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Jatropha Tree as a Source of a Fuel for The Future:An Overview

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Abstract: The whole world is currently facing two crisis in food as well as in energy. The energy crisis is getting worse with time due to the expected depletion of the natural reserves of petroleum in the very near future. Such depletion will be certainly reflected on the whole products derived from petroleum. One of the major products is diesel oil which is commonly used to operate diesel engines in the transportation vehicles. Therefore, an interest is now directed worldwide to find alternatives to diesel fuel and to explore suitable sources for these alternatives. Biodiesel fuel derived from plant oils has been proven to be an excellent alternative for diesel fuel. Jatropha oil, a non edible oil, which can be obtained from the fruit of Jatrophacurcas can be used for such purpose and the product has been proven to have very good fuel properties compared to regular diesel fuel.
This paper outlines all basic information about the tree of jatropha as well as its cultivation worldwide, its benefits, the composition of the fruit, the composition as well as characteristics of the oil that can be extracted from the seed and the toxicity of meal after oil extraction. The methods used for oil extraction, general uses of the oil and the potentiality of the oil to produce biodiesel fuel are also discussed. The current status of jatropha cultivation in Egypt are also referred to.
Key words: Jatropha Tree; Cultivation; Jatropha Oil; Extraction; Biodiesel.

Introduction

Jatropha tree is a drought-resistant shrub or tree which grows almost anywhere except water logged lands, even in desert and close to the sea shore as well as in soil rich n stones. It is widely distributed in huge areas in the United states and in Africa[1,2]. Jatropha is easy to grow in short periods and since it can tolerate dryness , it can be used to reclaim erosion and to establish a fence in the arid lands[3,4]. While Jatropha grows well in locations where the fall of rain is as low as two hundred mm of rain,it can survive also in locations where the rain is as high as one thousand two hundred mm especially at hot climate. An example of this is that in Nicaragua .The reason behind its ability to stand long times of drought is that it can reduce transpiration loss by shielding most of its leaves [5]. The plant can be used to reduce the rate of erosion of soil and it can be also utilized for land reclaiming. Moreover, they can be grown as a live fence for farm animals since its height can be as high as three to five meters and it can reach a nine meter tall.

There are some locations worldwide where the cultivation of Jatropha tree became an important issue such as in Egypt which is marked as a country with "hyper arid" soil to be grown and where it can use sewage water instead of normal water to grow Jatropha. More than 95% of the land area in Egypt is desert. Recently,

the plantation of Jatropha species on wastelands in Egypt became so important as to protect the environment and guarantee energy requirements in the future.

A field experiment was carried out at Enshas Experimental Station, Egypt. In this field experiment, Jatropha was planted and was then irrigated by different amounts of water and under different potential evapotranspiration (ETp). The results have shown that the consumption rate of water by Jatropha tree during a week was six liters during the season of growing which meant that the survival of Jatropha under minimum water requirements is much better than that of other crops. The results have also proved that the effect of the water stress on the oil properties was negligible. However, the best Jatrophaoil quality can be achieved when the potential evapotranspiration is 100%. It should be emphasized that flowering of Jatropha tree occurs twice per year and in permanently humid regions, flowering occurs throughout the year. The seeds mature in around four months and the mature seed is black in color. Usually one kilogram of seed consists of around 1400 seeds .

This article is an overview on the general benefits of the tree , composition of Jatropha seed, Jatropha oil and its uses especially as a feed stock for biodiesel production and the potential of the seed cake as an animal feed. Jatropha cultivation in Egypt using waste water has been also referred to

