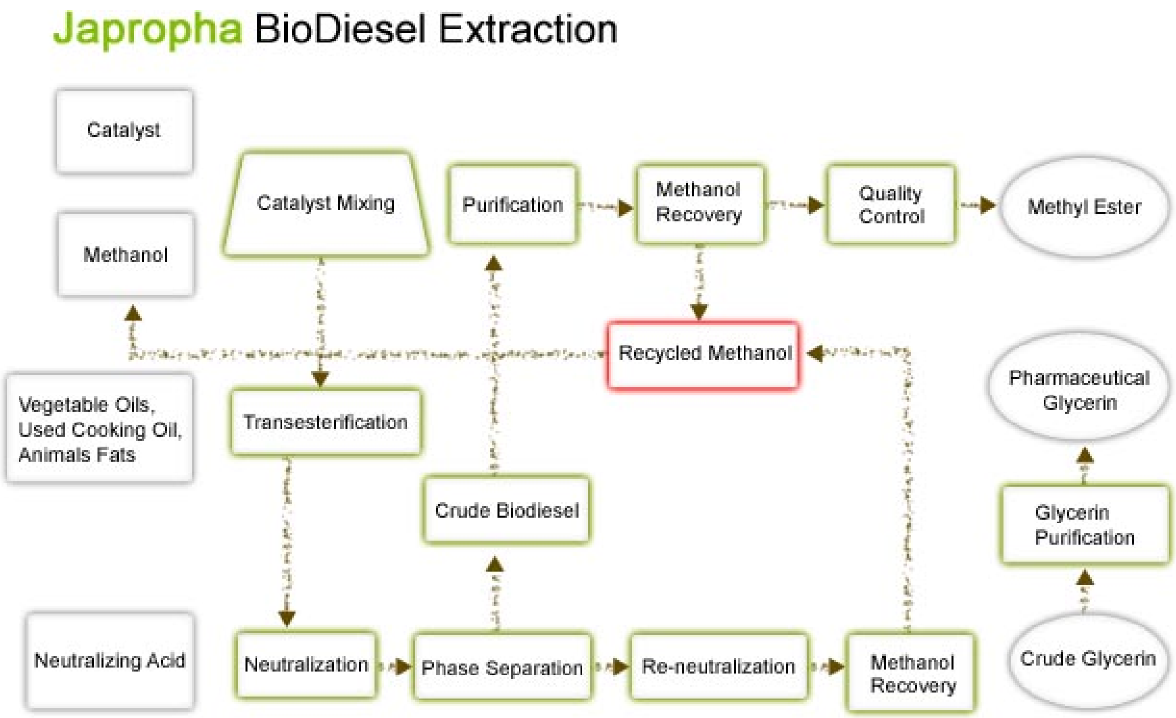


Figure 5. Jatropha biodiesel extraction methods (http://www.aumkiipure.com/oil-extraction.html).

physical and chemical properties of produced biodiesel. The fatty acid composition of jatropha oil has been reported in Table 6. The Gas Chromatographic analysis of the fatty acid compositions of the oils showed oleic acid to be significantly higher ($p < 0.05$) than linoleic, palmitic, stearic and myristic acids.

Also, medically, it is used for different diseases due to its antioxidant, anticancer and antibacterial activities. These activities may be due to the presence of various active ingredients including phenolic compounds and flavonoid groups.

Fatty acids	Formula	Structure	Wt%
Myristic	$C_{12}H_{28}O_2$	14:0	0.5-1.4
Palmitic	$C_{16}H_{32}O_2$	16:0	12-7.0
Stearic	$C_{18}H_{36}O_2$	18:0	5.0-9.7
Oleic	$C_{18}H_{34}O_2$	18:1	37-63
linoleic	$C_{18}H_{32}O_2$	18:2	19-41

Table 6. Fatty acid profile of jatropha oil

Oils extracted (Figure 4) from jatropha seeds as one of non-edible crops are potential feedstock's for biodiesel production. From all non-edible oil plants, jatropha, karanja, mahua and castor oils are the most often used in biodiesel production (Figure 5). In many countries, edible

http://dx.doi.org/10.5772/59178

oils are not produced in enough amounts to meet the nutrition requirements for human use and must be imported. Hence, the price of biodiesel produced from edible oils is much higher than that of petrodiesel. Therefore, non-edible oils from plants like jatropha, karanja, neem, mahua and other plants (Figure 6) are the only possibility for biodiesel production.

