Production and testing of biodiesel fuel from Jatropha Curcas (Al-Sharb) in Yemen

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Abstract

Biodiesel is an alternative fuel for diesel engines that is gaining attention all over the world. Its primary advantages deal with it being one of the most renewable fuels currently available and it is also non-toxic and biodegradable. It can also be used directly in most diesel engines without requiring extensive engine modifications. Besides, the clear decreases in petroleum fallback in Yemen we have to search for alternatives, the biodiesel is an important alternative to reduce petroleum dependency in Yemen and for this reason our effort is focused on studying the possibility of producing Jatroph Curcas biodiesel and testing the resulting crude oil. Moreover, the paper focuses on the characteristics of "Jatropha Curcas", Biodiesel production technology, Production Process of Jatropha Biodiesel, quality and specifications as to the ASTM standards.

Key Word: *Production, Testing, Biodiesel, Jatropha Curcas*

Introduction:

The consumption and demand for the petroleum products are increasing every year due to increase in population, standard of living and urbanization. Besides, accompanying concerns about the depletion of the world's non- renewable resources provided the incentives to seek alternatives to conventional, petroleum-based fuels (Alamu *et. al*., 2007; Al Widyan and Al Shyouk, 2002; Bernado *et al*., 2003). Globally at present, the most widely used fuels are gasoline and diesel, both coming from fossil fuel. Diesel consumption pattern in Yemen has not varied much and is around 230 000 ton/month. The increase in crude oil import affects the country's economy and its development. Besides the fear for depletion of fossil fuel, due largely to its non-renewable status, use of gasoline is associated with environmental problems. The diesel vehicles were banned for serious problem of air pollution due to higher emissions of polluted gases (Munack *et. al*., 2000). The acid rain, global warming and health hazards are the results of ill effects of increased polluted gases like SOx, CO and particulate matter in atmosphere. The need to consider renewable sources of fuel, with acceptable environmentally friendliness, to meet the ever increasing global energy demands can therefore not be over emphasized.

There are so many sources exit in the form of renewable energy and non-renewable energy, Such as coal, mineral, diesel and petrol. If we see the today's scenario, there is huge demand for this non- renewable energy sources and this demand is increasing day by day, which could create a critical problem in the future because of unbalance demand-supply ratio of these non-renewable energy sources, this could cause the energy crises, which could become an abstracts in the development of human being. For this critical problem many scientists have been working constantly on the search of alternative renewable sources, viz solar energy, Tidal energy, Wind energy (Bernado et al., 2003, Kritana Prueksakorn and Shabbir

H. Gheewala, 2006). Vegetable oil as an alternative fuel has been under study in certain part of the world far back as 1979 (Peterson *et al*., 1990). In most of the developed countries, biodiesel is produced from soybean, rapeseed, sunflower, peanut, etc. The use of chemically altered or transesterified vegetable oil does not require modification in engine or injection system or fuel lines and is directly possible in diesel engine (Chitra *et al*., 2005). Among the various vegetable oil sources, non-edible oils are suitable for biodiesel production, because edible oils are already in demand and too expensive than diesel fuel (Silvio *et al*., 2002).

Among the non-edible oil sources, jatropha curcas is identified as potential biodiesel source and comparing with other sources, which has added advantages as rapid growth, higher seed productivity, suitable for tropical and subtropical regions of the world (Kritana Prueksakorn and Shabbir H. Gheewala, 2006, Rolando Zanzi, et. el., 2008). Jatropha curcas has quite good diesel content and can be obtained and cropped easily because of their natural climatic condition. These species have efficiency to provide good enough diesel as fuel for this country and these species could also save huge export currency of this country.

Jatropha Curcas (Al-Sharb)

Jatropha curcas or physic nut is a bush or small tree (up to 5 m height) and belongs to the euphorbia family. The genus Jatropha contains approximately 170 known species. The genus name Jatropha derives from the Greek jatrós (doctor), trophé (food), which implies medical uses. The plant is planted as a hedge (living fence) by farmers all over the world, because it is not browsed by animals. Jatropha curcas or physic nut, has thick glabrous branchless. The tree has a straight trunk and gray or reddish bark, masked by large white patches. It has green leaves with a length and width of 6 to 15 cm (Fig.1).

Figure 1. Jatropha Curcas (Ministry of agriculture and irrigation).

The plant produces yellowish green flowers in racemes inflorescences with dichasia cymae pattern. Numerically, 1-5 female flowers and 25 to 93 male flowers are produced per inflorescences. The average ratio of male to female flower is 29:1. Female flowers are quite similar to male flower in shape but are relatively larger. Fruits are grey-brown capsule, 4 cm long and generally tri-halved, each comprised of one seed. Seeds are black, about two cm long and one cm thick. Generally fruits are matured by September-October. The seeds mature in three months after flowering (Fig. 2).