Benefits of the tree

Several parts of Jatropha tree have potential uses including its seed(oil and meal),its flowers and park. First, the seeds of Jatropha contain viscous oil which is not suitable for human consumption as it is a strong purgative but it can be used for non edible purposes. Examples are its use in the industrial production of soap, candles and cosmetics. Its most important application is its use as a feed stock for the production of biodiesel which can be used as an alternative fuel for regular petrol diesel. The importance of its use as a fuel emerges from the fact that natural resources of petroleum are depleting with expectation of severe shortage in petroleum products such as diesel fuel in the near future. In addition, the use of biofuel instead of fossil fuel will definitely reduce the greenhouse effect due to excessive carbon dioxide emissions. In addition to the benefit of Jatropha seed as being a source of oil, Jatropha meal left over after oil extraction can be served as an animal feed since it is rich in protein especially if the toxic phorbol esters present in the meal are removed[6]. Jatropha cake can be also used as an organic manure based on its high content of nitrogen, phosphorous and potassium[5]. In addition, the bark of Jatropha tree contains tannin and it has a potential for honey production as its flowers attract bees . However, more studies are still required to throw more light on the effect of environmental conditions on the growth of Jatropha tree [7].

Jatropha seed

The seeds of Jatropha are toxic in general for both humans and animals and their toxicity is attributed to the presence in the seed of phorbol esters [8,9]. These types of esters are usually present in plants that belong to Euphorbiaceae and Thymelaeaceae families[10].Symptoms of human poisoning due to eating Jatropha seed are giddiness, vomiting and diarrhea[6]. They are quite heat stable so that their destruction by heat treatment is not effective .However, their concentration can be reduced by some chemical treatment which is quite expensive. Ionizing radiation treatment may be the most promising tool to inactivate phorbol esters[11,12,13].

Although of the toxicity of Jatropha seed, it is considered as an important source of an oil that is quite suitable as a feed stock for the production of fuels alternative to petrol fuels. The oil content in the seed gradually increases with maturity and it is therefore recommended not to harvest the seed until it becomes fully mature. Seeds are said to be mature if the color of the fruits has been turned to be dark brown and this usually takes around three months after flowering. However, the fruits have to be harvested manually at regular intervals because fruits do not mature at the same time making this step time and effort consuming. The harvesting time and period varies according to the environmental conditions . The latter depend on the season and the region where it is cultivated.

Jatropha oil

The major issues which will be covered below include the methods applied for the oil extraction, composition and characteristics of jatropha oil as well as its uses especially as a biodiesel fuel

Extraction of Jatropha oil

The extraction of the oil from Jatropha nut on an industrial scale can be made via one of three main methods being mechanical extraction, solvent extraction and pre-press solvent extraction using the first two technologies together. In case of oil extraction by mechanical pressing, the grinding of whole seed or kernel is not needed .In case of the extraction using solvent extraction technology the seed should be ground prior to extraction and the ground seed may be flaked to facilitate the intracellular solvent diffusion to extract the oil. Mechanical extraction can be made using one of two ways either by hydraulic pressing or by screw pressing. The percentage oil yield by screw pressing is usually higher than that by hydraulic pressing but the heat developed during screw pressing may result in some deterioration of the oil and meal.

Compared to the mechanical pressing technology, solvent extraction technology yields higher percentage of recovered oil. However, solvent extraction technology has some disadvantages as compared to mechanical extraction .The capital cost and the rates of energy and water consumption are higher. Also, the hazards of using flammable solvent (hexane) with possible fire risk have put some limitations in concern of solvent extraction technology.

Characteristics of Jatropha oil

The specific gravity of Jatropha oil is in between 0.85 and 0.9 which is in the normal range of all vegetable oils as well as regular diesel fuel. Its calorific value ranges between 38 and 42 KJ/KG oil which is about 80%to 90% of that of regular diesel fuel. Its pour point is quite low (-3C^{0}) which can be attributed to the high percentage of unsaturated fatty acids(about 75%). Its flash point is high (210-240C^{0}) which makes it quite safe during handling and storage. However,its viscosity ranges between 38 and 55 Cst which is quite high compared to that of the Egyptian standard specifications of diesel fuel which should not be higher than 6Cst.It follows that its atomization through the injector nozzle of a diesel engine will be inefficient resulting in a non-complete combustion. Therefore, it should be chemically modified to a less viscous liquid before its use for running a diesel engine. Like all plant oils, its sulfur content is very low being less than 0.13% .Hence, its use as a feed stock for biofuel production will yield a product of very low sulfur content. This is a favorable property of a fuel since its combustion will not release corrosive sulfur oxides which have a detrimental effect on the environment as well as the engine components.