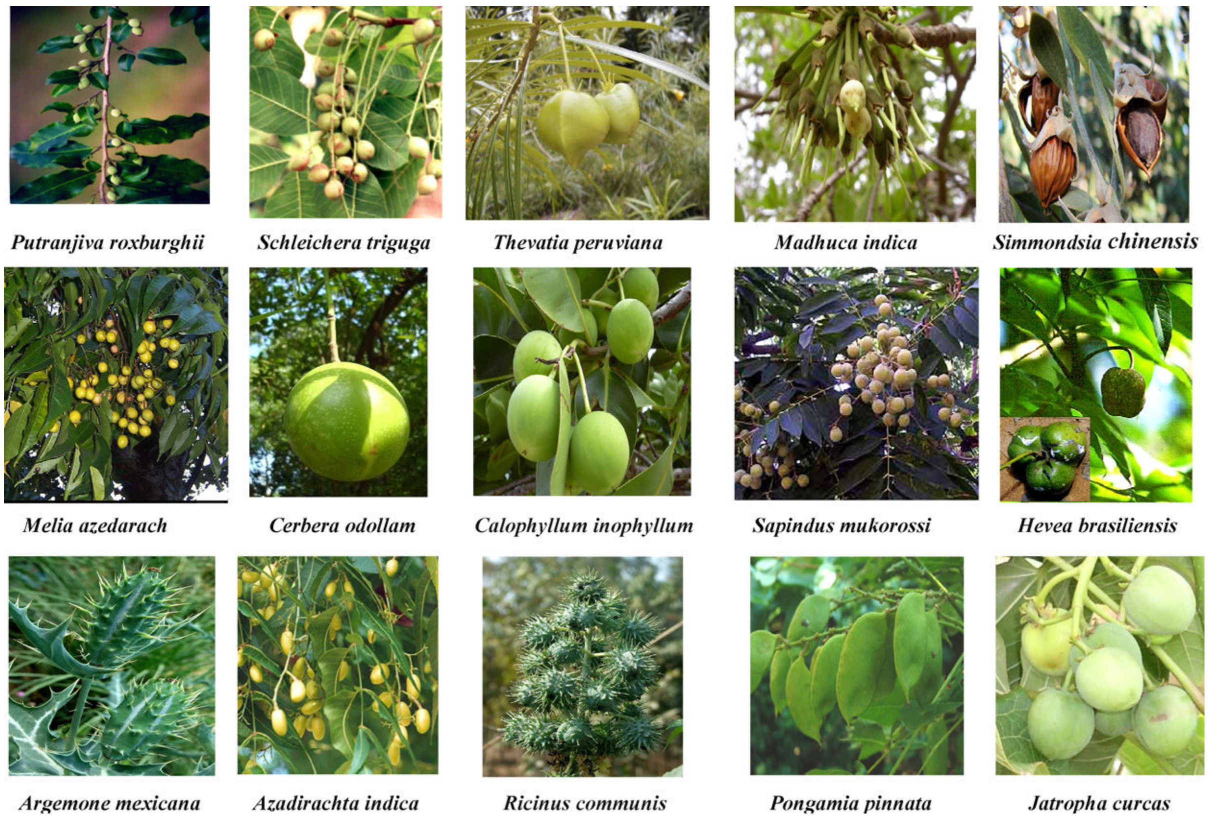


Figure 6. Selected non-edible fruits bearing plants.

2.3. Agricultural residues as biomass sources

From the different economy sectors, there is different industrial, agricultural, forestry, municipal residues. Of these residues (Figure 7), agricultural residues produced in large quantities every year. Wheat, Rice, sugar cane, maize, soybeans and groundnuts are just a few examples of crops that generate considerable amounts of residues. These biomass residues are an important source of energy both for domestic as well as industrial purposes. Juninger et al. [14] mentioned that, if only all process-based agricultural residues alone would be used, they could contribute between 25% and 40% of the total primary commercial energy production in various Southeast Asian countries

Until now, bagasse and rice husk are considered the two major biomass resources being used for power generation (approx. 15–17 and 5.0 Mio t/year, respectively). Moreover, forest residues and wood wastes represent a large potential resource for energy production; the primary advantage of using forest residues for power generation is that an existing collection of infrastructure is already set up to harvest wood in many areas.

