Egyptian Jatropha Oil Extraction for Biodiesel Production

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Extracción de aceite de Jatropha egipcia para la producción de biodiesel

Extracció d'oli de Jatropha egípcia per a la producció de biodièsel

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RESUMEN

El biodiesel es el biocombustible económicamente y técnicamente más atractivo, y se puede preparar a partir de cualquier aceite vegetal. En Egipto, el aceite de Jatropha parece ser la mejor fuente para la producción de biodiesel, ya que este árbol es fácil de hacer crecer y multiplicar.
Además, Jatropha prospera en áreas marginales y desérticas que no pueden sustentar cosechas y se puede irrigar con aguas residuales municipales con tratamiento primario.
El principal objetivo de este estudio es comparar y optimizar el rendimiento de aceite extraído de las semillas de Jatropha a pequeña escala y a escala planta piloto.
Se estudian diferentes disolventes bajo diversas condiciones de extracción a fin de determinar el tipo óptimo de disolvente, la razón sólido:líquido y el tiempo de extracción que dan el máximo rendimiento de aceite.
Se detallan también las especificaciones del aceite extraído, las pérdidas ocasionadas al desvainar y limpiar las semillas, las pérdidas del disolvente utilizado y el análisis y usos de la harina obtenida.

Palabras clave: Biodiesel. **Aceite de Jatropha. Semillas de Jatropha. Extracción.**

SUMMARY

Biodiesel is the most desirable biofuel economically and technically and it can be made from any vegetable oil. In EGYPT jatropha oil seems to be the best source for biodiesel production because jatropha tree is easily growing and easily propagated.
Also jatropha tree thrives in marginal and desert areas that are unable to support crops and it can be irrigated with primary treated municipal wastewater.
The main purpose of this investigation is to compare and optimize the oil yield extracted from jatropha seeds on both bench and pilot scale.
Different solvents under different extraction conditions were studied to determine optimum solvent type, solid: liquid ratio and extraction time which gave maximum oil yield.
Oil extracted specifications, losses in seeds dehulling & washing, losses in solvent used and extracted meal analysis & uses were also concluded.

Key words: **Biodiesel. Jatropha oil. Jatropha seeds. Extraction.**

RESUM

El biodièsel és el biocombustible econòmicament i tècnicament més atractiu, i es pot preparar a partir de qualsevol oli vegetal. A Egipte, l'oli de Jatropha sembla ésser la millor font per a la producció de biodièsel, ja que aquest arbre és fàcil de fer créixer i multiplicar.
A més, Jatropha prospera en àrees marginals i desèrtiques que no poden sustentar collites i es pot irrigar amb aigües residuals municipals amb tractament primari.
El principal objectiu d'aquest estudi és comparar i optimitzar el rendiment d'oli extret de les llavors de Jatropha a petita escala i a escala planta pilot.
S'estudien diferents dissolvents sota diverses condicions d'extracció per tal de determinar el tipus òptim de dissolvent, la raó sòlid:líquid i el temps d'extracció que donen el màxim rendiment d'oli.
Es detallen també les especificacions de l'oli extret, les pèrdues ocasionades en esbajocar i rentar les llavors, les pèrdues del dissolvent emprat i l'anàlisi i usos de la farina obtinguda.