Figure 2. Fruits and seeds of Jatropha Curcas

Jatropha Curcas or Al-Sharb is old enter in Yemen. Jatropha is planted on the boundaries of fields as live fence dales riversides into hills shed in Tehama west heights middle high and south heights from Taiz. Figure 3 shows initial result which executing by Ministry of agriculture and irrigation - Public Authority for agriculture research and teaching - the regional station for southern heights – Taiz.

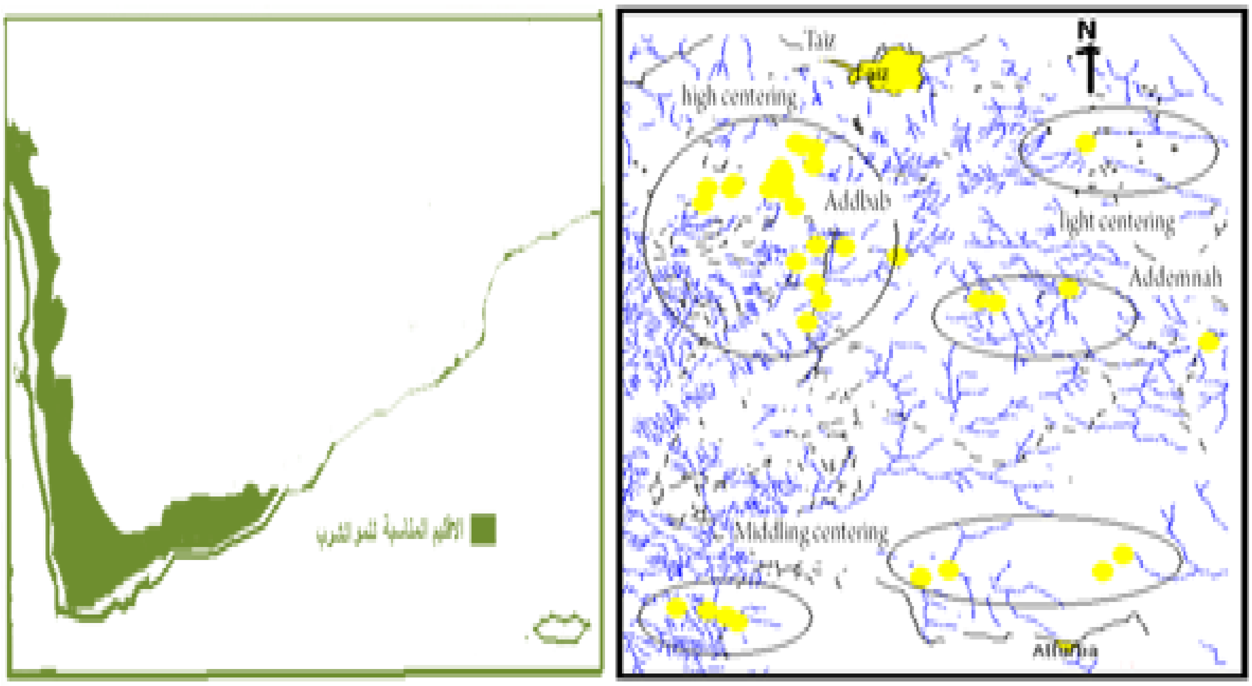

Figure 3. Jatropha Curcas grow up places and its spread in Taiz (yellow colors)

Beside the advantage of the Jatropha Curcas as a source for biodiesel production, it has other advantages as follows:

- It can be grown in areas of low rainfall (600 mm/year) and in problematic soils, in high rainfall and irrigated areas, it can be grown with much higher yields.

- Jatropha is easy to establish, grows relatively quickly and is hardy.

- Jatropha lends itself to plantation with advantage on lands developed on watershed basis and on low fertility marginal, degraded, fallow, waste and other lands such as along the canals, roads, railway tracks, on borders of farmers' fields as a boundary fence or live hedge in the arid/semi-arid areas and even on alkaline soils. As such it can be used to reclaim waste lands in the forests and outside.

- Being rich in nitrogen, the seed cake is an excellent source of organic manure.
- Various parts of the plant have medical value, its bark contains tannin, the flowers attract bees and thus the plant has honey production potential.
- Like all trees, Jatropha removes carbon from the atmosphere, stores it in the woody tissues and assists in the buildup of soil carbon. It is thus environment friendly.

