

Obtaining and Characterization of Biodiesel from Castor Oil (*Ricinus communis*) and Sunflower (*Helianthus annuus*) Grown in Tabasco, Mexico

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Abstract

*The use of biodiesel represents a much lower environmental impact caused by the petroleum diesel. It offers a high lubricity to engines extending its useful life, non-toxic and readily biodegradable. In the present work were two transesterification reactions to compare and select the best result, the first from castor oil (*Ricinus communis*) and the second with sunflower oil (*Helianthus annuus*), with sodium hydroxide catalyst and as a basis for carrying out the reaction, methanol. According to the results showed that the best in quality is the sunflower oil, but in performance of biodiesel obtained is castor oil. Both products were characterized by instrumental techniques confirming its quality. In conclusion, we considered it better to use castor oil for its ease of production and is not used in the State of Tabasco.*

Keywords: Transesterification reactions, *Helianthus annuus*, *Ricinus communis*, biodegradable, methanol.

1.0 Introduction

The use of biodiesel represents a much lower environmental impact caused by the petroleum diesel as it is a technology that fits within the guidelines for reducing greenhouse gases (GHG) and applied as Clean Development Mechanisms (CDM) [1-3]. It offers a high lubrication for extended life engines, non-toxic and readily biodegradable [4-6].

Biodiesel is derived from the transesterification reaction, this process consisting in combining an oil (typically vegetable oil) with a light alcohol and glycerol byproduct is obtained that can be used by various industries including cosmetics industry [7].

Although the transesterification reaction of triglycerides is relatively simple, have not been fully identified conditions in which the use of methanol or ethanol are more suitable vegetable oil used. The aim of this work was to identify the optimal concentrations of reagents, which will provide higher yields in the production of biodiesel compared to the products of the transesterification reaction, using sunflower oil (*Helianthus annuus*), one of the best studied plant [8] and compare these results with castor oil (*Ricinus communis*), the latter was selected because in the state of Tabasco, is not used or is given a specific application and is also easy to produce. Likewise perform the characterization of both products obtained in order to confirm the quality thereof.

2.0 Materials and methods

2.1 Stages of obtaining Biodiesel

It took castor oil and sunflower commercially. For obtaining biodiesel used a volume of 200 ml of base oil, which was poured into a 500 ml Erlenmeyer flask, was introduced a magnetic stirrer, the flask was placed with the oil and stirrer in a heating grid Cimarec mark with stirring, and SP131325 SP131015 model, a temperature of 110°C and stirring at 1000 rpm to remove particulates from water that may be oil, this was for 5 min.

After preheating the oil conducted for the elimination of humidity, the temperature stabilized at 50°C to carry out the transesterification reaction and to avoid higher temperatures which allows the methanol evaporate. With stirring was sought to have the uniform temperature, all this is performed at atmospheric pressure.

After preheating the oil base, methoxide was prepared by adding NaOH reagent grade methanol, according to the values given in Table 1. Once hydroxide dissolved in methanol, poured oil methoxide, maintaining constant temperature of 50°C and atmospheric pressure with agitation was continued at 1000 rpm for 45 min. To try to prevent alcohol loss by evaporation tape was placed on parafilm mouth of the flask during the transesterification process. The reaction time is directly proportional to it, however this also may suffer variations depending on the base oil used, as well as the catalyst [9]. During the first minutes of the reaction, with good agitation, the formation of methyl esters is abundant, after 90 min of reaction progress is almost zero [10, 11]. The stirring time to carry out the transesterification during the experiment was 45 min at 1 000 rpm.

Table 1. Experimental treatments

Factors				Treatments	
Oil (200 ml)		Methanol (% volumen)	NaOH (% w)		
Higuerilla	levels	10%	0.3%	H 13	
			0.4%	H14	
			0.5%	H 15	
		20%	levels	0.3%	H 23
				0.4%	H 24
				0.5%	H 25
		30%	levels	0.3%	H 33
				0.4%	H 34
				0.5%	H 35
Girasol	levels	10%	0.3%	G 13	
			0.4%	G 14	
			0.5%	G 15	
		20%	levels	0.3%	G 23
				0.4%	G 24
				0.5%	G 25
		30%	levels	0.3%	G 33
				0.4%	G 34
				0.5%	G 35

Once the reaction mixture was poured into a separatory funnel of 500 ml, the mixture was allowed to stand 24 h at room temperature, after this time was able to appreciate the two phases formed (biodiesel, glycerol), subsequently separated biodiesel and glycerol.