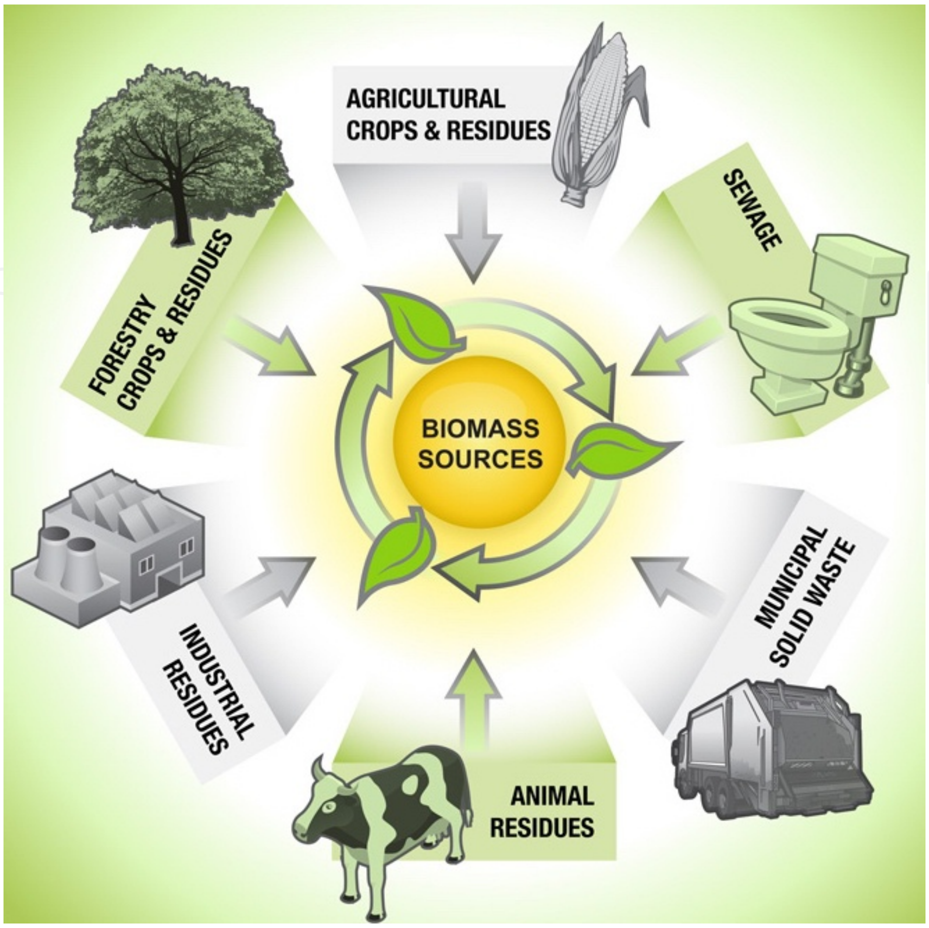


Figure 7. The major expected biomass sources for biofuel production (http://i2.wp.com/www.bioenergyconsult.com/wpontent/uploads/2012/04/biomass_resources1.jpg).

2.4. Waste cooking oils

Recycling of waste cooking oils is increasingly being carried out to produce biofuel (Figures 8 and 9). Opportunities for businesses and consumers to recycle used cooking oil ("yellow grease") have increased due to the price of waste cooking oils (WCO), which is 2–3 times cheaper than virgin vegetable oils. A significant advantage is that, biofuels derived from waste cooking oil typically burn clean, have low carbon content and do not produce carbon monoxide. This helps communities to reduce their carbon footprints (there was on average of a decrease of 14% for CO2, 17.1% for CO and 22.5% for smoke density when using biodiesel from recycling of waste cooking oils.). The recycling of cooking oil also provides a form of revenue for restaurants, which are sometimes compensated by cooking oil recyclers for their used deep fryer oil. However, the optimum conditions for biodiesel production (methanol/oils ratio and concentration of catalyst) are inconsistent. They strongly depend on the properties of WCO.

The processes of such oils and fats pose a significant challenge because of their disposal problems and possible contamination of the water and other resources.

Using Gc analysis of biodiesel produced from waste cooking oil, 60% of the fatty acids were found to be monounsaturated (C18:1). Polyunsaturated fatty acids were found to be approximately 26% (C18:2, C18:3). However, 8% fatty acids were saturated. (Palmitic acid and stearic acid were the major saturated fatty acids) as reported by Chhetri et al. [15].