And some of its limitations are:

- Jatropha cannot be grown on waterlogged lands and slopes exceeding 30°C.
- The ideal climatic conditions for Jatropha can be summarized as annual rainfall not.
- Exceeding 600 mm in moderate climatic conditions, 1200 mm in hot climatic zones and soil pH less than 9. The atmospheric temperature should not fall below 0°C as the plants are sensitive to ground frost that may occur in winters.
- Jatropha seeds are hard and possess toxicity, the golden flea beetle (Podagrica spp.) can harm particularly on young plants.

Jatropha can be established from seed, seedlings and vegetative from cuttings. Use of branch cutting for propagation is easy and results in rapid growth. The bush can be expected to start bearing fruit within two years and in some cases after one year of planting. The plant is undemanding in soil type and does not require tillage. It can meet a number of objectives such as meeting domestic needs of energy services including cooking and lighting, as an additional source of household income and employment through markets for fuel, fertilizer, animal feed, medicine, and industrial raw material for soap, cosmetics, etc. in creating environmental benefits - protection of crops or pasture lands, or as a hedge for erosion control, or as a windbreak and a source of organic manure.

Production process of Jatropha biodiesel

To produce biodiesel, fat and oils are chemically reacted with an alcohol such as methanol or ethanol in presence of a catalyst, usually a strong base, such as sodium or potassium hydroxide. The desired products of the reaction are the methyl or ethyl esters of the fatty acids initially contained in the fat or oil. Glycerin and alkali salts are also obtained as byproducts, which may be used as raw materials in the chemical industry. Glycerin may be used in the pharmaceutical industry. The potassium salts are used for production of potassium fertilizer.

The most cursory look at the literature relating to biodiesel will soon reveal the following relationship for prediction of biodiesel from fats and oils (Peterson, *et. al.*, 1991).

100 lbs of oil + 20 L of methanol → 100 lbs of biodiesel + 20 lbs of glycerol

This equation is a simplified form of the following transesterfication reaction shown in (Fig. 4).