2.2 Purification of biodiesel

After performing phase separation, purification was performed by washing the biodiesel by adding 30% volume of distilled water based on the total volume of biodiesel obtained by each treatment, immediately the mixture was stirred using a water-biodiesel mixer with blades long speed of 1000 rpm for 10 min in glass vessel. 24 hours was allowed to stand in a separating funnel and was observed after this time phases of biodiesel and water.

We proceeded to decant for separating biodiesel, three washes were performed for each experimental unit, following the same procedure and confirming that in the last wash water separated out as clearly as possible, which indicated the removal of waste sample NaOH [12].

2.3 Drying and storage

To remove any water that may have remained in the washing treatment during the biodiesel was poured into a beaker of 250 ml with a magnetic stirrer and subjected to heating at 110°C and stirring between 150 and 200 rpm during 5 min. Later the measurement of the volume of pure biodiesel obtained by using a 250 ml graduated cylinder, then the storage of the effected tests cap glass bottles with a capacity of 355 ml.

2.4 Experimental design

We used a factorial experimental design [13] asymmetric. Independent variables were established (Table 1):

- Oil (two levels: castor and sunflower)
- Methanol (three levels: 10%, 20% and 30% volume)
- NaOH (three levels: 0.1%, 0.2% and 0.3% by weight)

And as dependent variables

- Volume
- pH
- Bulk Density
- Kinematic Viscosity
- Heat Capacity
- Infrared Spectroscopy

We determined the number of treatments derived from that there were three factors, of which one of them had two levels and the other with three levels each, we obtained the following equation:

$$L = 2^1 * 3^2 = 18 \quad (\text{Eq. 1})$$

In total there were 18 experimental runs or treatments, each treatment had five replicates. By using the statistical program SAS 9.1.3 were introduced biodiesel volume data obtained in each of the experimental units and so the best treatments were obtained from the level statistically achieved.

2.5 Physicochemical characterization

Oils (castor, sunflower) used as raw materials, were subjected to several characterization tests, because the labels of the containers containing them, did not provide significant information. To perform characterizations to oils, eliminated any residue that may contain water, by heating with stirring at 110°C for 10 min. These tests were also conducted to commercial diesel, aiming to know their characteristics and reference values have [14].

After having carried out obtaining biodiesel samples, having measured the volume of the biodiesel obtained in each of the treatments and treatments have selected which during the transesterification reaction is achieved a higher production of biodiesel, are following characterizations carried out:

a) Determination of pH

For biodiesel pH value before the first washing and final washing at the end of a pH meter was used brand Hanna Instruments, Model HI 9813-6, with a resolution and accuracy of 0.1 (20°C) ± 0.2. The pH meter was calibrated previously according to manufacturer's recommendations. Once calibrated pH meter was poured 50 ml of biodiesel sample was introduced electrode, and measurements were performed for 5 min until the readings stabilized.

b) Determination of Kinematic Viscosity

The kinematic viscosity was measured by capillary viscometer Cannon Instrument brand, model 2B, determining the time required for a given volume of the biodiesel sample flow through the capillary. The viscometer used was Ubbelohde type and by using Equation 2 is obtained from the kinematic viscosity value:

$$\eta = (K)t \quad (\text{Eq. 2})$$

where:

η = Viscosity (cSt)

K = capillary viscometer constant supplied by the manufacturer (cSt / s)

t = time in the fluid flowing through the capillary (s)

The capillary viscometer constant (K) was provided by the manufacturer (0.52 cSt/s) as calibration certificate. The calibration was carried out using water as sample at a temperature of 40°C and under ASTM D445 [15]. It should be mentioned that biodiesel is classified as transparent liquid.

