Production and use of Jatropha Curcas Oils as Biofuel for Internal Combustion Engines (diesel engines)

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ABSTRACT: *Increasing consumption of oil, today's main fossil fuel, is leading to its gradual depletion, Environmental pollution and shortages of fossil fuels and natural gas have led to a growing demand for biodiesel. As a result, the quest for alternative renewable energy sources and sustainability has gained importance in most countries of the world, particularly in the field of biofuels. Countries, particularly in the area of biofuels Because Jatropha oil cannot be used for food without being detoxified, it can be used as a source of energy/fuel. This study aimed to explore the possibilities of using jatropha oil for biodiesel production and examined physicochemical characteristics such as acid number, viscosity and density. According to the study, it was shown that the physicochemical characteristics of the oils are beneficial and can be beneficial as a feedstock for biodiesel and the industrial sector.*

KEYWORDS: *biofuel Jatropha curcas oils, diesel, diesel engine, density, greenhouse gas, biodiesel, petroleum.*

I. Introduction

From the last century to the present day, the high consumption of fossil fuels has led to major global warming and environmental pollution (Koh et al 2011).Carbon dioxide is the main gas responsible for global warming, mainly emitted by the burning of fossil fuels. In most countries of the world, the search for alternative renewable and sustainable energy sources has taken centre stage, in particular biofuels. This renewable energy source is seen as the most suitable alternative to diesel fuel for running internal combustion engines. Since it is used in all sectors where it can be transported and stored. As well as being affordable compared with other renewable energy sources, it is a renewable and safe source (Sarin et al.2007).In addition, biofuels have similar characteristics to diesel fuel, making them the best alternative to the diesel engines currently on the market. One of the main reasons for studying the widespread use of biofuels in all regions of the world is the diversity and availability of biofuel sources. Biodiesel can easily be made from renewable biological sources such as vegetable oils and animal fats. Jatropha is considered one of the key crops for making biodiesel. Jatropha has multiple benefits, as it can grow in wetlands. It requires little water and fertiliser, and can live in sterile soil. It is also highly resistant to pests and has a high seed yield, with a lifespan of 30 to 40 years, and the oil content of jatropha seeds is around 30 to 40% (Ballerini D et al 2007). The aim of this study was therefore to explore the possible uses of jatropha oil for the production of biodiesel as a substitute for fossil fuels, using simple techniques.

II. MaterialsandMethodology

This is a cross-sectional study conducted from 10 April to 25 Novembre 2023 in the provincial city of Kinshasa. The variables used were: 1.manual extraction to obtain oils.2.analysis to measure the physico-chemical parameters of our samples.

2.1. Materials

2.1.1. Biological materials

Jatropha curcas is a large shrubby plant with narrow branches that can reach a height of 5 to 6 metres, belonging to the sub-region Phanerogams, a branch of Angiosperms in the class Magnoliopsida, subclass Rosidae, order Euphorbiales and family Euphorbiaceae. The plant belongs to the subfamily Crotonoideae, which comprises around 8,000 species in more than 300 genera. The genus Jatropha - from the Greek Jatros, meaning "doctor" and "trophé", meaning "food" - is part of the tribe Joannesieae, which comprises around 170 species. Two-thirds of these species come from Latin America, according to a review by Pax (1910). However, curcas appears to be the vernacular name for the plant on the Malabar coast in south-west India. In Africa, jatropha is also known as pourghère, tabanani in Senegal, or bagani ("poison") in Bambara because of its texture. The shrubs produce fruit for 40 to 50 years(MactarDiop 2009).

2.2.2. Leaves and flowers

Leaves green, white, pentagonal, lenticular, not toothed, 8.5 cm long and wide, without cilia and similar to vine leaves. The neck of the leaf is about 11 cm long. The plant has a single colour. The flowers are different. Each single column of the androecium is made up of two separate coils of five, and they are close together in the gynoecium. The three subspecies are linked at about two-thirds of their length(MactarDiop 2009).

2.2.3. The fruit

The fruit is a spherical capsule about 4 cm long and 3 cm thick, made up of three distinct parts, each containing a seed. The fruit is green when first formed, then yellow, then reddish-black, wrinkled and rough, with 1 to 3 seeds similar to castor beans. The dry, ripe fruits remain on the plant and are very often not released, even when they fall to the ground. According to, the average weight of ripe fruit is 2.16 g. (Mactar Diop.2009).

Figure1: Fruit of jatrophacurcas.

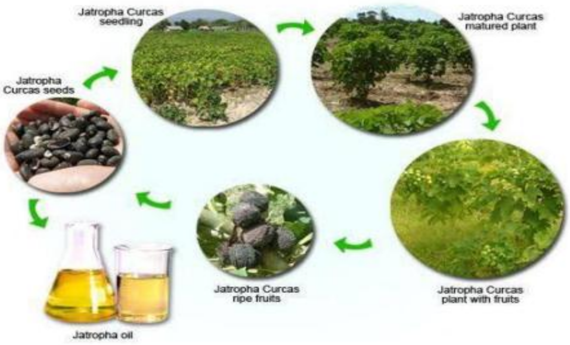
2.2.4. The seeds

The seeds are mottled black or dark brown. They are 1.5 cm to 2.5 cm long and 0.8 cm to 1.2 cm thick. According to **Figure 2**, the seeds represent between 53 and 62% of the weight of dried fruit and 15% of fresh fruit. About 20% of the saturated fatty acids and 80% of the unsaturated fatty acids are found in the seeds, which represent 25 to 40% of the weight of the oil. About 37% of the husk and 63% of the kernel are present(Henning et al 2007;Yacine2006)).