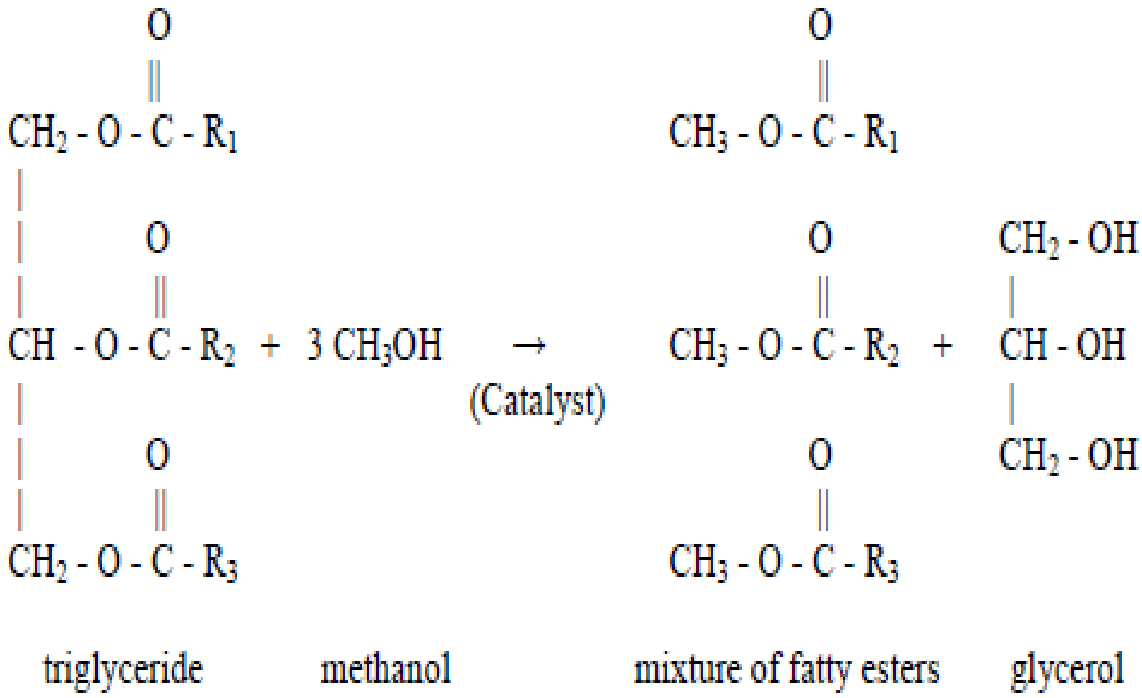

Figure 4. Transesterification Reaction

Jatropha Curcas crude oil process steps

1. Preparation of seeds

The ripe fruits are plucked from the trees and the seeds are sun dried. They are decorticated manually or by decorticator. To prepare the seeds for oil extraction, they should be solar heated for several hours or roasted for 10 minutes. The seeds should not be overheated. The process breaks down the cells containing the oil and eases the oil flow. The heat also liquefies the oil, which improves the extraction process. Oil can be extracted from the seeds by heat, solvents or by pressure. Extraction by heat is not used commercially for vegetable oils. The oil from Jatropha seeds can be extracted by three different methods. These are mechanical extraction using a screw press, solvent extraction and an intermittent extraction technique viz. soxhlet extraction (Rolando Zanzi *et. al.*, 2008).

2. Oil Seed Crushing and Oil Extraction

The seed contains about 38% wt oil. Between 27% and 32% oil can be mechanically extracted from seed using a screw press. Oil extraction can be more effectively carried out using known mechanical methods, because of constraints of availability of these methods, a traditional method done by an old expertise woman was carried out as shown in Fig. 5.

Figure 5. Oil seed crushing and extraction using traditional methods

The oil received at the plant can be refined-oil, which is sent directly to the transesterification unit, or crude-oil, which must be pre-treated before the transesterification process begins. Thus crude oil will pass through the following stages: First, the oil is neutralized to eliminate phosphates. For this, a different range of chemical products must be used, for which purpose a separation process and a centrifugal cleaning system are needed. Second, the oil is whitened to eliminate the remains of phosphates, soap, and oil pigments. This will be done by filtration and by dragging the oil.

3. Purification of oil

The oil extracted as above can be purified by the following means of sedimentation, or boiling with water or filtration [1].

4. Transesterification

The process of converting the raw vegetable oil into biodiesel, which is fatty acid alkyl ester, is termed as transesterification. There are three basic routes to biodiesel production from biolipids (biological oils and fats):

- Base catalyzed transesterification of the biolipid carried out under atmospheric pressure and at temperature ~60-70°C.
- Direct acid catalyzed transesterification of the biolipid.
- A Novel Non-catalytic transesterification by Supercritical Methanol [1].

The processing steps for the most commonly used method base catalyzed transesterification would be as follows:

1. Heat oil to 60 - 70°C. In order to speed up the reaction, the oil must be heated. The ideal temperature range is 60 – 70° C. The reaction can take days at room temperature and will be inhibited above 70°C.

Titrate the oil (Determine how much sodium hydroxide to add). In order to determine the percent of free fatty acid (FFA) in the oil, a process called titration is used. The vegetable oil is first mixed with methanol. Next, a mixture of Sodium Hydroxide NaOH and water is added until all of the FFA has been reacted. This is confirmed by checking the pH of the mixture. A pH of about 9 signifies all of the FFA has been reacted. Virgin vegetable oil from the same feed stock will usually titrate at approximately the same level, so checking every batch is not necessary. Waste Vegetable oil feed stocks will vary greatly. Every batch must be titrated. Adding 1 gram to 1,000 ml of solution by making volume with distilled water.

2. Mix the sodium hydroxide and methanol to make methoxide. The purpose of mixing methanol and the catalyst NaOH is to react the two substances to form Methoxide. The amount of Methanol used should be 20% of the volume of the oil. Methanol and NaOH are dangerous chemicals by themselves, with Methoxide even more. So none of these substances should ever touch skin. Vapors should not be inhaled. Gloves, goggles and ventilation are required at all times when working with these substances. NaOH does not readily dissolve into Methanol. It is best to turn on the mixer to begin agitating the Methanol and slowly pour the NaOH in. When particles of NaOH cannot be seen, the Methoxide is ready to be added to the oil. This can usually be achieved in 20 –30 minutes.

3. Let the Mix settle and drain the glycerol. After the transesterification reaction, one must wait for the glycerol to settle to the bottom of the container. This happens because Glycerol is heavier than biodiesel. The settling will begin immediately, but the mixture should be left a minimum of eight hours (preferably 12) to make sure all of the Glycerol has settled out. The Glycerol volume should be approximately 20% of the original oil volume.

4. After that wash the biodiesel. The washing of raw biodiesel fuel is one of the most discussed subjects among do it yourselfers. The purpose is to wash out the remnants of the catalyst and other impurities.