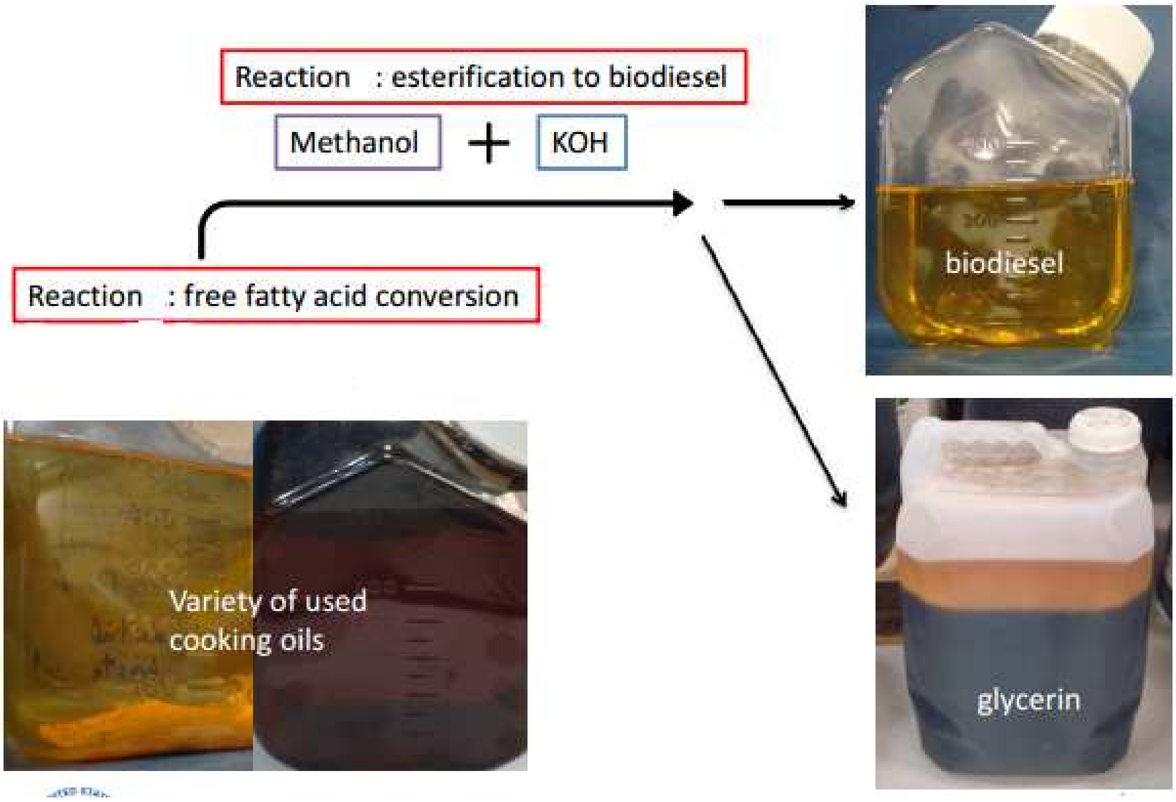


Figure 8. Biodiesel production from waste cooking oils.

The chemical properties of waste cooking oil and produced biodiesel are very important factors for using the biodiesel in industrial sector. From these properties; Acid value (AV) refers to the content of free acids in the sample, which have an influence on fuel aging. It is measured in terms of the quantity of KOH required to neutralise sample. Predojevic [7]reported that, the base catalyzed reaction is reported to be very sensitive to the content of free fatty acids, which should not exceed a certain limit recommended to avoid deactivation of the catalyst, formation of soaps and emulsion. Sharma *et al*. [16] found that, AV of the feedstock for alkaline transesterification has to be reduced to less than 2 mg KOH/g (1%), while only few examples of transesterification with feedstock acid value of up to 4.0 mg KOH/g (2%) were found. The authors also reported that, the limit of free fatty acids is a bit relaxed and the value a little beyond 1% (i.e. 2 mg KOH/g) when using waste cooking oil as feedstock for biodiesel production. In addition, the acid value of WCO feed stocks was 5 mg KOH/g oil. From this result it could be concluded that the used WCO had values above the recommended (2 mg KOH/g). However, this value did not turn out to be limiting for the efficiency of the applied two-stage process, as it will be discussed along with the obtained product yield and purity later.

Furthermore, The AV of the produced Fatty acids methyl ester (FAME) was 0.48 mg KOH/g oil. The recorded acid value of the produced biodiesel is higher than that of standard petro-diesel, but it meets the standard limits of biodiesel EN14215 and biodiesel D-6751, indicating that the free fatty acid content will not cause operational problems, such as corrosion and pump plugging, caused by corrosion and deposit formation [5].