To maintain a constant temperature during the determination is used a constant temperature bath mark Cannon Instrument, model CT-500 and a recirculating, constant temperature controller Polyscience brand, model 9712. The capillary viscometer was washed with soap and water, washed once with dry acetone for removing any grease or contaminant.

Completely dry the capillary viscometer, are supplied to 15 ml of biodiesel sample to be analyzed is introduced into the viscometer constant temperature bath and was left for 20 min before the test, to have a uniform temperature in the test; for temperature control, a digital thermometer was placed outside. Kinematic viscosity analyzes were performed at 40°C as prescribed in the ASTM D445 standards [15] and EN ISO 3104[16]. Was performed by connecting the circulator constant temperature bath and thereby to have more control of the temperature, the recirculator contained a volume mixture of 60% water and 40% volume ethylene glycol. With the help of a plastic knob sucked fluid in the viscometer (taking due care to avoid the formation of bubbles) to the crest of the sample exceeded the capacity of the upper mark located in the viscometer using a timer after measured the time it took the sample flow from the higher capacity to the mark with lower capillary viscometer. Once the elapsed time data, Equation 2 was applied.

c) Determination of Heat Capacity

For the heat capacity of each sample was used oxygen bomb calorimeter Shanghai Changji Geological mark Instruments, model XRY-1B, coupled with microcomputer. ASTM D240 [15] explains the procedure for determining the heat capacity of liquid oils and transparent. The equipment was calibrated using benzoic acid pill (provided by your computer manufacturer) with predetermined weight. For analysis of the data is entered biodiesel weight of the sample. For operation of the equipment used 18 Kg of distilled water, supplied through an opening located in the upper right of the equipment, this water has the function of trying to keep the temperature constant within the tub where it was the analysis, in this vat there is a stainless steel container which is introduced into the bomb calorimeter with the sample inside the holder.

Few drops were placed in the sample holder of biodiesel in the sample and its mass was obtained using an analytical balance, in the bomb calorimeter was placed 9 cm of copper-nickel wire, properly positioned without touching the walls of the sample holder, then placed 10 ml of distilled water with a 20 ml pipette. Then we proceeded to the bomb calorimeter closed, filled with oxygen through two gauges, a connector towards the tank of oxygen (99% purity), the other towards the pump 2.5 MPa is supplied to the pump pressure, then held a hydrostatic test to verify that there was no leak in the pump.

When container is in the tub the calorimeter and into which was placed the bomb calorimeter, were added 6 kg of distilled water and placed the bomb in it, this bowl with the bomb was placed inside the calorimeter tub, the pump is connected by electrodes which are held in the sample ignition. Close the lid of the calorimeter, which include an indicator had thermocouple for reading temperatures, since the variation of temperature was mainly in performing this analysis also had a small motor with propeller blades and to homogenize temperature of the water inside container. Measuring the team had three stages: initial period (temperature stabilization), initial test (combustion of the sample) and final period. You enter the data of the sample mass and the computer is programmed to perform the analysis, the team has two methods for adjusting the temperature variations, the method Regnault and the method Regnault-Pfaundler, in this case Regnault method used. The computer automatically performs the analysis and at the end, in the control panel displays the final result in units of J/g.

d) Determination of density

For the determination of density of the samples was used brand team Anton Paar, model DMA 4500M with screen touchscreen control and programming, has different functions for measuring °Brix, °API, acid concentrations sulfuric, density, relative density, among others, the computer performs the analysis of the density at which the operator wishes temperature in a range of 0°C to 90°C. The equipment was used to measure the density at a temperature of 15°C as determined by the EN ISO 3675 and ASTM D1298 [15-16], although the latter does not provide a value range to establish the quality of biodiesel in based on this property. The equipment was calibrated previously with distilled water at 25°C.