Figure 2: Seeds of jatrophacurcas

2.2.5. Growing cycle

The plant, which starts producing during the first year, flowers after 120 days of sowing at the beginning of the rainy season and spreads ad infinitum. Fruit appears after 180 days and ripens after 60 days of flowering, demonstrating its ability to produce for 30 years. According to some reports, productivity varies between 2,000 and 5,000 kg of grain per hectare per year (**Figure.3**), illustrating the jatropha crop cycle.



2.2.6. Pests of the crop

Disease and pest attacks on J. curcas are rare (**Figure 4**). Leaves and flowers can be affected by powdery mildew, while Alternaria can cause leaf drop. Several species of beetle feed on the leaves of young plants, while Spodopteralitura caterpillars feed on the leaves. Pests can also have an impact on plants grown in the presence of J. curcas. It is recommended not to plant it as a hedge around cassava fields as it is a facultative host for cassava viruses(Mactar Diop.2009).

Figure 4:Jatropha insect parasite.

As the raw material, Jatropha curcas seeds were purchased from the University of Kinshasa's organic garden on the one hand, and harvested from plots on INDONDO avenues in the commune of N'Sele, Mpasa II district on the other.

2.3. Laboratory Equipment

Mortar (local manufacture),Pestle (local manufacture), 200 mL Beaker, 500 mL volumetric flask,STUART hot plate,500 mL decanting ball, KERN analytical balance (10-1 mg precision), 100 mL graduated pipette, Kettle containing raw products, 25 mL burette, UN110 -Memmert incubator, Glass pycnometer, 250 mL glass Erlenmeyer flask, Getty thermometer (0 - 200°C), S2C F862 viscosimeter, 100% cotton filter (handkerchief). Figures 5a to 5e illustrate the different types of equipment used to produce Jatropha curcas oil and the various laboratory analyses carried out. Test samples are shown in Figures 5a and 5b.

2.3.1.Reagents

The following reagents were used in our laboratory measurements: Potassium hydroxide (KOH); Copper sulfate ($CuSO_4$); Ethanol; Phenolphthalein 1%; Sulfuric acid; Distilled water.

Figure 1a. Mortar and pestle

Figure 5b: A burette

Figure5c: An oven

Figure 5d: A Viscometer

Figure 5e: the different biofuel sample

2.3.2. Test equipment

1. diesel engine JOHN DEER (JD13)(Figure.6a) (Atta Pascal2017) **.**

2. Diesel filter (Fig.6b).

Figure.6a: JD diesel engine

Figure 6b: diesel filter

III. Steps in the Production of Jatropha CurcasOil

3.1. Manual extraction

Less expensive than extraction with laboratory equipment. The experimental protocol for this method is as follows:

1) Principle

The principle is to extract the oil from Jatropha curcas seeds by hand.

2) Procedure

- Place 1 kilo of pre-dried seeds in a 2-litre mortar; - Grind the seeds with a pestle to a paste; - Add a spoonful of ordinary water at 40°C to the paste and continue grinding; - Observe the mixture of lukewarm water and paste, then recipe the liquid phase, which consists of 97% oil and only 3% water; - Continue the operation, adding water at the same temperature until you have obtained the bulk of the oil contained in the seeds (SticklenM.B.2008):

3) Expression of result

The extraction yield is calculated by the following equation:

$$\eta = \frac{V_P}{V_T} \times 100 \ (1)$$

With:
η: yield expressed as a percentage (%) ;
V_P: practical volume;
V_T: Theoretical volume

3.2.Process for Determining the Physico-Chemical Parameters of Pure Vegetable Oil

a) By settling and filtration

Decanting is a liquid treatment method that generally consists of removing particles after settling. Filtration, on the other hand, is also a treatment technique, but consists in passing the solution to be treated through a body (membrane) which retains all substances whose diameter is greater than its porosity. Thus, for decantation, Jatropha curcas oil is placed in a pot for 5 days before a layer ofimpurities appears below the pot. As for filtration, after decanting, the oil ispassed through a filter (handkerchief) as many times as possible. Collect the filtered oil and weigh it to obtain its final mass(Rakotoravo T. 2016) .

b)Different Calculations and Expression of Results

b.1 Impurity rate

The impurity rate is known by the expression:

$$m_1 \rightarrow 100\%$$

$$m_1\text{-}m_2 = m_i$$

$$m_i = \frac{m_i}{m_2} \times 100 = \text{impurity rate}(\%)(2)$$

With:

m_i : Mass of impurities

m_1 : Initial oil mass before settling and filtration;

m_2 : Final oil mass after settling and filtration.

b.2 Water content

1) Principle

The principle consists in placing the oil in a drying oven at atmospheric pressure at a temperature of 110° ± 2°C until an almost constant mass is obtained. The optimum drying time for the oil is 17 hours.

2) Procedure

- Weigh the initial solution (41.01g); - Equate initial mass to 100% humidity; - Steam the solution at 110°C for 17 hours;- Weigh the final solution after steaming; - Subtract the final mass from the initial mass; - The difference is the mass of water evaporated, and a simple rule of three is used to determine the percentage of moisture; - Add a few drops of anhydrous copper sulfate ($CuSO_4$);If the solution remains colorless after dissolving the copper sulfate, there's no water lef;.- Add a few drops of anhydrous copper sulfate ($CuSO_4$): if the solution remains colorless after dissolving the copper sulfate, there's no water left; - Test the final solution with the copper sulfate crystals to ensure that 100% of the water has evaporated.(R. Brun,1973) .

3) Expression of results

The moisture content is given by the expression:

$$m_1 \rightarrow 100\%$$

$$m_1 - m_2 = m_i$$

$$m_i = \frac{m_1}{m_2} \times 100 = \text{humidity }(\%)(3)$$

With:

m_i : Evaporated water mass

m_1 : Initial mass of solution before steaming;

m_2 : Final mass of solution after steaming

b. 3. Determining the acid number

The acid number corresponds to the number of milligrams of a base (in our case, potassium hydroxide) required to neutralise the free acids present in one gram of fat.

