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Review and Prospects of Jojoba *Simmondsia chinensis* used as Biodiesel in Libya

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ABSTRACT

The development and use of renewable energy have been put forward on the national agenda due to high oil prices, limited resources, environmental pressure and rapid-economic growth. Jojoba (Simmondsia chinensis) is chosen as an ideal biodiesel crop in Libya because its seed kernel has high oil content (45–60%) and it does not compete with food. Its oil is non-edible, and the trees can resist drought and grow on barren and marginal lands without using arable land. This article reviews biodiesel productions, sources, characteristics, economy and life cycle analysis. Further, future prospects of Jojoba biodiesel industry in Libya are discussed in detail.

مراجعة وآفاق استخدام نبات الجوجوبا *Simmondsia chinensis* **كوقود حيوي في ليبيا**

محمد أ الطاهر   محمد مسعود عبد الله

ان التطور الملحوظ والاستخدام الواضح للطاقات المتجددة نتيجة لارتفاع اسعار النفط ومحدودية الموار د, اضف الي دلك الضغط البيئي والنمو الاقتصادي السريع. ان اختيار نبات الجو جوبا كمصدر للوقود الحيوي في ليبيا لما يتميز به من خصائص تشمل احتواء نواة البدور علي نسبة عالية من الزيت تبلغ من 45–60% ولاتتنافس مع الطعام وزيتها غير صالح للأكل. اضف الي دلك مقاومة الاشجار للجفاف والنمو في الاراضي القاحلة والمهمشة دون استخدام الاراضي الصالحة للزراعة. تستعرض هدة الورقة انتاج الديزل الحيوي ومصادرة وخصائصه والجودة الاقتصادية له. علاوة علي دلك مناقشة التفاصيل المستقبلية لصناعة الوقود الحيوي من الجو جوبا في ليبيا.

INTRODUCTION

The energy security and demand on the reduction of carbon emissions have accelerated the R&D of the alternative fuels in the transport, heating and power generation sectors in the last decade. The heating and power generation sectors are two of the major contributors to carbon dioxide emissions, along with transport sector, which are due to the combustion of fossil fuels.

Biodiesel is biodegradable, non-toxic and environmentally friendly as compared to petro diesel and can be run in diesel engine with same or better performance as compared to normal diesel fuel. It is defined as the monoalkyl esters of long chain fatty acids derived from renewable feed stocks like vegetable oils or animal fats (Bhale, Deshpande & Thombre,2009).
The wide range of available feed stocks for biodiesel production represents one of the most important advantages of producing biodiesel as an alternative energy resource (Atadashi, Aroua & Abdul Aziz, 2010). Although there are over 350 species of oil producing plants, only a few such as palm, sunflower, safflower, cottonseed, rapeseed and peanut oils are considered as potential alternative fuels (Demirbas, 2007). Figure.1 gives the fractions of commonly used oil crops in terms of annual oil yield(Mckibben, 2005). However, some

other non-edible oils such as jatropha, karanja and neem are gaining worldwide attention. Fig.2 shows some main biodiesel feedstocks. The availability of feedstocks for producing biodiesel depends on the geographical locations and agricultural practices of the country. Therefore, selecting the best feedstock is vital to ensure low production cost of biodiesel. From literature, it has been found that feedstock alone represents more than 75% of the overall biodiesel production cost.

Rapeseed oil represents the largest contribution of world biodiesel production with 84%, whereas palm and soybean are the lowest(Mckibben, 2005).

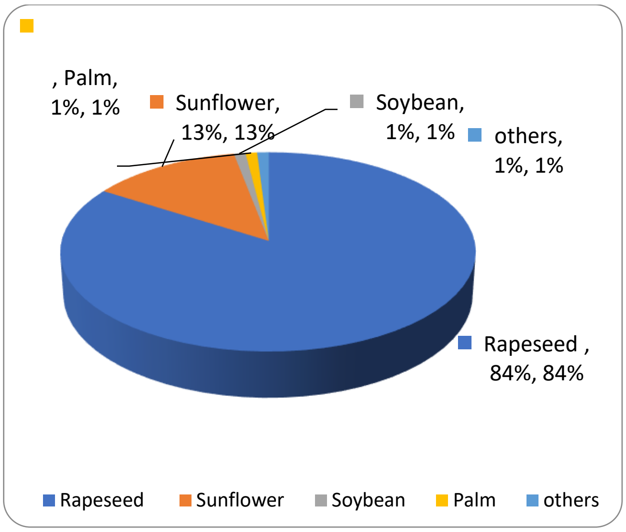


Fig.1 Representatives raw materials for biodiesel 2005 (Mckibben, 2005)