Before loading the sample, the U-tube cleaned with isopropyl alcohol and air was supplied for 15 min to remove any residual liquid. The computer is programmed by setting the density measurement and the measurement temperature (15°C) for approximately 30 min was allowed to stabilize at the set temperature equipment. After the set temperature, the sample was introduced in the borosilicate glass tube in the form of U (sample holder) by syringe, the sample holder was slightly within the densimeter oscillating at a certain frequency. The frequency changes depend on the density of the sample, due to these changes in oscillation and a mathematical conversion is possible to measure the density. This is calculated from the ratio between the period of the oscillations of the U-glass tube that is located inside the equipment and the reference oscillator. During delivery of the sample to the U-tube, be careful not to introduce bubbles. Because the sample was at room temperature than the temperature set on the computer, you have to let the temperature stabilize what happened in a span of 5-8 min, then the team marked the density calculation, the result was shown after about 40 seconds, the results are expressed in the density and specific gravity and temperature of the sample when the measurement was performed.

e) Infrared Spectroscopy Study

FTIR spectroscopy analysis gave the possibility to characterize simple treatments from their vibrational spectrum thus be able to meet the functional groups that should contain the treatments. This characterization was performed at room temperature and confirming that the sample was completely dried as this could interfere with the results. FTIR spectrophotometry was carried out in KBr. We used a Perkin-Elmer FT-IR Spectrum GX system, all FTIR spectra were obtained in the range from 4000 to 370 cm⁻¹.

f) Determination of Elemental Analysis

With this determination composition is known in quantitative terms, the presence of carbon, hydrogen and nitrogen that will help us determine the variations that are according to the variables involved in Table 1. Determinacionbes ESTs were performed on an elemental analyzer, Perkin Elmer, Model 2400 Series CHN/SO

g) Analysis ultraviolet-visible UV-Vis

UV-vis spectroscopy was performed using a Perkin Elmer spectrophotometer model Lambda 40, using dilutions 1:100 (v/v) in n-hexane. All data were collected in the range of 220-300 nm.

3.0 Results and discussion

3.1 Characterization of the raw material

Castor oil mainly consists ricinoleic acid (80-85%, 12-hydroxy-cis-octadec-9-enoic acid, Figure 1), linoleic acid (3-6%), oleic acid (2-4%) and unsaturated acids (1-5%). Due to its chemical composition, has certain particular physical and chemical properties that are exploited in various processes in the chemical industry, for example in the manufacture of paints, coatings, lubricants, cosmetics and resins [17-19].

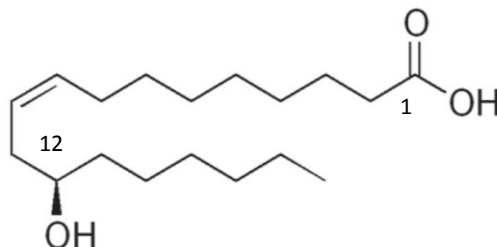


Figure 1. Ricinoleic acid structure

Sunflower oil consists mainly linoleic acid (63-67% cis, cis, cis-9,12,15-octadecatrienoic Figure 2), oleic acid (20-24%), palmitic acid (5-8%) and stearic acid (3-5%). It is observed that despite being both 18 carbon atoms in the linoleic acid is present three unsaturations.

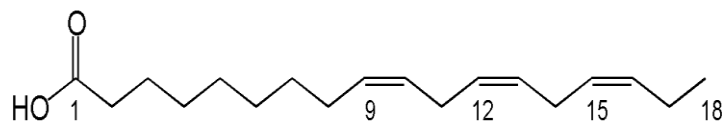


Figure 2. Linoleic acid structure

Table 2 shows the main results of characterization of the raw materials used. As can be seen, the variation was between these oils was only 0.1 pH unit, which is not significant, slightly acidic obtaining values very close to what Forero and colleagues have reported [20] when indicate that in one well refined sunflower oil is obtained a pH of 6.3. The values of kinematic viscosities of the oils at 1 atm pressure were very different, note that the value obtained from castor oil is 7 times higher than that obtained for sunflower oil, which is explained by three unsaturations present in its composition majority of linoleic acid and oxygen unless ricinoleic acid from castor oil, for the same reasons that explain this lower density.

The results of the heat capacities of the oil showed that the oil was a higher heat capacity of sunflower oil 3 624 / g greater than the castor oil Cp. The absolute density values obtained from the analysis of the oils at 15 ° C, had a difference of 0.041 g/cm³. Arancibi and Calero and [21] Guerrero et al [22] reported a value 0.960 g/cm³ for the density of castor oil at 25°C, and 0.919 g/cm³ for the density of sunflower oil the same temperature, which corresponds to the one found in this work.