1) Principle

The principle consists in neutralizing the free acids with a basic solution of titrated potassium hydroxide.

2) Procedure

- Weigh 4 grams of sample in a beaker and dissolve in 100 mL of ethanol; - Shake, then place the mixture on a hot plate; - Heat the mixture until the ethanol boils, allowing the oil to dissolve in the ethanol; - Allow to cool for 15 minutes; - Take 10 mL of the cooled solution and place in an Erlenmeyer flask; - Add 2 to 3 drops of phenolphthalein; - Dose the mixture with a 0.1 N solution of alcoholic KOH, stirring constantly until the violet coloration appears; - Excess KOH is measured with HCl until neutralized (white color).(SticklenM.B.2008):

3) Expression of Results

The acidity index is determined by the expression:

$$I_a = \frac{(V_b - V_E) * CHCl * M}{P_e}(4)$$

With:

M: the molar mass expressed in grams per mole (g/mole) of KOH, which is 56.1;

V_b: the volume, expressed in milliliters (ml), of the spawn;

V_E: sample volume expressed in milliliters

CHCl: the concentration of HCl used, which is 0.1N

P_e : the mass in grams of my test sample.

b.4. Determination of density

1) Principle

Density, also known as mass density, is a volumetric quantity that characterizes the mass of a substance per unit volume. Its ratio to the density of water at standard temperature gives the density (a unitless quantity).

2) Procedure

- Weigh the mass of the empty pycnometer (Mv); - Weigh the mass of the pycnometer filled with distilled water (Meau);- Subtract the mass of the whole from that of the empty pycnometer; the difference constitutes the mass of the water, which corresponds to the volume of the pycnometer; - Weigh the pycnometer filled with oil;

- Subtract the mass of the whole by that of the empty pycnometer, and the difference isthemassof the oil;- The ratio of the mass of the oils to the volume of the pycnometer gives the density of the oils;- The density of the oils is the ratio of the density of the oils to that of water (reference liquid).(Sticklen M.B.2008;R. Brun,1973)

3) Expression of results

The density of the oil is given by the following relationship:

$$\mathbf{m_v} = \frac{\mathbf{m_H}}{\mathbf{V_P}} \quad \mathbf{(5)}$$

With:
m_v: density ;
m_h : the mass of the oil ;
V_p: the pycnometer volume
Density is expressed by the following formula:

$$d = \frac{\text{density of the liquid}}{\text{density of the water}} \qquad (6)$$

With: d: the density

b.5. Viscosity determination

1) Principle

Viscosity is the ability of a liquid to resist flow, and is influenced by temperature in the sense that the lower the temperature, the greater the liquid's resistance. It also influences the evaporation and emulsification of hydrocarbons. It is involved in all phenomena linked to fluid flow, such as head loss in piping, settling, pumping, filtration and others.The higher the flow resistance,the greater the viscosity. Due to the different measurement methods used to determine it, a distinction is made between dynamic viscosity and kinematic viscosity. In this work, kinematic viscosity was measured.The measurement is based on determining the flow time of a given volume of liquid in the capillary of a calibrated viscometer tube at a specific, controlled temperature.(Mactar Diop.2009).

2) Procedure

- Hold the viscometer tubes in an inverted vertical position, immersing the end of the capillary arm in the oil;- Suck oil into the ball up to the dipstick mark; - After filling, wipe off any excess oil adhering to the ends, then invert the viscometer tube; - As soon as the liquid fills half of the lower ball (BI), prevent the liquid from running out by means of a rubber stopper attached to the bottom of the capillary;- Maintain the bath at test temperature and keep the viscometer in it for a while;- As soon as the sample reaches bath temperature, remove the rubber stopper andallow the liquid to flow freely, measuring the time taken for the meniscus to move from the lower line to the upper line;

3) Expression of results

The two times obtained (first and second tests) will be used to calculate the viscosity according to the relationship:

$$\upsilon = K \times t \qquad (7)$$

With:

υ : kinematic viscosity expressed in stocke or centistokes (cSt) or in square millimeters per second (mm2/s) in the International System;
k : the viscometer calibration constant of 0.054 mm2/s2 ;
t :average time between trials (s).

3.3. Determination of the Physico-Chemical Parameters of Different oil-Diesel blends.

The use of different blends is justified insofar as the results obtained with pure oils are not convincing in terms of viscosity and density for use as such in an engine. To deal with this, we're going to use several blends, such as D75, D50, D25 and D10 (Fuel with X% diesel).
The measurement methodology is the same as for pure jatropha oil.(Guibet J et al 2011; Ejazet al.2011)

3.3.1. Testing biodiesel in diesel engines

1) Principle

The principle consists in using a JD13 (JOHN DEER) diesel engine as test equipment for our product. Its characteristics are summarized in Table 1.

Table.1 Characteristics of the JD brand diesel engine used

2) Procedure

Take an initial volume of the biodiesel to be tested; Pour the sample back into the engine tank; Start the engine; Determine running time using stopwatch;Observe other parameters such as engine sound, exhaust smoke smell and color;Stop the engine after a time to measure the remaining volume.

The difference in volume is the quantity consumed at time t;

Determine the volume flow rate.(Gilles Vaitilingom;Penehev et al 2010)

3) Expression of result

Volume flow (Qv) is expressed by the following formula:

$$Q_v = \frac{V}{t} \qquad (8)$$

With

Q_v : Volumetric flow rate in mL/min ;

V : milliliter (mL) volume or its equivalent;

t : time in minutes.