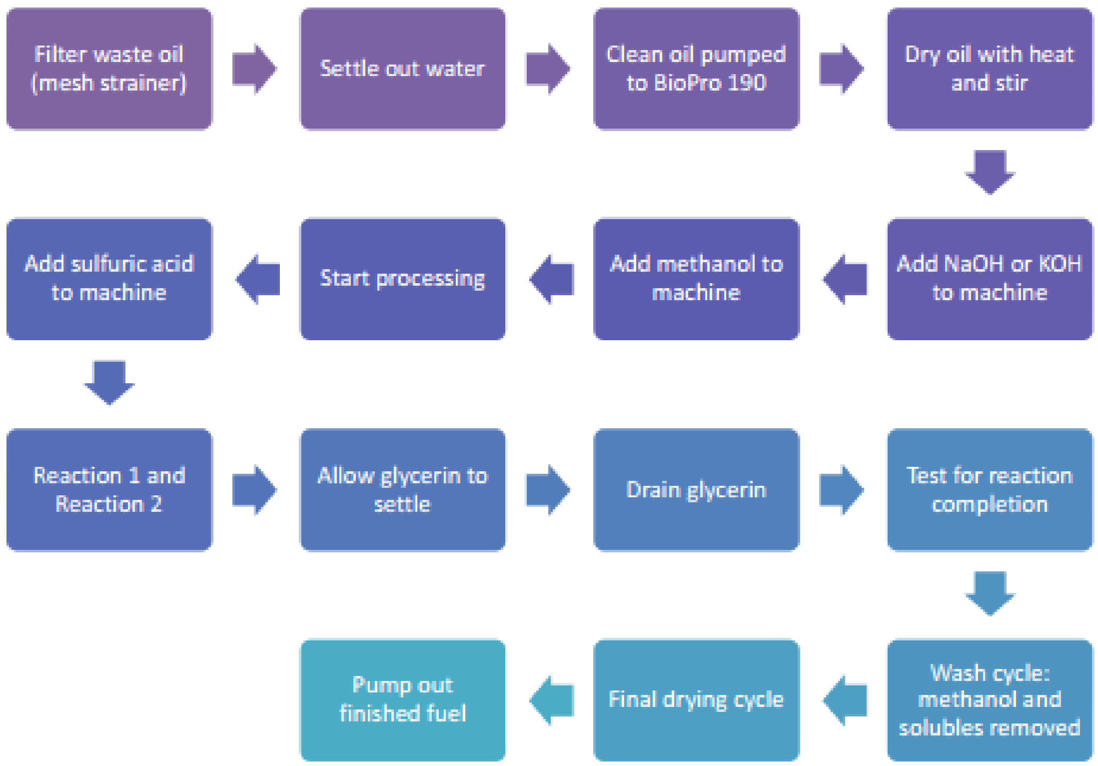


Figure 9. The processes for biodiesel and glycerin production from waste cooking oils

2.5. Algae (especially microalgae)

Microalgae are photosynthetic microorganisms that are able to rapidly generate biomass from solar energy, CO_2 and nutrients in bodies of water. This biomass consists of important primary metabolites such as sugars, oils and lipids, for which process path-ways exist for the production of high-value products including human and animal feed supplements, transport fuels, industrial chemicals and pharmaceuticals. Algae are capable of producing 30 times the amount of oils and lipids per unit area of land as compared to terrestrial oilseed crops (microalgae are capable of producing much higher amount oil per unit area of land, compared to many terrestrial oilseed crops, such as soybean, coconut and palm [17].

Many microalgae are exceedingly rich in oil, which can be converted to biodiesel using existing technology (Figure 10). More than 50% of their biomass as lipids, sometimes even up to 80%, and oil levels of 20%–50% are quite common [18]. Lipids production and biodiesel extraction from algae depend on algal species and extraction solvent system[19].