Table 2. Physical chemical characterization of the oils used as raw material

Characteristic	Castor Oil	Sunflower Oil
pH	6.00	6.10
Kinetic viscosity at 40°C (mm ² /s)	115.58	16.17
Heat capacity (J/g)	34509	38133
Heat capacity (J/g)	0.963	0.921

3.2 Physicochemical characterization of Biodiesel

Of all the experimental units made only one repetition was selected from each treatment, they were selected based on the highest volume of biodiesel obtained after washing made for disposal of NaOH that may have been left after carrying the transesterification. Table 3 shows the average values of each volume of the treatments of biodiesel produced from castor oil, were obtained through the SAS statistical program 9.1.3.

One can observe that the values obtained in the treatment volume H33, H34 and H35 no significant difference was found ($R^2 = 0.7755$, $\alpha = \leq 0.05$, Tukey) as well as between treatments H23, H24 and H25, however between both treatment groups for significant differences. The transesterification reaction does not successfully completed with 10% by volume of methanol (H13, H14 and H15 in Table 1), with castor oil and only one point of saponification attained because the amount of alcohol supplied was not sufficient for will carry out the reaction. Unlike treatments with sunflower oil (G13, G14 and G15 in Table 1), in this case all experimental units were obtained satisfactorily.

According to what reported in Table 3 and the analysis of variance, significant treatment differences sample G33 ($R^2 = 0.9077$, $\alpha = \leq 0.05$, Tukey) compared to other treatments (G34 and G35) obtained from oil sunflower. The volume percentage of biodiesel obtained (yield) than the total volume of the reaction mixture prior to each of the samples was:

- Coming from castor oil: Minimum: 86.1% High 91.0%.
- Coming from sunflower oil: Minimum: 77.8% Maximum: 89.6%.

With regard to the above, Benjumea et al [23] in their study of biodiesel production from crude palm oil using NaOH or KOH as catalysts and methanol, mentioned that after making an analysis of the performance of the procurement process, including washing and drying of the biodiesel obtained an average value of 86.6%. The value found in this study is in line with those reported by these authors.

The best evidence of all treatments in general with respect to volume, treatments were H33, H34 and H35 (89-91% yield), without significant differences between them ($R^2 = 0.9165$, $\alpha = \leq 0.05$, Tukey). Regarding H34 and G33 treatments including no significant differences, however slightly significant differences regarding treatments appointed in the first instance. H34 and G33 treatments have significant ($R^2 = 0.9165$, $\alpha = \leq 0.05$, Tukey) to all other treatments performed.

Table 3. Volumes of biodiesel obtained from the different treatments derived from castor oils and sunflower.

Castor oils		
Sample	Vol (ml)	Performance (%)
H 23	189.4 ^a	86.1
H 24	195.8 ^a	89.0
H 25	193.6 ^a	88.0
H 33	206.2 ^b	89.7
H 34	204.6 ^b	89.0
H 35	209.2 ^b	91.0
Sunflower		
Sample	Vol (ml)	Performance (%)
G 13	172.6 ^a	82.2
G 14	165.6 ^a	78.9
G 15	188.2 ^a	89.6
G 23	192.8 ^b	87.6
G 24	188.6 ^b	85.7
G 25	171.2 ^b	77.8
G 33	194.2 ^c	88.8
G 34	187.8 ^b	81.7
G35	185.7 ^b	80.7

Different letters in columns indicate significant differences

3.3 Determination of pH

The pH values of the samples of biodiesel obtained from castor oil showed the lowest value that was obtained was 6.0 in H33 treatment, while the highest value obtained H23 and H35 treatments, this value being 6.5.

Within treatments sunflower oil obtained the lowest value was 6.0, which was obtained in four different treatments (G13, G33, G34 and G25) and the highest value was 6.3 in G14 and G24 treatments. Having the above results, we can notice that the pH values of biodiesel samples from the two types of oils are very similar and differ from the pH of the starting raw materials.