IV. Results and Discussion

4.1. Presentation of results

4.1.1. Jatropha curcas oil production

The yield of Jatropha curcas oil production is: -

Hammerrotation speed	**1700 tr/min**
Mechanical power	**13 ch = 9724 watts**
Mass flow rate	**Between 150 and 250 kg/h**

Mass of Jatropha curcas fed: 5 kg =5000 g - Density of Jatropha curcas oil: 880 g/L - Theoretical volume is mass/density, i.e.

$$V_t = \frac{5000\,g}{880\,g/L} = 5.7 Liters \qquad (9)$$

- The practical volume is 2.1 liters
- Hence the yield is:

$$n = \frac{V_P}{V_T} \times 100 \qquad (10)$$

$$n = \frac{2.1}{5.7} \times 100 = 36.8\% \qquad (11)$$

4.1.2. Physico-chemical parameters of the pure oils used

4.1.2.1. Impurity rate

m_1 = 542 g (before settling and filtration)

m_2 = 530 g (after settling and filtration)

$m_i = m_1 - m_2$ = 542 g -530 g = 12 g

So 542 g correspond to 100 %

So 12 g corresponds to $\frac{12}{542} \times 100 = 2.2\%$ (12)

4.1.2.2. Water content

mi= 45.01 g (before steaming)

m_f= 44.79g(after steaming)

$m_i - m_f$= 45.01 g – 44.79 g = 0.22 g

If 45.01 g correspond to 100 %

So 0.22 corresponds to $\frac{0.22}{45.01} \times 100 = 0.49\%$ (13)

Of water in the solution.

4.1.2.3. Density (pycnometer method)

The various densities of pure Jatropha curcas oil calculated by the pycnometric method are shown in Table 2.

Table 2. Density values for Jc oil extracted at different temperatures.

T°C	**Measures**	**1st test**	**2nd test**	**3rd test**	**Average**	**Δd (error)**
27	**Empty pycnometer mass (g)**	**28.01**	**28.03**	**28.02**	**28.02**	**± 0.01**
	Mass of pycnometer with distilled water (g)	**53.15**	**53.13**	**53.12**	**53.1333**	**± 0.0167**
	Mass of pycnometer with Jc oil (g)	**51.05**	**51.02**	**51.04**	**51.0367**	**± 0.0167**
	Mass of Jc oil (g)	**23.04**	**22.99**	**23.02**	**23.0167**	**± 0.0267**
	Volume of pycnometer (mL)	**25.14**	**25.1**	**25.1**	**25.1133**	**± 0.0267**
	Oil density of Jc (g/mL)	**0.916**	**0.916**	**0.917**	**0.9163**	**± 0.007**

40	**Empty pycnometer mass (g)**	**28.00**	**28.03**	**28.01**	**28.0133**	**± 0.0177**
	Mass of pycnometer with distilled water (g)	**53.11**	**53.15**	**53.12**	**53.1267**	**± 0.0233**
	Mass of pycnometer with Jc oil (g)	**50.99**	**51.01**	**51.00**	**51.0000**	**± 0.01**
	Mass of Jc oil (g)	**22.99**	**22.98**	**22.99**	**22.9867**	**± 0.0067**
	Pycnometer volume (mL)	**25.11**	**25.12**	**25.11**	**25.1133**	**± 0.0067**
	Density of Jc oil (g/mL)	**0.916**	**0.915**	**0.916**	**0.9157**	**± 0.007**
60	**Empty pycnometer mass (g)**	**27.99**	**28.03**	**28.02**	**28.0133**	**± 0.0233**
	Mass of pycnometer with distilled water (g)	**53.14**	**53.15**	**53.15**	**53.1467**	**± 0.0067**
	Mass of pycnometer with Jc oil (g)	**51.04**	**51.01**	**51.00**	**51.0167**	**± 0.0233**
	Mass of Jc oil (g)	**23.05**	**22.98**	**22.98**	**23.0033**	**± 0.0467**
	Pycnometer volume (mL)	**25.15**	**25.12**	**25.13**	**25.1333**	**± 0.0167**
	Density of Jc oil (g/mL)	**0.916**	**0.915**	**0.914**	**0.915**	**± 0.001**
80	**Empty pycnometer mass (g)**	**28.01**	**27.99**	**28.02**	**28.0067**	**± 0.0167**
	Mass of pycnometer with distilled water (g)	**53.15**	**53.17**	**53.14**	**53.1533**	**± 0.0167**
	Mass of pycnometer with Jc oil (g)	**51.06**	**50.94**	**50.91**	**50.97**	**± 0.09**
	Mass of Jc oil (g)	**23.05**	**22.95**	**22.89**	**22.9633**	**± 0.0867**
	Pycnometer volume (mL)	**25.14**	**25.18**	**25.12**	**25.1467**	**± 0.0333**
	Density of Jc oil (g/mL)	**0.917**	**0.911**	**0.911**	**0.913**	**± 0.004**

4.1.2.4. Density

Density is the ratio of oil density to water density.

$$d = \frac{\text{density of JC oil}}{density\ of\ water} \quad (14)$$

À 27°C $d = \frac{9163\ g/mL}{1\ g/mL} = 0.9163 \pm 0.007$ (15)

À 40°C $d = \frac{9157\ g/mL}{1\ g/mL} = 0.9157 \pm 0.0007$ (16)

À 60°C $d = \frac{915\ g/mL}{1\ g/mL} = 0.915 \pm 0.001$ (17)

À 80°C $d = \frac{913\ g/m}{1\ g/mL} = 0.913 \pm 0.004$ (18)

The weighed masses of the Jatropha curcas oil sample decrease with increasing temperature. The resulting density also decreases with increasing temperature. The variation in Jatropha curcas oil density is illustrated in figure 7.