Uses of Jatropha oil

Jatropha oil has several uses and mainly as a source for fuel production. The importance of plant oils as a source of fuels alternative to petroleum fuels emerges from the following facts:

- Crude oil prices are rising every year.
- Petroleum reserves are depleting with time
- Global warming represents a very serious problem
- Petroleum importing nations are concerned about their security
- Rate of energy consumption is increasing world wide

However, plant oils including Jatropha oil are quite more viscous than petroleum fuels Therefore, the use of pure plant oils in diesel engines results in so many problemsby long term use [14].These problems are mainly due to the high viscosity and low volatility of vegetable oils compared to regular diesel fuel. High viscosity values result in difficult fuel atomization through the injector nozzle with subsequent incomplete combustion and formation of carbon deposits on the injector nozzle and other engine parts. These problems are outlined below:

1. Abnormal carbon buildup on the injection nozzle tips (injector coking),
2. Valves and valve stems sustain heavy deposits and there is a general degradation of combustion conditions.
3. Coking on the injectors causes poor atomization of the injected fuel or even prevented as a result of plugged orifice. As a result, fuel droplets impinge on the cylinder walls, eventually polymerizing on the piston rings. Deposits of polymerized fuel on the rings cause them to stick in their grooves, effectively ruining their sealing ability

Therefore, it became so necessary to reduce the viscosity of plant oils before their use to run an engine. This can be made either by blending with petroleum fuels or through mixing with short chain alcohols in presence of a suitable emulsifier such as 1-octanol that helps the formation of a micro -emulsion of the oil with alcohol. Reduction of the viscosity of plant oils can be also achieved by chemical treatment whereby the molecular weight of the oil (triglyceride) which is around 900 is greatly reduced. Reduction of the molecular weight greatly reduces the liquid viscosity. Chemical modification can be made by one of two methods; transesterification of the oil with short chain alcohols [15,16,17,18,19], or by Thermal cracking in presence of catalyst such as CaO[20,21,22].Thermal cracking of a plant oil occurs in one step yielding a mixture of hydrocarbons of low viscosity and volatility. However, the percentage loss is usually high so that the yield is not more than 50%of feed. On the reverse , the product yield by trans-esterification reaction is usually much higher but the process occurs in several steps. The transesterification process can be conducted close to the boiling point of the alcohol at atmospheric pressure for a given time. Such mild reaction conditions require the use of alkaline catalyst or acidic catalyst. The esterified oil is referred to as biodiesel fuel

CH2-OCOR1			R-OCOR1		CH2-OH
CH -OCOR2	+ 3 R-OH	------→	R-OCOR2	+	CH -OH
CH2-OCOR3			R-OCOR3		CH2OH
Vegetable oil	Alcohol		Ester		Glycerol

Trans-esterification Reaction

The process can be base- catalyzed as well as acid- catalyzed. Base-catalyzed trans-esterification is preferred over acid-catalyzed process if the oil acidity is low (acid value < 1).At the end of the reaction, the mixture separates into two phases; the upper phase is rich in the un-reacted alcohol together with the major portion of the produced esters. The lower phase is rich in glycerol; a byproduct of the process with some little of the un-reacted alcohol together with some little amount of the esters dissolved in the alcohol.

It should be emphasized that the transesterification of plant oils occurs in three consecutive reversible reaction steps. The first step yields di-glycerides and fatty acids esters, while the second step yields mono-glycerides and fatty acids esters. The third and final step yields glycerol and methyl esters. Excess of alcohol is usually used to push the reaction in the forward direction as to complete the last reaction step. Incomplete conversion will result in the formation of partial glycerides which have surface active properties that makes the separation of produced biodiesel from the product mixture a very difficult task.