Within this analysis also determined the pH of commercial diesel and was taking as reference, the value obtained was 6.02, this indicated that pH values of biodiesel obtained are close to the pH of commercial diesel. In analyzes conducted with cooking oils (corn and canola), using methanol and sulfuric acid, was obtained having a pH of 7.19 and 7.03 respectively for each oil [24]. However it should be noted that according Kac [25], biodiesel pH should be neutral (pH 7), or vary between 6 and 8.

3.4 Kinematic Viscosity Determination

According to ASTM D445 [15], viscosity at 40 ° C of a biodiesel, should be between 1.9 and 6.0 mm²/s, however, according to the European standard EN ISO 3104 [16] to 40 ° C must be between 3.5 and 5 mm²/s. As seen in Figure 3, and also according to EN ISO 3104 [16], none of the evidence obtained from castor oil, are within the range, are above the set maximum value, however with respect to the standard ASTM D445 [15] only 4 samples fall within the range (H25, H33, H34 and H35) and 2 of them (H23 and H24) are off, indicating that the obtained oil biodiesel castor is slightly more viscous in combination with 20% by volume of methanol unlike the samples which were used 30%.

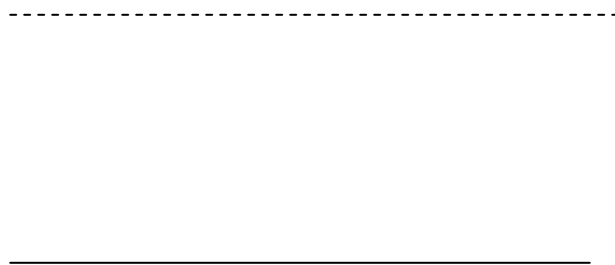


Figure 3. Values of kinematic viscosities at 40 ° C, samples of biodiesel obtained from castor oil. - - - - - Max ASTM D445; _____ Maximum of European standard EN ISO 3104

Values shown in Figure 4 note that unlike castor obtained treatments, samples obtained from sunflower oil are less viscous. Therefore according to EN ISO 3104 four treatments (G25, G33, G34 and G35) sunflower oil obtained are below the minimum limit. All others are within the range of this rule. However, all samples meet the range set by ASTM D445.

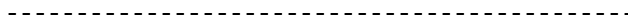


Figure 4. Values of kinematic viscosities at 40 ° C, samples of biodiesel obtained from sunflower oil. - - - - - Maximum of European standard EN ISO 3104

The viscosity obtained from the analysis to commercial diesel sample temperature of 40°C, was of 2,802 mm²/s, based on the provisions of PEMEX in the MSDS for diesel, in Section IV, physicochemical properties [26], the value of commercial diesel viscosity at 40°C should be between 1.9 and 4.1 mm²/s, according to this, the data obtained was within the diesel range, however in this case none of the samples obtained biodiesel from castor oil resembles this value, only those obtained from sunflower oil.

3.5 Determination of heat capacity (Cp)

The calorific value of commercial diesel is about 43 330 J/g [27], the values obtained in this study are within the range. In Figure 5 a) A comparison of the values of Cp with respect to the volume in each treatment carried out with castor oil, according to Figure 5 b) the best of these treatments based on their Cp was H33 (36 107 J/g), with error bars show standard deviation so. Regarding the value of Cp obtained from commercial diesel these treatments have a 15 to 17% less.