Mots clau: Biodièsel. **Oli de Jatropha. Llavors de Jatropha. Extracció.**

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1. INTRODUCTION

Fossil fuels are the most used form of energy, however the world reserves are declining.
In addition, fossil fuels use results in global warming, and pollutes the environment. On the other hand alternative fuels such as biofuels, hydrogen, solar and wind are renewable, and environmentally friendly[1].
Biodiesel is a substitute or extender for traditional petroleum diesel and it does'nt need special pumps or high pressure equipment for fueling[2]. In addition, it can be used in conventional diesel engines, so it is not necessary and don't need special vehicles or engines to run biodiesel. Pure biodiesel (100% biodiesel) reduces CO_2 emissions by more than 75% over petroleum diesel while using a blend of 20% biodiesel reduces CO_2 emissions by 15%[2]. Biodiesel can directly replace petroleum products: reducing the country's dependence on imported oil. Biodiesel offers safety benefits over petroleum diesel because it is much less combustible, with a flash point greater than 150ºC, compared to 77ºC for petroleum diesel[2]. Also biodiesel is safe to handle, transport, and store, and it mixes readily with petroleum to diesel at any blend level, making it a very flexible fuel additive[2].
Biodiesel is the most desirable biofuel economically and technically and it can be made from any vegetable oil[3, 4, 5]. Also biodiesel can be prepared from waste vegetable oils[6] or from oil produced from microalgae[7].
In EGYPT we prefer to make biodiesel from non – edible vegetable oil to eliminate any competition for oil uses in food industry[8].
Jatropha plant is fast growing, easily propagated and thrives in marginal and desert areas that are unable to support crops. Also jatropha trees can be irrigated with municipal wastewater primary treated.
The government in EGYPT has been interested in greening the desert, and finding an outlet for municipal wastewater, so cultivation of jatropha in EGYPT desert succeeded very well.
Jatropha oil can be extracted mechanically using simple oil mills and oils expellers, mechanical pressing technique is simple and feasible for farmers. While chemical extraction or solvent extraction gives maximum oil, but cannot be achieved on small scale basis[9]. Solvent extraction can provide 95% to 99% of the total available oil.
Extraction and processing of jatropha seeds is similar to that of other oil seeds. Separation of the hull from the kernel is easily done when dried and requires simple preprocessing to maximize oil yield (i.e. grinding, heating, cooling and then pressing).
The cost for extraction and associated equipment ranges from as low as several hundred dollars (US) for simple hand operated equipment to US $ 15000 or more for sophisticated diesel powered equipment[10].
Solvent extraction (with hexane) generally obtains the maximum oil content from jatropha seeds about 35% by weight from the curcus seeds, or 95% to 99% of the total available oil[11].
Although extracting oil using organic solvents is the most efficient method, but it is more costly and advanced technology which cannot be carried out economically on a small scale. Pressing of oil from seeds may be more appropriate, particularly for small or decentralized operations.
Thus our purpose in this paper is to reach optimum conditions for oil extraction from Egyptian Jatropha seeds for biodiesel production.

2. EXPERIMENTAL PROCEDURE

2.1. Experimental apparatus

2.1.1. Bench scale set – up

a. Soxhlet apparatus made by Quickfit, England.
It consists mainly of a round flask, 2 L capacity, mounted by a special tube in which the seeds were placed with a capillary side tube which permits solvent drainage and circulation in closed loop from the round flask to the seeds. Above this tube, a condenser is quick – fitted to prevent any losses of solvent and permits its condensation and circulation through the seeds.
b. Water – Bath – Julabo model TWB 20 for controlling solvent temperature above its boiling temperature.
c. Rota – vapor: oil recovery by separation of solvent by evaporation under vacuum, provided with 1L rotating glass flask.

2.1.2. Pilot Scale Set – up

a. Cross Beater – Mill from RETSCH Co. West Germany. Its capacity is up to 80 Kg/hour, feed size < 15 mm, final fineness to < 100 μm.
b. Solid – liquid extraction apparatus made by QVF Co., Germany.
It consists mainly of a round flask (100 L capacity), heated electrically by a mantle provided with three heaters at different levels. This flask is mounted by two condensers and connected with a side tower in which the crushed seeds were placed inside a cloth bag.
c. Liquid – liquid extraction unit, It is of 100 L capacity and it is manufactured by QVF Co. Germany. In this unit the solvent was recovered and pure oil is obtained.
d. Pilot scale Rota – vapor, of 20 L capacity, flask made by QVF Co. Germany and it is similar to that of bench scale, but different in volume.

2.2. Materials

2.2.1. Jatropha seeds

Are obtained from Ministry of Agriculture: they were collected from two years old. Jatropha trees cultivated and grown in Luxor (southern EGYPT).

2.2.2. Solvents

Solvents used are illustrated in Table 1.

TABLE I

Solvents used and their sources.