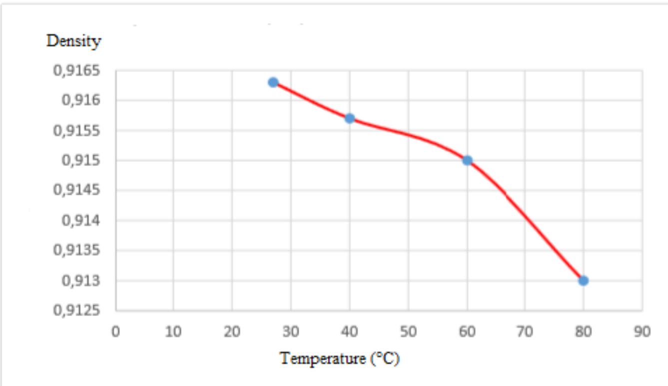


Figure7: Variation in density of pure Jatropha curcas oils as a function of temperature.

4.1.2.5 Viscosity

The expression for viscosity is: υ = k * t n (19)
The various data required to calculate the viscosity of Jatropha curcas oil include the following flow time and viscometer calibration constant (k) are shown in Table 3.

Table 3: Viscosity of extracted pure Jc oil

T°C	*TIME (s)*			*k (constant)*	*Viscosity (mm2/s)*	*Δv(viscosityerror)*
	T 1(s)	T 2 (s)	Tmoy(s)			
27	**819.42**	**820.12**	**819.77**	**0.054**	**44.26758**	**± 0.0189**
40	**799.67**	**738.87**	**739.27**		**39.92058**	**± 0.0216**
60	**682.40**	**6844.17**	**683.285**		**36.89739**	**± 0.0478**
80	**640.74**	**639.97**	**640.285**		**34.57917**	**± 0.0208**

From this table, it can be seen that viscosity decreases with increasing temperature. This means that the sample becomes less viscous at higher than normal temperatures (**figure 8**).

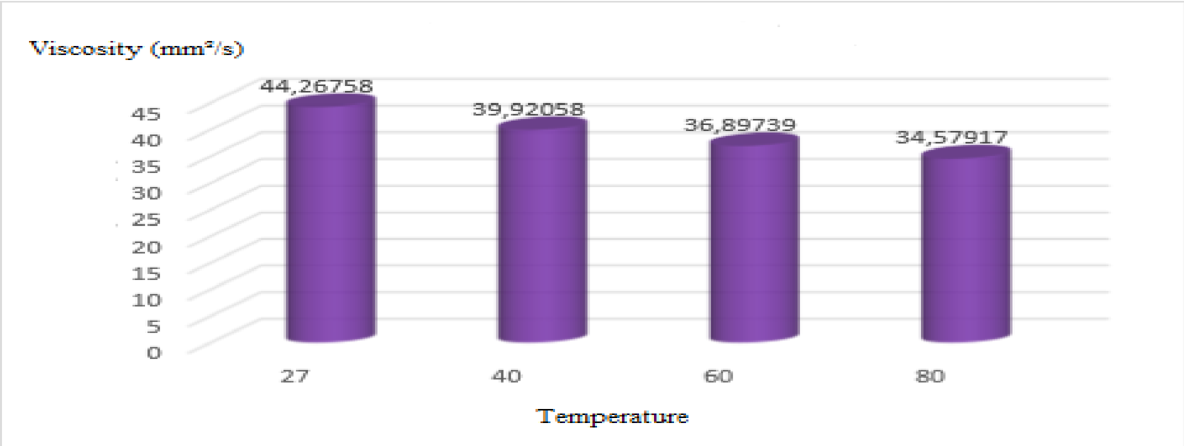


Figure 8: Variation in viscosity of Jatropha curcas oil as a function of temperature

4.2.1.6 Acidity index

The following proportions were used in our experiment:

KOH solution of normality 0.0855 N (concentration around 0.1 N)

V (KOH) = 10 mL

V_b (volume of white) = 7,6 ml,

V_E (Volume of oil) = 6.6ml,

$$I_a = \frac{(V_b - V_E) * C_{HCl} * M}{Pe} \quad (20)$$

$$I_a = \frac{(7.6 - 6.6) \text{ X } 0.1 \text{ X } 56.1}{0.4} = \frac{5.61}{0.4} = 14.025 \quad (21)$$

Table 4 below summarizes the physico-chemical properties of Jatropha curcas oil.

Table 4: Physico-chemical properties of pure oils

Temperature (°C) / **Parameter**	**27**	**40**	**60**	**80**
Density	**0.9163**	**0.9157**	**0.915**	**0.913**
Viscosity (mm2/s)	**44.26758**	**39.92058**	**36.89739**	**34.57917**
Acidity index	**14,025**			
Humidity level (%)	**0,49**			
Oil yield (%)	**36.8**			
Water content (%)	**0.49**			
Flow point(◦C)	**−3**			

4.2.1.7. Physico-chemical properties of mixtures (Oils-Gasoil).

The characteristics of the crude Jatropha curcas oils presented above do not allow them to be used as such in an engine, in accordance with the various values given in **Table 5**. This is why we have made various blends to see what proportion is compatible. Viscosity, for example, is a parameter of vital interest, since it determines the ability of jatropha oil to flow in engines. Too high a viscosity poses two problems. Firstly, the pressure in the engine may not be sufficient for the oil to pass through the engine's diesel filter.Secondly, spraying jatropha oil at the injector generates larger droplets, which can lead to poor combustion and engine fouling. For our blend, the diesel fuel came from a Cobil/Intendance Générale service station. The blends were made in 100ml bottles and systematically weighed using a KERN analytical balance accurate to ± 0.01g, in order to determine the physicochemical parameters. Details of the density calculations are given below, and the results are reported in **Table 5**.

$$d = \frac{\text{density of blends}}{\text{density of water}} = \frac{m_m - m_V}{m_{water} - m_V} \quad (22)$$

(Withm_m = mass of mixture)