Transesterification of jatropha oil with methanol has been studied also in absence of catalyst at the super critical conditions of the used alcohol (about 80 bar and 340 C^{o} in case of methanol) [18].The transesterification process at these conditions has been completed in four minutes only compared to almost six hours using conventional base- catalyzedtransesterification. This method has an additional advantage due to the exclusion of the step needed for catalyst removal(18)

Esterified plant oils has the following advantages as alternative fuels for diesel engines

- It is renewable
- Its heat of combustion is very close to that of regular diesel fuel
- It is environmentally friendly as it is free from sulfur, biodegradable and as they do not increase global warming in comparison to fossil fuels (CO2 neutral system)

Biodiesel fuel is marketed as pure or blended with petroleum diesel

- B100 = 100% Biodiesel fuel
- B80=fuel mixture of 80% Biodiesel + 20% petroleum diesel
- B20 = fuel mixture of 20%Biodiesel + 80% petroleum diesel

Biodiesel good qualities

- It has high cetane number compared to petro-diesel
- Superior lubricating properties, particularly if mixed with low sulfur diesel fuel
- No sulfur, or aromatic substances associated with fossil fuels

- Its oxygen content (up to 10%) ensures more complete combustion of hydrocarbons and low particulate emissions
- Its higher flash point makes it safer to store
- Biodiesel is biodegradable.
- Biodiesel almost completely eliminates the increase in atmospheric carbon dioxide compared to fossil fuel.

Jatropha seed meal

After the extraction of the oil from Jatropha nuts, the residual solids are called seed meal.. The meal contains residual unrecovered oil whose percentage varies according to the extraction technology used. In general, oil recovery by solvent extraction is much higher than that by mechanical extraction which will be reflected on the percentage of residual oil in the meal being higher in case of mechanical extraction .Therefore the gross energy content of the meal obtained by mechanical oil extraction will be higher and its average value is18.0 $MJkg^{-1}$.The average protein content of Jatropha meal is quite good being 58% in the average. However, there are some restrictions on the use of Jatropha meal as an animal fodder. This is attributed to the presence of toxic phorbol esters in the meal.

Jatropha cultivation in Egypt

Egypt is known as a dry desert country (98% is dry/desert and only 2% of the land along the Nile River and Nile Delta is cultivated). Egypt had successfully grown Jatropha trees and harvested seeds by using waste-water as a part of desert forestation program although it is still in the experimental level.

Forestation Program by Using Waste-Water since 1995

Lack of water supply is always the primary issue in agriculture and in a forestation. Egypt is marked as a country with "hyper arid" soil and "under 250 millimeters" of precipitation annually. Based on Japan Bank for International Cooperation (JBIC) study member's interviews [23], there is almost no precipitation in Jatropha high oil seed production area. Even with Jatropha's amazing strength of draught, it cannot survive without irrigation. Since the population of Egypt had been continuously growing, counter-measure for water quality issue can be solved by waste-water usage. According to a Ministry of Agriculture (MOA), Egypt official, Egypt had nearly 3,000 Mm3 / year waste water and 22 waste water plants with 150 more plants under construction in 2006. The National Program for The Safe Use of Treated Sewage Water for Forestation, known as "Man made forest" program is led by MOA, Egyptian Environmental Affairs Agency (EEAA), and Ministry of Housing (MOH). Using sewage water instead of normal water to grow Jatropha, the pollution rate caused by waste water treatment is reduced and at the same time it provided nutrition-rich water which fastened the growth of Jatropha.

Luxor Jatropha Experimental Plantation since 2005

Within the desert forestation program, the plantation of Jatropha was started since 2005 in the Luxor governorate (Upper Egypt), Jatropha seeds has been planted in sandy soil and treated sewage water of almost neutral pH has been utilized for its irrigation without any fertilization. The current area planted by Jatropha is 200 Hectares which is expected to yield 378 tons Jatrophaoil annually[24].Surprisingly, It has been proved that Jatropha plantation in Luxor was more successful than that in so many other locations in the world based on the following:

1. The rate of growth and productivity is high,
2. Seed production occurs after one and half year only compared to three years in other countries.,
3. The average seed yield of a tree is 3-4 kg seed and that yield increases as the tree becomes older,
4. The Jatropha oil extracted from the ones in Egyptian soil proved to have a high productivity level (30% to 35% oil content) than other countries after taken and refined in UK laboratories.

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