Solvents	Use	Source
Hexane (99%)	Solvent	Adwic Company, EGYPT
Isopropanol (99%)	Solvent	Adwic Company, EGYPT
Methanol (99%)	Solvent	Adwic Company, EGYPT
Commercial Hexane	Solvent	Misr Petroleum Co. Alexandria, EGYPT

2.3. Experimental Technique

2.3.1. Jatropha seeds preparation

Jatropha seeds were prepared according to the following steps.

a. Separation and cleaning from any foreign materials such as stones, leaves ...etc.
b. Dehulling to separate the hulls from the seeds.
c. Crushing of seeds to optimum size.
d. Weighing a certain mass of the crushed seeds, (≈ 500 gm for bench scale and ≈ 20 kg for pilot scale extraction).

2.3.2. Solvent extraction procedure on bench scale

a. About 500 gm of crushed seeds were placed in the soxhlet between two cotton pieces. The lower piece of cotton is used to prevent seeds from clogging the outlet of the oil – solvent mixture, while the upper one is used to spread the condensed solvent.
b. Known volume of the solvent was placed in the round flask and was boiled by using a water bath provided with temperature control.
   Boiling and further condensation of solvent on the Jatropha seeds which is accumulated till certain height then it drains into the round flask by siphoning effect. When the drained solvent became very clear and colourless, this indicated that all oil in seeds was extracted in the solvent.
c. Different types of solvent are tested on bench scale.

2.3.3. Pilot scale jatropha oil extraction.

About 208 kg of crushed jatropha seeds were extracted in eleven batches using hexane as solvent. In each batch about 20 kg of seeds and 140 L of hexane boiled at 65ºC for a time ranging from 10-15 hours.
Hexane was left to drain from jatropha seeds for about 20 hours. Extracted meal was weighed, dried and subjected to chemical analysis.
Studied seeds - hexane ratios are summarized in table 2.

2-3-4- Solvent – Oil separation

– For both bench and pilot scale after complete oil extraction from seeds, there is liquid – liquid extraction step for solvent recovery and oil purification.
– Amount of Jatropha oil obtained is then determined filtered using whatman filter paper and subjected to viscosity measurement and free fatty acid analysis.

3. RESULTS

3.1. Bench Scale Results

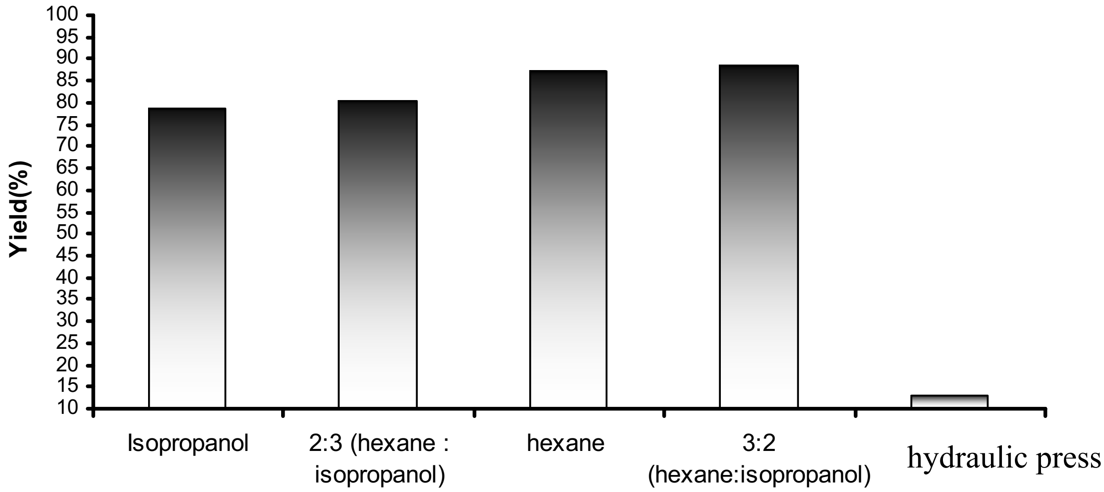
3.1.1. Effect of using different solvents

Three solvents were used namely isopropanol, methanol and hexane and also two mixtures of hexane and isoproponol with two different volume ratios. Results obtained revealed that hexane is the optimum solvent for jatropha oil extraction as shown in figure 1. From the figure it is obvious that pure hexane extracted 87.25% by wt of available oil while hexane- isopropanol extracted 88.5% which can be considered negligible difference.
Using methanol as solvent for jatropha oil extraction resulted two layers of dark colour which considered as negative result.
Mechanical extraction using hydraulic press resulted in only 13% of available oil yield.