http://dx.doi.org/10.5772/59178

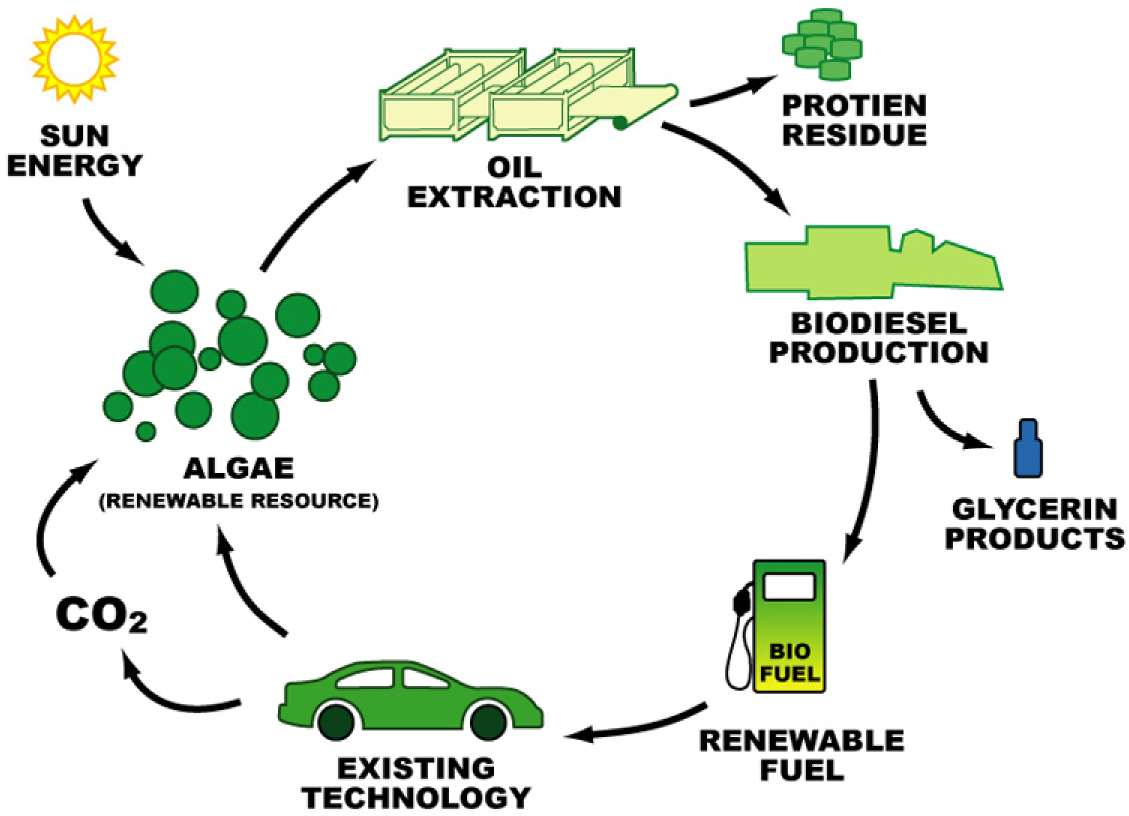


Figure 10. Process for conversion of algal oils to biodiesel. (http://refuelingthefuture.yolasite.com/third-generation-bio-fuels.php)

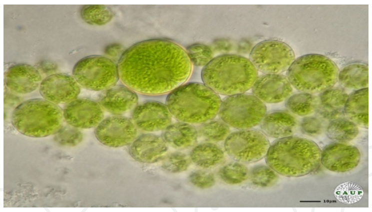
2.5.1. The benefits of Algae over previous generations

- Algae are one of the most promising long-term, sustainable sources of biomass and oils for fuel, food, feed and other co-products.
- Easy cultivation and growth.
- Easy to enhance the oil production using biotechnological tools (cultivation under biotic and a biotic stress).
- It is currently one of the most researched topics. This means algae fuel can become even more efficient than it already is. This also means that there will be new, more practical methods for growing and processing algae.
- Low cost of producing biodiesel from algae oils.
- Algae are not a food crop. Therefore, is does not compete with food consumption.
- Although an alga does not reduce carbon emissions, it does stop the introduction of new carbon dioxide into the atmosphere as it displaces the use of fossil fuels.
- Algae can be grown in sea water. Therefore, algae farms do not have to compete with agricultural farmland.

- Algae can be cultivated in different wastewater sources. This can be used as an alternative water treatment method. This method is cost effective. It requires a low amount of energy. It reduces sludge, and in the end, it cleans the water and produces algae for biofuel use.

Results in Table 7 show the lipid amounts extracted from eight algal species (5 macro and 3 microalgae) by the two extraction methods described in the experimental section. The red macroalga *Jania rubens* produced 2.8% lipid when extracted using hexane: ether (1:1, v/v) system whereas the recovery was doubled (4.4%) using the extraction system based on chloroform / methanol (2:1, v/v). No significant difference in the total lipid content was obtained from the red algae *Galaxaura* and *Gelidium* using both systems for extraction (2.4, 3.1 and 2.5, 3.0, respectively). The red seaweed *Asparagopsis taxiformis* and the green *Ulva* produced 1.2-fold increase in extracted lipid percentage and the brown macroalga *Colpomenia sinuosa*, produced a 1.52-fold increase in lipids when extracted by chloroform / methanol (2:1, v/v) system, as illustrated clearly in Tables 1 and 2. Moreover, the microalga *Dictyochloropsis splendida* showed 2.4 % of total lipid when extracted with hexane / ether (1:1, v/v) system, but on using chloroform/methanol (2:1, v/v) as extraction mixture, the percentage of total lipids increased 5.2 times to reach 12.5 % showing at the same time the highest biodiesel production (8.75 %) of the eight algal species used in this investigation. The cyanbacterium *Spirulina platensis* produced a 3-fold increase in lipid content using the chloroform/methanol-based method (Tables 8 and 9).