However, the rapeseed oil is not the one having highest oil yield and instead the oil palm gives the highest harvest and oil yield per unit of land. Table 1 shows the comparison of harvest and oil yield for different oil crops (Tickell, 2003).The molecule of vegetable oil is composed of three fatty acid chains attached to a molecule of glycerin and known as triglycerides. Many researchers have concluded that vegetable oils have a great potential to be alternative fuels for diesel engines (Mckibben, 2005).

In general, biodiesel feedstock can be divided into four main categories as below (Dorado, et al, 2006), (Lue, et al , 2001):

(1) Edible vegetable oil: rapeseed, soybean, sunflower, palm and coconut oil.

(2)Non-edible vegetable oil: jatropha, karanja, sea mango, algae and halophytes.

(3) Waste or recycled oil.

(4) Animal fats: tallow, yellow grease, chicken fat and by-products from fish oil.

Table1.World production average of common oil crops can be used as alternative fuels (Tickell, 2003).

Plant	Ib.oil/acre	Kg.oil/hectare
Oil palm	4,585	5.000
Coconut	2,070	2,260
Jatropha	1,460	1,590
Rapeseed	915	1,000
Peanut	815	890
Sunflower	720	800
Safflower	605	655
Soybean	345	375
Hemp	280	305
corn	135	145

1.1 The production of biodiesel

Using raw vegetable oils for diesel engines can cause numerous engine problems. The higher viscosity and lower volatility of oils compared with diesel lead to engine cold start problems, engine deposits, injector coking and piston ring sticking (Canakci, 2005), (Phan & Phan, 2008). Thus, animal Fats and natural vegetable oils are made up of one mole of glycerol and three moles of fatty acids and commonly referred as triglycerides and are extracted to obtain crude oil or fat(Bhale et al., 2009). There are four different methods of producing biodiesel from vegetable oils include direct use and blending, microemulsion, thermal cracking and transesterification(Ma & Hanna, 1999). The first three technologies will be summarized briefly and finishing with an emphasis on the most common and the current process transesterification.

A) Direct use and blending

Considerable research has been done on vegetable oils include palm oil, soybean oil, sunflower oil, rapeseed oil and Tallow oil and concluded that they have various fatty acids in there compositions(Ma & Hanna, 1999). It shows that they consist mainly of C14 to C22 with higher proportion of saturated acid. The advantages of direct use of vegetable oils and /or the use blends of oil are heat content, renewability, availability and liquid nature portability. However, direct use of vegetable oils and blends has major effects on diesel engines and considered to be not satisfactory. The mains reasons behind this are high viscosity, acid composition, carbon deposits and lubricating oil contamination for both direct and indirect diesel engines (Ma & Hanna, 1999).

Fig.2 Biodiesel feedstock(Bozbas, 2008).

B) Microemulsions

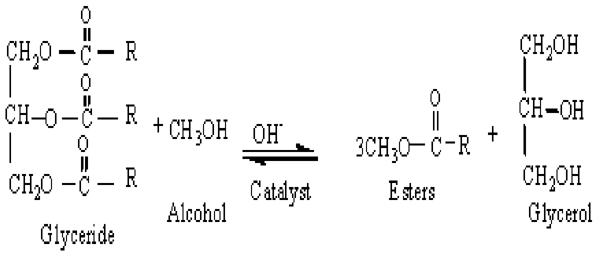
High viscosity of vegetable oil can be solved by process of microemulsion with solvents such as methanol and ethanol. Microemulsion is defined as '' a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1-150nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles''(Ma & Hanna, 1999).