TABLE II

Different Solid Liquid Ratios for Jatropha Oil Extraction Using Hexane.

Scale	Run Nº	Jatropha Seeds Mass (kg)	Hexane Weight (kg)	Solid : Liquid Ratio
Bench Scale	1	0.545	1.380	1 : 2.53
	2	0.500	1.380	1 : 2.76
	3	0.040	0.088	1 : 2.2
	4	0.040	0.200	1 : 5
	5	0.040	0.280	1 : 7
	6	0.130	1.300	1 : 10
Pilot Scale	7	20	88.3	1 : 4.4
	8	17.9	84.3	1 : 4.7
	9	15.8	77.8	1 : 4.9



Fig(1) : Oil yield vs. different extraction solvents

Figure 1. Oild yield vs. different extraction solvents and methods.

3.1.2. Effect of different solid: liquid ratios

Extraction of jatropha oil using hexane was conducted at six different solid: liquid ratios as shown in table 2. It was found that increasing liquid: solid ratio, improved oil extraction till a ratio of 1 : 5 then more increase in this ratio does not affect oil extraction. These results were illustrated in Figure 2.

3.2. Pilot Scale Results

3.2.1. Effect of liquid : solid ratio.

From results of bench scale investigation only hexane as solvent was used at pilot scale. But three different solid: liquid ratios were tried namely 1: 4.4, 1: 4.7 & 1: 4.9 and it was found that increasing liquid: solid ratio increases oil extraction as shown in table 3.

3.2.2. Effect of extraction time

From pilot scale results it was found that increasing liquid: solid ratio decreases extraction time as illustrated in Table 3.

3.2.3. Effect of Jatropha Tree Age

The above results in table 3 were for oil from Jatropha trees of two years old, while extraction at optimum conditions for three years old Jatropha trees, the %oil extracted reached 30% which is 84.4% of the available in seeds.

3.2.4 Jatropha Oil Characteristics

Extracted jatropha oil was subjected to many tests and characterized as follows

Viscosity	=	46.8 m Pa.s
Density	=	0.91 kg /L
Free Fatty Acid	=	1.8%

3.2.5. Extracted meal analysis and uses

Jatropha seeds after oil extraction were dried, weighed and analyzed.

Extracted meal constituents were:

Moisture	5.6%
Ash	5.95%
Fats	6.87%
Protein	21.81%
Nitrogen	2.13%
Phosphrous	0.45%
Potassium	1.55%

The cake was tested as fertilizer and positive results were obtained[12].

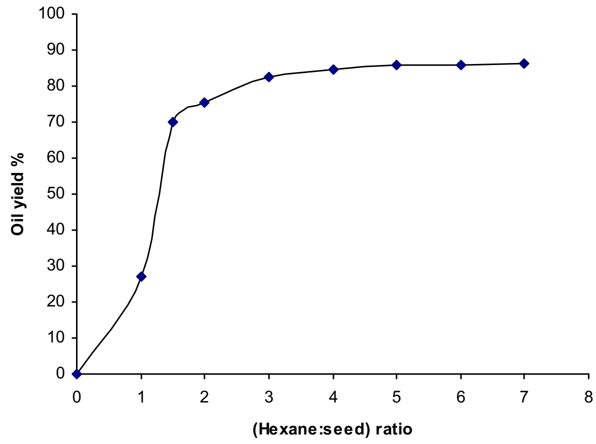


Figure 2. Yield% vs. (hexane:seed)ratio.

TABLE III

Effect of Solid: Liquid Ratio on Both Extraction Time and Percent Oil Extracted.