Algal species	**Algal pictures**	**Chloroform/ methanol (2:1, v/v)**	**Hexane/ether (1:1, v/v)**
Jania rubens		4.4±0.12	2.8±0.04
Galaxaura oblongata		2.5±0.09	2.4±0.01
Gelidium latifolium		3.0±0.0	3.1±0.02

Algal species	Algal pictures	Chloroform/ methanol (2:1, v/v)	Hexane/ether (1:1, v/v)
Asporagopsis taxiformis		4.1±0.08	3.4±0.05
Ulva lactuca		4.2±0.1	3.5±0.1
Colpomenia sinuosa		3.5±0.05	2.3±0.03
Dictyochloropsis splendida		12.5±0.23	2.4±0.14
Spirulina platensis		9.2±0.25	3.0±0.10
	LSD	**0.3261**	**0.3261**

Each value is presented as mean of triplet treatments, LSD: Least different significantly at $P \leq 0.05$ according to Duncan's multiple range test

Table 7. Comparison between lipid percentages (%) produced by eight algal species using hexane/ether (1:1, v/v) and chloroform/methanol (2:1, v/v) extraction systems [21].

The obtained results illustrated in Table 8 revealed that the solvent mixture hexane/ether were not the most suitable system for lipid biodiesel extraction from algae because these solvents were unable to extract polar lipids. On the contrary chloroform/methanol system extracted greater percentage of lipid (non-polar and polar lipids) and gave place to higher biodiesel yields by transesterification. The lowest biodiesel production was observed in the red seaweed *J. rubens* (0.25%) followed in ascending order by *Gelidium latifolium* (1.3%), *Galaxaura oblongata* (2.06%) and A. taxiformis (3.64%). While the green macroalga Ulva lactuca and the brown seaweed Colpomenia sinuosa produced comparable biodiesel percentages (3.8 and 3.1%, respectively), the greatest yield of biodiesel was achieved by the green microalgae *D. splendida* (8.75%) followed in descending order by the cyanbacterium *S. platensis* (7.5%) as illustrated in Table 2. Using chloroform/methanol (2:1, v/v) solvent system, we are able to produce not only biodiesel in large percentage but also a sediment containing glycerin and pigments. The produced biodiesel have slightly alkaline pH values ranging 7.5–8.5 in all preparations. Our results concerning the green microalga *D. splendida* (produced 12.5% lipids) agreed with those obtained by Hossain and Salleh [20] who reported that the green filamentous alga Oedogonium sp produced higher lipid.

Biodiesel colour	**Sediment %**	**Biodiesel%**	**Lipid %**	**Algal sp.**
Light brown	± 0.05 → 4.2[a]	0.25±0.01	4.4±0.12	*Jania rubens*
Light green	0.08±0.0	2.06±0.02	2.5±0.09	*Galaxaura oblongata*
Yellow	1.6±0.01	1.3±0.0	3.0±0.0	*Gelidium latifolium*
Dark green	0.40±0.01	± 0.10 → 3.64[c]	4.1±0.08	*Asporagopsis taxiformis*
Light green	0.44±0.0	3.8±0.12	4.2±0.1	*Ulva lactuca*
Yellow	0.31±0.05	3.1±0.05	3.5±0.05	*Colpomenia sinuosa*
Colourless	3.75±0.08	8.75±0.24	12.5±0.23	*Dictyochloropsis splendida*
Light green	1.66±0.06	7.5±0.30	9.2±0.25	*Spirulina platensis*
	0.1786	**0.3314**	**0.3261**	**LSD**

Each value is presented as mean of triplet treatments, LSD: Least different significantly at P ≤ 0.05 according to Duncan's multiple range test.

Table 8. Total lipid, biodiesel, sediments percentage and biodiesel colour of different algal species using the extraction solvent system Chloroform/methanol (2:1, v/v) (Afify et al., 2010).

3. Conclusion

From this chapter we conclude that non-edible biomass can be used as a suitable and cheap feedstock for producing biodiesel. Most of non-edible biomass has a considerable amount of low-chain fatty acids, which gives special features to biodiesel. The most important advantages of the current biomass are production of biodiesel with high cetane number, low viscosity. These factors can increase engine's output and decrease pollution compared with other biodiesel fuels. The present experimental results support that methyl ester of non-edible biomass can be successfully used as a biodiesel in the internal combustion engine.