Some Physical Properties Testing of Jatropha Curcas Biodiesel

The pure biodiesel obtained through the above steps gave the ester yield, measured on weight basis. The ASTM system is the basis for defining product specifications and measurement methods for most segments of the fuels and industrial products market in the U.S ASTM D 6751 – 02 sets forth the specifications that must be met for a fatty acid ester product to carry the designation “biodiesel fuel” or “B100”. Products that meet the specification, by implication, will perform properly as a compression ignition fuel either as B100 or in blends with any petroleum-derived diesel fuel defined by ASTM Specification D 975 Grades 1-D, 2-D, and low sulfur 1-D and 2-D. The values of the various biodiesel properties specified by ASTM D 6751 are listed in Table 1.

In characterizing the Jatropha Curcas biodiesel produced as alternative diesel fuel, the biodiesel was analyzed or some its physical properties in our home or in the laboratory of science at the Taiz University.

Acid Number

The acid number is “The quantity of base, expressed as milligrams of potassium hydroxide per gram of sample, required to titrate a sample to a specified end point.” The acid number is a direct measure of free fatty acids in B100. The free fatty acids can lead to corrosion and may be a symptom of water in the fuel. Usually, for a base catalyzed process, the acid value after production will be low since the base catalyst will strip the available free fatty acids. However, the acid value may increase with time as the fuel degrades due to contact with air or water. From the washing process the Acid Number of our crude oil was 7.10 pH after the wash number 13. This value is falling within the limited specified values of biodiesel and diesel fuel.

Table 1. ASTM D 6751 – 02 Requirements.

Property	***Method***	***Limits***	***Units***
Flash point, closed cup	D 93	130 min	°C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity, 40°C	D 445	1.9 – 6.0	mm^2/s
Sulfated ash	D 874	0.020 max	wt. %
Total Sulfur	D 5453	0.05 max	wt. %
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min	
Cloud point	D 2500	Report to customer	°C
Carbon residue	D 4530	0.050 max	wt. %
Acid number	D 664	0.80 max	mg KOH/g
Free glycerin	D 6584	0.020	wt. %
Total glycerin	D 6584	0.240	wt. %
Phosphorus	D 4951	0.0010	wt. %
Vacuum distillation end point	D 1160	360°C max, at 90% distilled	ºC
Storage stability	To be determined	To be determined	To be determined

Flash Point

The flash point is defined as the "lowest temperature corrected to a barometric pressure of 1.013×10^5 Pa (760 mm Hg), at which application of an ignition source causes the vapors of a specimen to ignite under specified conditions of test." This test, in part, is a measure of residual alcohol in the B100. The flash point is a determinant for flammability classification of materials. The typical flash point of pure methyl esters is > 200°C, classifying them as "non-flammable". However, during production and purification of biodiesel, not all the methanol may be removed, making the fuel flammable and more dangerous to handle and store if the flash point falls below 130ºC. The Flash Point of Our Crude Biodiesel was 332.6°F = 167°C. This value is higher than the value of fuel diesel but still fall within acceptable limit.

Cloud Point

The cloud point is "The temperature at which a cloud of wax crystals first appears in a liquid when it is cooled down under conditions prescribed in this test method." The cloud point is a critical factor in cold weather performance for all diesel fuels. The chemical composition of some biodiesel feedstocks leads to a B100 that may have higher cloud points than customer's desire. The cloud point, however, is another parameter that can be predicted ± 5% with knowledge of the esters composition. Since the saturated methyl esters are the first to precipitate, the amounts of these esters, methyl palmitate and methyl stearate, are the determining factors for the cloud point. The cloud point for our crude biodiesel was obtained to be between -10° C to -13°C. The cloud point obtained here is comparable to the -12°C obtained for the petroleum diesel in contrast to other biodiesel such as palm kernel oil (PKO) obtained by Alamu, *et. al.*, 2007, more on cloud point values for different biodiesel refers to Alberta Research Council, 2008.

Conclusion

From our studies of the possibility of production and characterization of Jatropha Curcas biodiesel, the following is concluded:

- Fat and oils are chemically reacted with an alcohol such as methanol or ethanol in presence of a catalyst, usually a strong base, such as sodium or potassium hydroxide for the purpose of producing Jatropha Curcas biodiesel, this process of converting the raw vegetable oil into biodiesel, is termed as transesterification.

- The test results obtained for the Acid Number (7.1 pH), Flash Point (167°C), and Cloud Point (-10°C to -13°C) demonstrated that the ethyl ester of Jatropha Curcas biodiesel can successfully be source for energy for diesel engine, even though, other ASTM standard tests are important and should be considered.

- Bio-Diesel should start immediately and adopting a Yemen-wide Bio-Energy Plan, In order to meet the future target for Bio-Energy production, Yemen should expand planting of Jatropha Curcas to a few million hectares targeting to become a net exporter of energy.

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