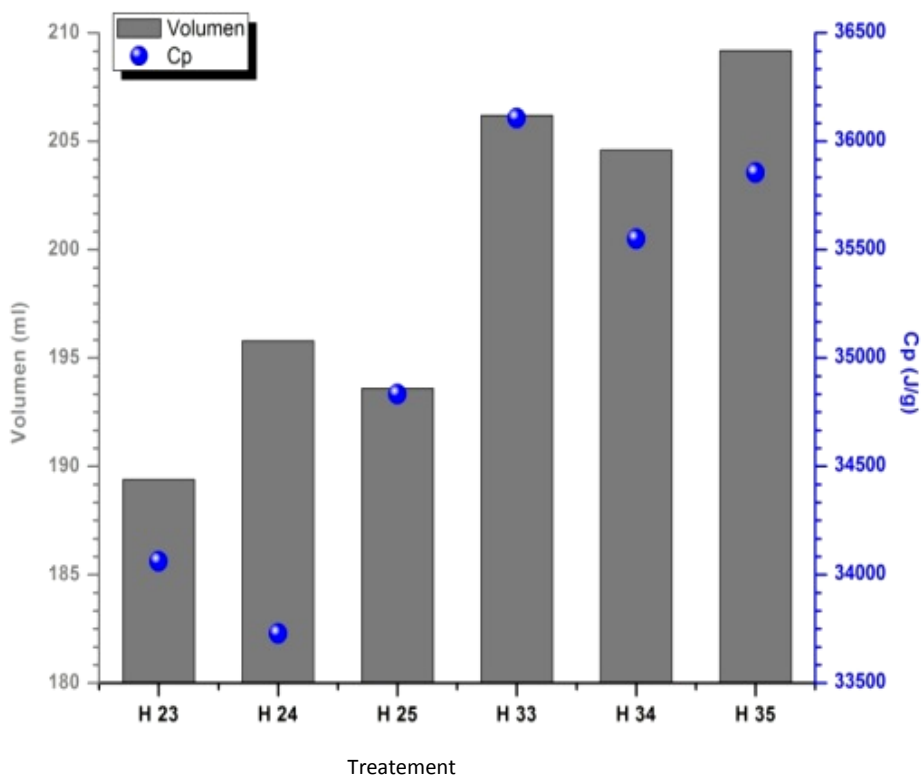


Figure 5. a) Heat capacities of biodiesel obtained from castor oil obtained compared to the volume of the same

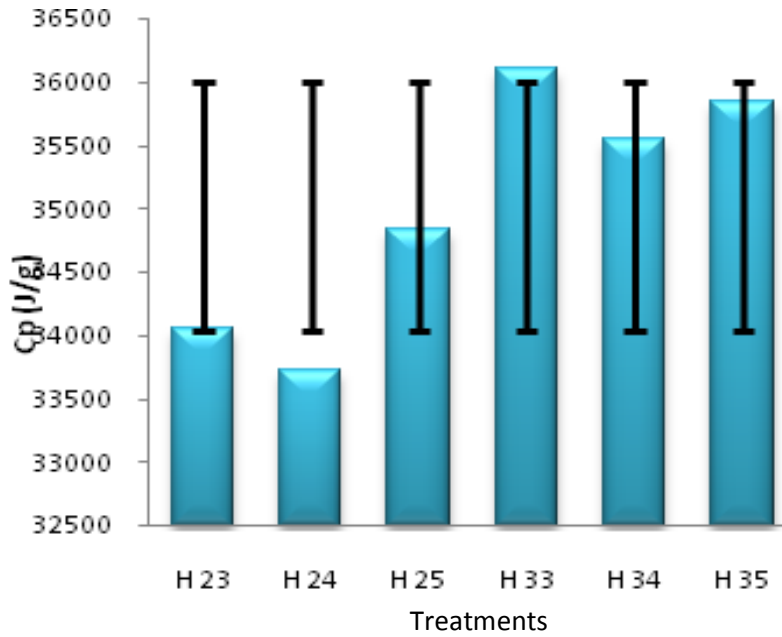


Figure 5. b) Heat capacities with error bars and standard deviation.

In Figure 6 a), to carefully analyze the values can be seen that in treatment decreases the value of Cp under increased concentration of NaOH. However according to the error bars with standard deviation (Figure 6 b) was the best treatment G35 (38136 J/g). It should be mentioned that although the G13 treatment is within the best in the question of Cp, in Figure 6 a) may be observed that the volume obtained in this treatment is the third lowest. The heat capacities of biodiesel from sunflower oil, with respect to the Cp value obtained from commercial diesel have a 15 to 16% less. According to the literature on the production of biodiesel from crude palm oil [23], referral Cp value was 40 192 J/g, however, in another analysis [27], shows a value of 38 020 J/g for biodiesel obtained. It should be mentioned that previous studies were carried out using an oxygen bomb calorimeter.