Author details

Emad A. Shalaby

Address all correspondence to: dremad2009@yahoo.com

Biochemistry Department, Faculty of Agriculture, Cairo University, Giza, Egypt

References

[1] FAO (2007). Statistical Databases. http:// faostat.fao.org (accessed 15.08.09).

[2] Habib, H.M. and Ibrahim, W. (2008). Nutritional Quality Evaluation of Eighteen Date Pit Cultivars. International Food Science and Nutrition, 60:99-111.

[3] Habib, H.M. and Ibrahim, W.H. (2011). Effect of Date Seeds on Oxidative Damage and Antioxidant Status *in vivo*. J. Sci. Food Agric., 91:1674-1679.

[4] Shanab, S.M.M., Hanafy E.A., & Shalaby, E.A. (2014). Biodiesel Production and Antioxidant Activity of Different Egyptian Date Palm Seed Cultivars. Asian Journal of Biochemistry, 9: 119-130.

[5] Shalaby, E. & El-Gendy, N. (2012). Two Steps Alkaline Transesterification of Waste Cooking Oil and Quality Assessement of Produced Biodiesel. International J of Chemical and Biochemical Sci., 1: 30-35.

[6] JUS EN 14214:2004. Automotive Fuels. Fatty Acid Methyl Esters (FAME) for dengines-Requirements and Test Methods. Standardization Institute, Belgrade, Serbia.

[7] Predojevic, Z.J. (2008). The Production of Biodiesel from Waste Frying Oils: A Comparison of Different Purification Steps. Fuel, 87: 3522-3528.

[8] Ojeh, O. (1981). Effects of Relining on the Physical and Chemical Properties of Cashew Kernel Oil. J. Fats Oils Technol., 16: 513-517.

[9] Eskin, N.A.M.; McDonald, B.E.; Przybylski, R.; Malcolmson, L.J.; Scarth, R. and Mag, T. (1996). Canola Oil, In: Hui, Y.H. (ed.). Bailey's Industrial Oil and Fat Products, Vol. 2, 5th ed., John Wiley and Son. New York. pp. 1-95.

[10] Oomah, B.D., Ladet, S., Godfrey, D.V., Liang, J. & Girard, B. (2000). Characteristics of Raspberry (*Rubus idaeus* L.) Seed Oil. Food Chemistry, 69: 187-193.

[11] Nehdi, I., Omri, S., Khalil, M.I. & Al-Resayes, S.I. (2010). Characteristics and Chemical Composition of Date Palm (*Phoenix canariensis*) Seeds and Seed Oil. Industrial Crops and Products, 32: 360-365.

[12] Yong, Y. & Salimon, J. (2006). Characteristics of *Elateriospermum tapos* Seed Oil as a New Source of Oil Seed. Ind. Crops Prod., 24: 146-151.

[13] Veeresh Babu, S.V., Veeresh, B., Patil, A. & Warke, B. (2009). Lauric Acid on Myristic Acid Prevent Testosterone Induced Prostatic Hyperplasia in Rats. Eur. J. Pharmacol., 22: 193-199.

[14] Junninger, M, Faaij, A, Van den Broek, R., Koopmans, A, & Hulscher, W, Fuel Supply Strategies for Large-Scale Bio-Energy Projects in Developing Countries, Electricity Generation from Agricultural and Forest Residues in Northeastern Thailand.

[15] Chhetri, AB.; Watts,KC.; and Islam, MR. (2008). Waste Cooking Oil as an Alternate Feedstock for Biodiesel Production. Energies, 1: 3-18; DOI: 10.3390/en1010003.

[16] Sharma, Y. C., Singh, B. & Upadhyay, S. N. (2008). Advancements in Development and Characterization of Biodiesel: a Review. Fuel, 87: 2355-2373.

[17] Sheehan, J., Dunahay, T., Benemann, J., Roessler. P. (1998). A Look back at the US Department of Energy's Aquatic species Program – Biodiesel from Algae. National Renewable Energy Laboratory (NREL) Report: NREL/TP-580-24190. Golden, CO.

[18] Chisti Y. (2007). Biodiesel from Microalgae. Biotechnology Advances, 25: 294-306.

[19] Afify AMR, Shalaby EA, Shanab SMM. (2010). Enhancement of biodiesel production from different species of algae. Grasas Y. Aceites, 61 (4): 416-422.

[20] Hossain, A.B.M., Salleh, A. (2008). Biodiesel Fuel Production from Algae as Renewable Energy. Am. J. Biochem. and Biotechn., 4(3): 250-254.