Run Nº	Solid : Liquid Ratio	Extraction Time (hours)	% Oil extracted (wt)	% Oil yield from available
1	1 : 4.4	15	18.2	64.3
2	1 : 4.7	11	21.3	75
3	1 : 4.9	10	23.05	81.5

TABLE IV

The individual fatty acid composition of Jatropha Oil is measured by gas chromatography and shown in the following table.

Fatty acid	Composition (% wt.)
Palmitic (16:0)	18.22
Stearic (18:0)	5.14
Oleic (18:1)	28.46
Linoleic (18:2)	48.18

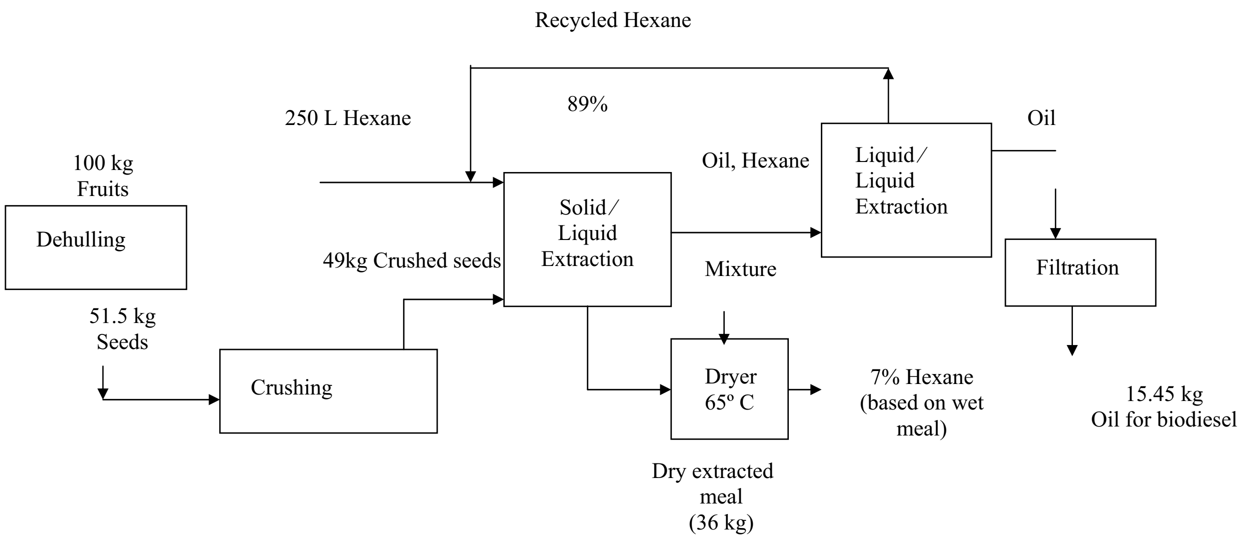


Figure 3. Block Flow Diagram for Jatropha Oil Extraction Using Hexane, from Pilot Scale at Optimum Conditions (for 3 years old Jatropha tree).

3.2.6. Optimum Extraction sequence

Optimum operating solvent extraction conditions for Jatroha oil using hexane are illustrated in the flow diagram represented in Figure 3.
According to the steps in Figure 3 it was found that:

– Ratio of Jatropha seeds to hulls	≈ 51.5 % by wt
– Losses in crushing jatropha seeds	≈ 0.98 % by wt
– Losses in hexane (total)	≈ 11%
hexane in meal	≈ 7% by volume
hexane losses in apparatus	≈ 4%
– Moisture content in Jatropha seeds after 24 hours drying at 105 ºC	≈ 6% by wt
– Hexane recovered	≈ 89% by volume

CONCLUSIONS

From the previous results it was concluded that:

1 - Optimum seed: hexane ratios were 1 : 5 by wt and extraction time 10 hours.
2 - Increasing solvent quantity means decreasing in extraction time to a certain limit.
3 - Oil extracted by hexane reached 23% of seeds while the available oil is 28.3% which is less than the average in Jatropha curcas seed cited in the literature which is about 35% this may be due to the trees are not yet matured enough, since they are only of 2 years old.
4 - Oil extracted from 3 years old Jatropha tree is increased to 30% while the available oil reached 35.5% which is in accordance with content of Jatropha seeds oil as recorded in the literature.

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