For 100% diesel

À 27°C $d = \frac{0.8331 \text{ g/mL}}{1 \text{ g/mL}} = 0.8331 \quad (23)$

À40°C$d = \frac{0.8323 \text{ g/mL}}{1 \text{ g/mL}} = 0.8323 \quad (24)$

À60°C $d = \frac{0.8311 \text{ g/mL}}{1 \text{ g/mL}} = 0.8311 \quad (25)$

À80°C $d = \frac{0.8305 \text{ g/mL}}{1 \text{ g/mL}} = 0.8305 \quad (26)$

For D75

À27°C $d= \frac{0.8386 \text{ g/mL}}{1 \text{ g/mL}} = 0.8405 \quad (27)$

À40°C$d = \frac{0.8386 \text{ g/mL}}{1 \text{ g/mL}} = 0.8386 \quad (28)$

À60°C$d = \frac{0.8385 \text{ g/mL}}{1 \text{ g/mL}} = 0.8385 \quad (29)$

À80°C$d = \frac{0.8370 \text{ g/mL}}{1 \text{ g/mL}} = 0.8370 \quad (30)$

For D50

À 27°C $d = \frac{0.8442 \text{ g/mL}}{1 \text{ g/mL}} = 0.844 \quad (31)$

À 40°C $d = \frac{0.8438 \text{ g/mL}}{1 \text{ g/mL}} = 0.8438 \quad (32)$

À 60°C$d = \frac{0.8426 \text{ g/mL}}{1 \text{ g/mL}} = 0.8426 \quad (33)$

À 80°C$d = \frac{0.8422 \text{ g/mL}}{1 \text{ g/mL}} = 0.8422 \quad (34)$

For D25

À 27°C$d = \frac{0.8486 \text{ g/mL}}{1 \text{ g/mL}} = 0.8486 \quad (35)$

À 40°C$d = \frac{0.8475 \text{ g/mL}}{1 \text{ g/mL}} = 0.8475 \quad (36)$

À 60°C$d = \frac{0.8474 \text{ g/mL}}{1 \text{ g/mL}} = 0.8474 \quad (37)$

À 80°C$d = \frac{0.8462 \text{ g/mL}}{1 \text{ g/mL}} = 0.8462 \quad (38)$

For D10

À 27°C$d = \frac{0.8537 \text{ g/mL}}{1 \text{ g/mL}} = 0.8537 \quad (39)$

À 40°C$d = \frac{0.8535 \text{ g/mL}}{1 \text{ g/mL}} = 0.8535 \quad (40)$

À 60°C$d = \frac{0.8510 \text{ g/mL}}{1 \text{ g/mL}} = 0.8510 \quad (41)$

À 80°C$d = \frac{0.8486 \text{ g/mL}}{1 \text{ g/mL}} = 0.8486 \quad (42)$

The same applies to the density of the various oil-diesel mixtures, which, as shown in Figures 8a to 8e, decreases with increasing temperature.

Table 5.Densities of different diesel-oil mixtures

Mix	T°C	Mass of empty pycnometer (g)	Mass of pycnometer with distilled water (g)	Pycnometer mass with mixture (g)	Mass of mixture (g)	Volume of pycnometer (ml)	Mix density (g/ml)
100% diesel	27	27.87	53.09	48.88	21.01	25.22	0.8331
	40	27.99	53.10	48.89	20.9	25.11	0.8323
	60	27.96	53.12	48.87	20.91	25.16	0.8311
	80	27.99	53.12	48.86	20.87	25.13	0.8305
D75	27	28.01	53.15	49.14	21.13	25.14	0.8405
	40	28.02	53.12	49.10	21.05	25.1	0.8386
	60	27.99	53.13	49.07	21.08	25.14	0.8385
	80	27.99	53.14	49.04	21.05	25.15	0.8370
D50	27	27.96	53.06	49.15	21.19	25.1	0.8442
	40	27.96	53.05	49.13	21.17	25.09	0.8438
	60	27.98	53.14	49.18	21.2	25.16	0.8426
	80	27.98	53.08	49.12	21.14	25.1	0.8422
D25	27	27.99	53.03	49.24	21.25	25.04	0.8486
	40	27.99	53.04	49.22	21.23	25.05	0.8475
	60	28.01	53.05	49.23	21.22	25.04	0.8474
	80	28.01	53.05	49.2	21.19	25.04	0.8462
D10	27	27.95	52.97	49.31	21.36	25.02	0.8537
	40	27.98	52.69	49.30	21.32	24.98	0.8535
	60	28.02	52.99	49.27	21.25	24.97	0.8510
	80	27.99	53.03	49.24	21.25	25.04	0.8486

The table shows that, as with pure Jatropha curcas oil, the density of diesel-oil mixtures also decreases as temperature rises.

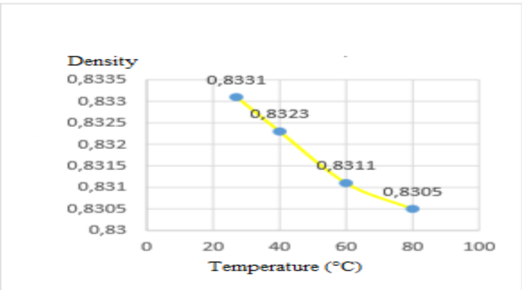


Figure 8 a): variation of density as a function of temperature of D100

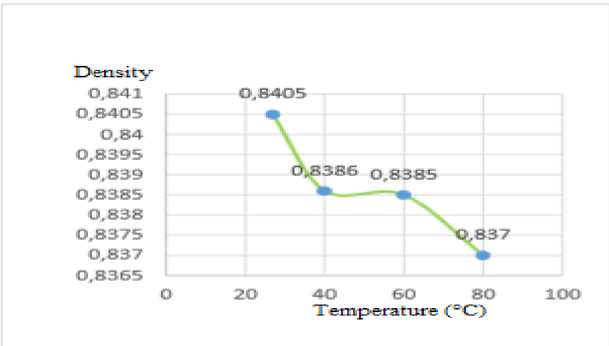


Figure. 8b): variation in density as a function of temperature of the D75 mixture.