C) Thermal cracking (pyrolysis)

The conservation of a substance into another by heat with aid of catalyst in the absence of oxygen or air is called pyrolysis. The mains drawbacks of this technology are high cost of thermal cracking and pyrolysis equipment, some material and gasoline and diesel fuel can be produced in the process and removal of oxygen during the thermal process removes the environmental benefits of the fuel(Ma & Hanna, 1999).

D) Transesterification(Alcoholysis)

Transesterification is defined as chemical reaction of vegetable oils or animal fats with alcohol in the presence of catalyst to form fatty acid methyl esters (FAME) and include glycerol by product Fig.3.(Dorado, et al, 2006),(Canakci, 2005). Methanol, ethanol, propanol, butanol and amyl alcohol are alcohols are used in transesterification process. However, methanol is the commonly used alcohol in this process due to part to its cost and its physical and chemical advantages which make it quickly react with triglycerides. It was found that a 3:1 molar ratio of alcohol to triglycerides is needed to complete the transesterification process. Nevertheless, to improve the reaction rate, catalyst (alkalis, acids) or enzymes are usually used[9].Moreover, alkali catalyst has been most often used commercially due to their fast reaction rate than its acid catalyst counterpart (Lapuerta, Rodríguez-Fernández & Agudelo, 2008). The typical alkali catalysts used in transesterification process are sodium hydroxide, potassium hydroxide or alkali methoxides. However, acid –catalyzed transesterification has less usage because it has relatively slow reaction rate and its insensitivity to free fatty acids in feedstock oil than its alkali catalyst counterpart (de Souza, et al, 2009).



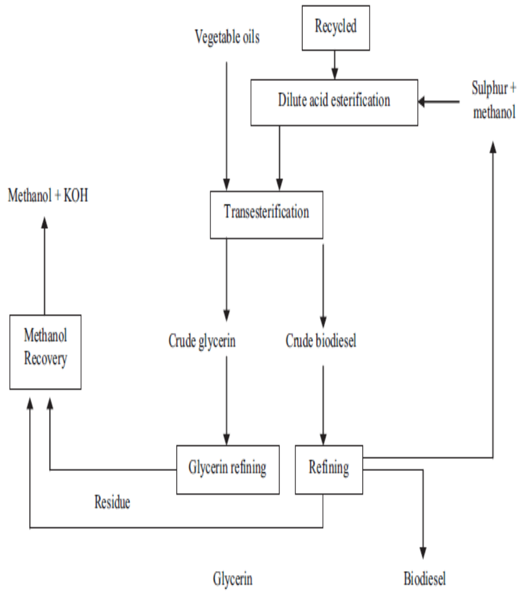


Figure.3 Transesterification process (Lue, Yeh & Wu, 2001).

Sulphuric acid, sulfonic acids and hydrochloric acid are used as acid catalysts; however, Sulphuric acid is the most commonly used in the reaction as acid catalyst[9].Nevertheless, acid –catalyzed transesterification can be used if there is more water and free fatty acid (more than 1) in the triglycerides(Ma & Hanna, 1999). However, there are some factors effect of ester formation using transesterification process include time, temperature, molar ratio, type of catalyst and moisture. Effect every factor on transesterification process will be discussed in the following section(de Souza, et al, 2009).

1.2 Characteristics of biodiesel

Biodiesel is sulphur-free, nontoxic, biodegradable, an oxygenated compound, renewable fuel and has high cetane numbers. The major advantage of biodiesel is the reduction of CO_2 emissions. These characteristics of biodiesel can result a significant reduction in the emissions of carbon monoxide, unburned hydrocarbons and particulate matter (soot) (Tickell, 2003), (Lapuerta, et al , 2008). Many researchers have shown that the properties of biodiesel are similar to diesel fuel. Therefore, biodiesel can be used in diesel engine with little or no modification(Atadashi et al, 2010).Table 2 shows physical properties of biodiesel compared to diesel fuel (NO_2). It shows that the density, cetane number, pour point and flash point of biodiesel is higher whereas the heating value is about 10% lower compared to diesel. The kinematic viscosity of both fuels is similar. Moreover, biodiesel prolongs engine life and better lubricating qualities that fossil fuels (Glaude, et al, 2009).However, there are some drawbacks of biodiesel low temperature performance, reduced energy density which increase mass fuel consumption and the increased cost of production (Atadashi et al, 2010).