For the viscosity of the different mixtures, the results of the calculations are shown in Table 6.

Table 6. Viscosity of different diesel-oil mixture

Mix (%)	T°C	K (constant)	T1(s)	T2(s)	Tmoy (s)	Viscosity (mm2/s)	Δd (viscosityerror)
Gazole 100 %	**27**	**0.054**	**84.6**	**83.4**	**84**	**4.536**	**± 0.0324**
	40		**80.02**	**79.98**	**80**	**4.3201**	**± 0.0011**
	60		**73.3**	**72.7**	**73**	**3.942**	**± 0.0162**
	80		**65.5**	**64.5**	**65**	**3.51**	**± 0.027**
D75	**27**	**0.054**	**110.6**	**111**	**110.8**	**5.9832**	**± 0.018**
	40		**104.73**	**104.69**	**104.71**	**5.6544**	**± 0.001**
	60		**98.37**	**98.31**	**98.34**	**5.3104**	**± 0.0017**
	80		**84.20**	**84.10**	**84.15**	**4.5441**	**± 0.0027**
D50	**27**	**0.054**	**178.04**	**178.00**	**178.02**	**9.6142**	**± 0.0011**
	40		**166.75**	**166.63**	**166.69**	**9.0013**	**± 0.0033**
	60		**143**	**135**	**139**	**7.506**	**± 0.216**
	80		**125.85**	**125.79**	**125.82**	**6.7943**	**± 0.0016**
D25	**27**	**0.054**	**274.52**	**274.44**	**274.48**	**14.8220**	**± 0.0022**
	40		**250.16**	**250.12**	**150.14**	**13.5076**	**± 0.0011**
	60		**231.92**	**231.86**	**231.89**	**12.5221**	**± 0.0016**
	80		**215.64**	**215.60**	**215.62**	**11.6435**	**± 0.0121**
D10	**27**	**0.054**	**401.80**	**401.78**	**401.79**	**21.6967**	**± 0.0005**
	40		**379.29**	**379.19**	**379.24**	**20.479**	**± 0.0027**
	60		**349.98**	**349.92**	**349.95**	**18.8973**	**± 0.0016**
	80		**301.40**	**301.32**	**301.36**	**16.2735**	**± 0.0021**

This table shows that the mixture of diesel oil and pure Jatropha curcas oil has a viscosity that decreases as the temperature of the medium increases. The sample of proportion G75 at 80°C is the only one of its kind which, according to the literature, is best suited to the operation of an internal combustion engine, due to its viscosity in the 2 - 4.5 range. Figures 9a to 9e below illustrate the variation in viscosity of each mixture as a function of temperature.

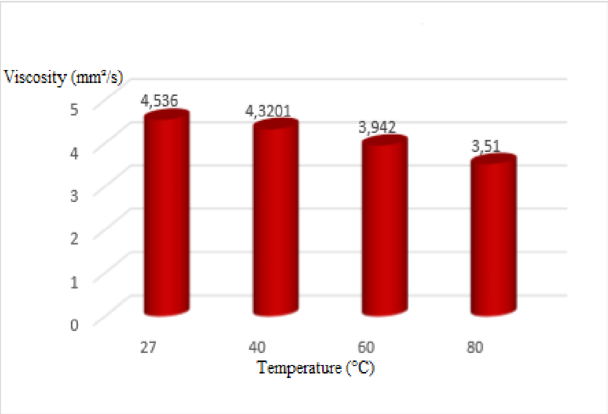


Figure.9a)Viscosity variation of 100% diesel fuel

Figure.9b) variation in viscosity of D75 mixture

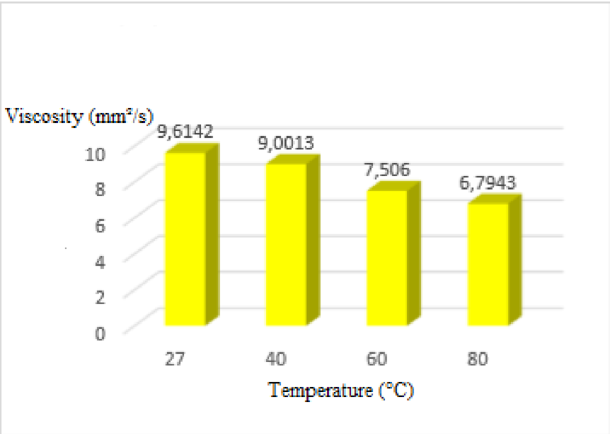


Figure .9 c) variation in viscosity of D50 mixture

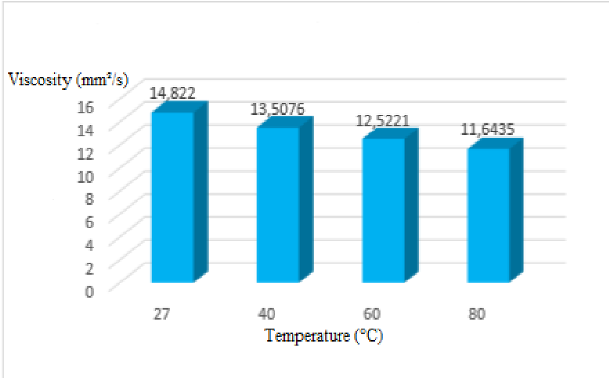


Figure.9d) Variation in mixture viscosity D25

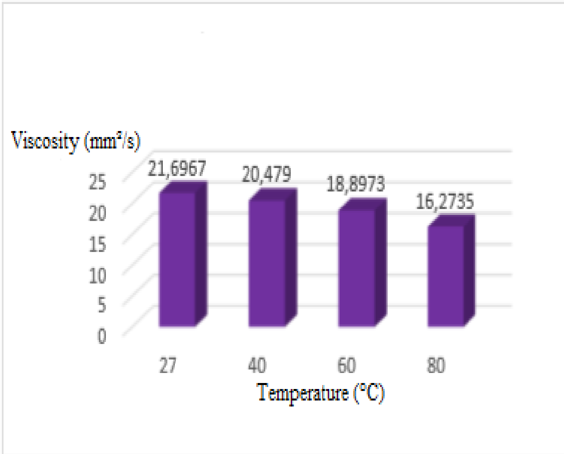


Figure .9 e) variation in viscosity of D10 mixture

Table7. Test results for different biodiesel sample

	SAMPLE			
	D75	D50	D25	D10
				500
Final volume (ml)	**405**	**50**	**360**	**315**
Operating time (min)	**15’08.8’**	**57’43.17’’**	**23’47.16’**	**20’14.53’’**
Start		**Normal**	**Normal**	**Lent**
Its engine	**Normal**	**Normal**	**Normal**	**Normal**
Color of smoke	**Dark**	**Quite dark**	**Claire**	**Claire**
Smell of exhaust smoke	**Gasoil**	**Intermediary**	**Odorless**	**Odorless**

4.2.1.8 Testing the carburation of our different biodiesels in the diesel engine.

4.3. DISCUSSION OF RESULTS

Extracted Jatropha curcas oils have the advantage of having lower density and viscosity in certain proportions than oils from other oilseeds proposed

in the literature. Fossil fuels take thousands of years to produce, whereas the raw material for biofuels is renewable much more quickly. In terms of security, jatropha oil helps us by reducing our dependence on foreign energy sources. This allows countries to preserve the integrity of their energy resources and free themselves from outside influences. When biofuels are burnt, they generate a considerable amount of carbon and a considerable amount of toxins. The production of jatropha oil has a number of disadvantages, as biofuels have a lower energy yield than traditional fuels, requiring a greater quantity to produce the same level of energy. In addition, refining biofuels to obtain more efficient energy and building the manufacturing plants needed to increase the

The data expressing the test results for our sample are shown in Table 7 below.

quantities of biofuels requires considerable initial investment. As can be seen from the curves and histograms of the variation in density and viscosity as a function of the temperature of the medium, when mixed with diesel these oils show an inverse evolution to that of temperature. Compared with diesel, the viscosity curves for jatrophacurcas oils show much steeper slopes figure.8. It has been shown that at 40°C and above, the density curve of diesel no longer varies significantly, whereas that of Jatropha curcas oil continues to decrease, a finding that is highly favorable for the quality of oil injection into the combustion chamber. Compared with the results obtained by MactarDIOP in 2009 on the production of biodiesel from Jatropha curcas oil in Senegal, our results show differences in density and viscosity (**table 8**).

Table 8.Comparative analysis of density and viscosity.

	T°C	***Mactar DIOP1***	***Our experience***
Density	**40**	**0.901**	**0.916**
	60	**0.889**	**0.915**
Viscosity (mm2/s)	**40**	**30.21**	**39.92058**
	60	**19**	**36.89739**

With the viscosity and density values of the oils obtained, MactarDiop (2009) has achieved rural electrification by using them locally as fuel for generators.

Table 9. Comparative analysis of diesel, blends and pure oil.

Sample	***Viscosity(mm2/s) at 40°C***	***Density***
Gasoil	**2-4.5**	**0.815 -0.855**
D75	**5.654**	**0.840**
D50	**9.001**	**0.844**
D25	**13.508**	**0.848**
D10	**20.479**	**0.853**
Pure JC oil	**30.21**	**0.916**

The results of our study show that Jatropha curcas oil is best suited to use in the diesel engines of generators, mills, tractors, etc., in a mixture with diesel fuel; consumption depends on the flow rate fed, the condition of the engine and the nature of the product to be ground.

V. CONCLUSION

Against a backdrop of economic development, the fight against climate change and energy autonomy, biofuels represent an attractive alternative to fossil fuels for developing countries.In concrete terms, this work focused on the physicochemical characteristics of Jatropha curcas oil and its energy potential as a biofuel, and identified four physicochemical parameters. Analytical methods have been developed for moisture content and acidity. With regard to moisture content, the oven drying method was tested. Experience has shown that it is possible to correctly assess the water content of jatropha oil, which is equivalent to 0.49% water. As for acidity, 14.025 milligrams of KOH are required to neutralize the free acids in 1 g of jatrophacurcasoil.Viscosity and density are two of the four parameters considered to be highly influential on Jatropha curcas oil quality. To this end, their measurements were carried out at different temperatures and in a mixture with diesel fuel, in order to study the oil's flow behavior (for viscosity) and its density in diesel engines. The various measurements of the density of pure Jatropha curcas oil gave results in the range [0.913 - 0.9163] and the viscosity expressed in mm2/s in the range [34.57919 - 44.26758], results were respectively in the range [0.8405 - 0.8537] and [5.9832 - 21.6967]. From thecomparison of the physico-chemical properties of the diesel with those of the jatrophacurcas oils obtained, and from the tests in the diesel engine, it emerges the conclusion that all the blends functioned normally in a diesel engine, with however a small delay in starting in terms of time for sample D10, for the simple reason that it contains a large proportion of oil. This confirms that jatrophacurcas oils can be used as a fuel in a blend with diesel in a diesel engine without any disadvantages for the latter. Other experiments will focus on measuring all the physico-chemical parameters of pure oils and blends, such as cetane number, flash point, calorific value, iodine number, saponification number, and others that we have not mentioned for operational reasons. To analyse the economic opportunity of a plant producing jatrophacurcas oils as fuel for diesel engines and the profitability of the initial investment; Jatropha curcas is grown for energy purposes.

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