1.3 Economic of biodiesel

The high cost of biodiesel is the main concern and major barrier to its commercialization(Demirbas, 2007). It is estimated to cost around one and half times compared to petroleum based diesel defending on feedstock oils. Thus, it was found that raw material such as vegetable oil and animal fats represent around 75% of the total cost of biodiesel production as shown in Fig.4 (Demirbas, 2007).

Table 2. Physical characteristics of biodiesel and No2. Diesel (Atadashi et al, 2010).

Property	Biodiesel	NO2 Diesel
Specific gravity(Kg/L)	0.87-0.89	86
Cetane number	46-70	47-55
Could point(K)	262-289	256-265
Pour point (K)	258-286	237-243
Flash point(K)	408-423	325-350
Sulphur (wt %)	0.0-0.0024	0.04-0.01
Ash (wt %)	0.002-0.01	0.06-0.01
Kinematic viscosity,313K	3.7-5.8	1.9-3.8
Higher heating Value(MJ/Kg)	39.3-39.8	45.3-46.7

The cost of production, however, is a major disadvantage of biodiesel. However, the use of waste cooking oils and animal fats for biodiesel production provides not only a resource for biodiesel but also saving the environment as it avoid these oils and fats pure into sewer system which is harmful for the environment and human health for biodiesel production provides not only a resource for biodiesel but also saving the environment as it avoid these oils and fats pure into sewer system which is harmful for the environment and human health(Dorado, et al, 2006). It was found that both used and unused vegetable oils are composed of methyl esters of fatty acids and have similar properties(Canakci, 2005). To evaluate the economics of biodiesel, there are some factors should be taken in the account such as capital cost, manufacturing cost and biodiesel break- even price (Demirbas, 2007). However, fixed capital cost refers to the cost associated with auxiliary facilities, total bare module and contingencies and fees. Thus, the total manufacturing cost consists of raw material cost, catalyst and solvent cost, maintenance and repairs, labour, storage, packaging, local taxes and insurance and represent around 70-90% of the total cost (Demirbas, 2007). Moreover, Dorado et al. Carried out an economic study on production of biodiesel from waste olive oil and Ethiopian mustard oil and they found that Ethiopian mustard oil cost up to two times per litter than waste olive oil (Dorado, et al, 2006).Thus, the final cost of the products include seed cost, oil extraction, processing and distribution was 0.66€ per kg and 0.44€ per kg respectively(Dorado, et al, 2006).

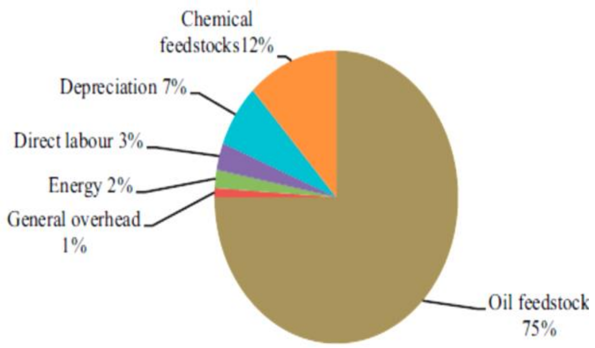


Fig.4 Biodiesel cost (ESRU, 2007).

1.4 Life cycle analysis (LCA) of biodiesel

To be a viable alternative, biofuels should provide a net energy gain, have environmental benefits and be economically competitive. However, life cycle analysis is required to assess and compare the upstream energy/environmental impact of biodiesel production with other fuels. Biodiesel is carbon natural which means any emissions associated with it comes from outside that of combustion of the fuel. Therefore, most of the CO_2 and N_2O emissions come from the fertilizer, pesticides, fuel, feedstock, extraction, refining, processing and transporting of biodiesel. However the previous results found that for every ton of biodiesel produced around 920 Kg of CO_2 was released to the atmosphere (Zhang, et al, 2003). Whereas, greenhouse gas emissions can be calculated in the same way as for CO_2 and each of GHG has an equivalent of 1,516 Kg of CO_2 are released(Zhang, et al, 2003). To analysis the biofuels cycle, the calculation of energy use will required. However, an energy balance ratio is a comparison of the energy stored in the fuel to the energy required to grow, fertilizer, oil extraction and distribute that fuel (energy balance=energy output/energy input).Thus, many researchers found that biodiesel has an energy balance ratio is about 2.5 to1. Other references say that biodiesel has an energy efficiency ratio of around 3.2 to 1(Mckibben, 2005). As for every ton of biodiesel produced is required around 16,269±896MJof energy, whereas, every ton of biodiesel will contain around 4,800MJ of energy35 (Zhang, et al, 2003). Biodiesel has a positive energy balance ratio and higher than most of conventional fossil fuels and provide more energy and less environmental impact mostly from production rather than from combustion. on the other hand, petro-diesel has a negative energy balance ratio of 0.83 to 1 (Mckibben, 2005). Nevertheless, according to the DOE/USDA study shown that the overall life cycle production of wastewater and hazardous solid from biodiesel production are around 79percent and 96 % respectively lower than the overall in petro-diesel(Mckibben, 2005).

1.5 Feasibility of Jojoba curcas as a biodiesel in Libya

Jojoba is a drought resistant crop that has a life expectancy of up to 50 years. It can grow in arid, semiarid and wastelands (Pradhan, et al , 2011). The plant has its native distributional range in Mexico, Central America, Africa, Brazil, Indian subcontinent, Peru, Argentina and Paraguay, although nowadays it has a pan tropical distribution with distinct JCL seed provenances. The plant develops a deep taproot and initially four shallow lateral roots. The taproot may stabilize the soil against landslides while the shallow roots are alleged to prevent and control soil erosion caused by wind or water. The leaves are smooth, 4–6 lobed and 10–15cm in length and width. The plant is monoecious and the terminal inflorescences contain unisexual flowers(Bozbas, 2008). The ratio of male to female flowers ranges from 13:1 to 29:1 and decreases with the age of the plant. The temperature for the growth is 20–26 ◦C, this plant also can adapt to fertile soil, good drainage, not stagnant, and pH from 5.0 to 6.5 (Pradhan, Mishra, Naik, Bhatnagar & Vijay, 2011), (Lu, et al, 2009). It bears fruits from the second year of its establishment, and the economic yield stabilizes from the fourth or fifth year onwards. The fruit is a kernel which contains three seeds each. It gives about 2–4 kg/seed/tree/year. In poor soils, the yields have been reported to be about 1 kg/seed/tree/year (Singh, Kumar & Haider,2007). The oil yields is reported to be 1590 kg/ha.

Jojoba can be bred by both seeds and cuttings. Seed breeding has high survival rate but its seedlings will fruit only after 3–4 years. Cutting propagation has the characteristics of fast growth, more branches and early fruiting (about 1 year). In addition, tissue culture of Jojoba has been bred successful in the laboratory(Pradhan, et al , 2011). This technique makes it possible to rapidly produce enough seedlings for large-scale commercial plantations. Jojoba trees in Libya are mainly distributed in Southern provinces, there are two farms in Murzak planted by seeds, one of the them one ha and the other 5 ha as showed in Fig(5&6). Both farms managed by Arabic centre of dessert research in Murzak.

Fig.5 Jezaow Farm

Fig.6 Murzek Farm

CONCLUSION

It can be concluded that the production of biodiesel from Jojoba offers many social, economical and environmental benefits for Libya and can play a great role to solve the problem of energy crisis worldwide. Its oil can be used to produce biodiesel with same or better performance results when testing in diesel and gas turbine Engines. It recycles 100% of the CO_2 emissions produced by burning the biodiesel. It can be bred by both seeds and cuttings, however tissue culture technique is being used widely for commercial plantation.

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