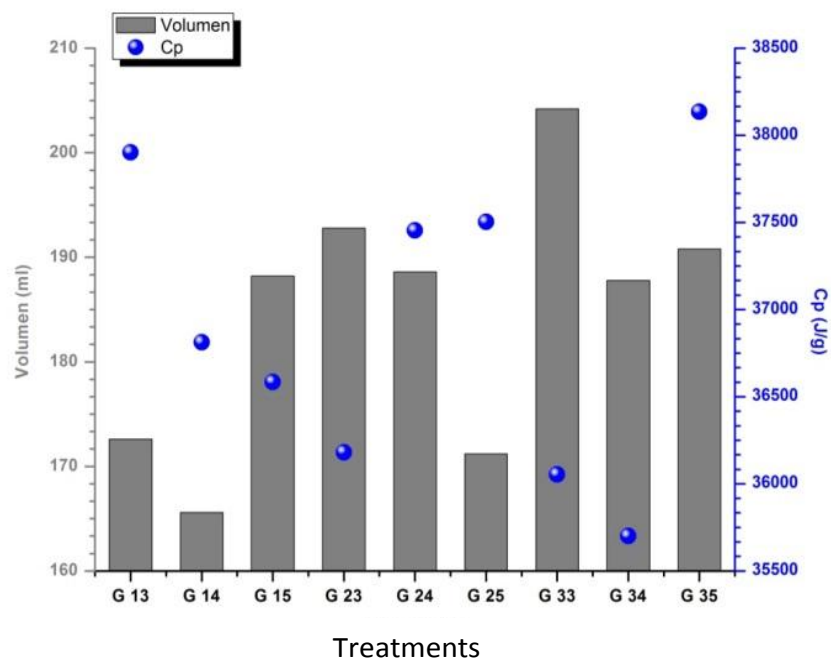


Figure 6. a) Heat capacities of the samples of biodiesel from sunflower oil compared with the same volume obtained

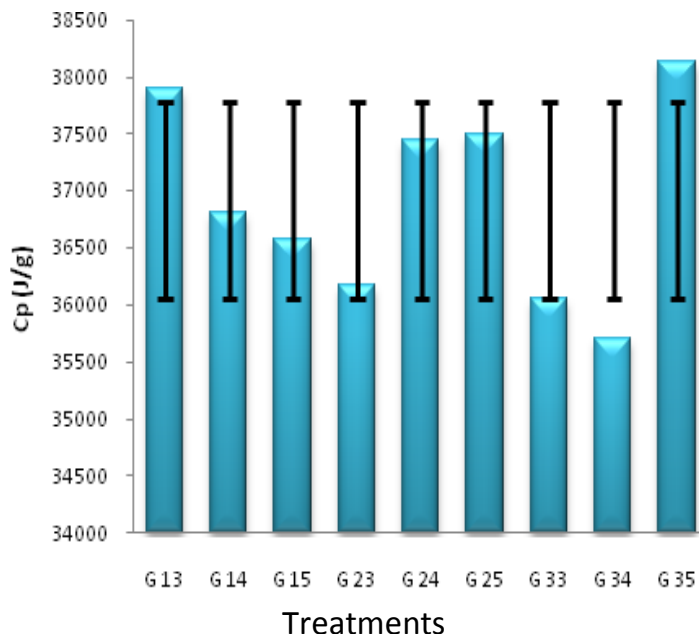


Figure 6. b) Capacidades caloríficas con barras de error y desviación estándar.

3.6 Bulk Density Determination

According to the European standard EN ISO 12185, the value of the density at 15°C should be between 0.86 and 0.90 g/cm³, however, ASTM D1298 [15] does not indicate a parameter for measuring this property . According to Figure 7, the densities of the samples obtained from castor oil, are outside the range of European standard, however between these values are very similar, with only ranging from 0.901 g/cm³ to 0.908 g/cm³, this study was performed at the temperature specified by the standard (15°C). According to the values shown in Figure 8, all samples obtained from sunflower oil are within the range of the standard mentioned.

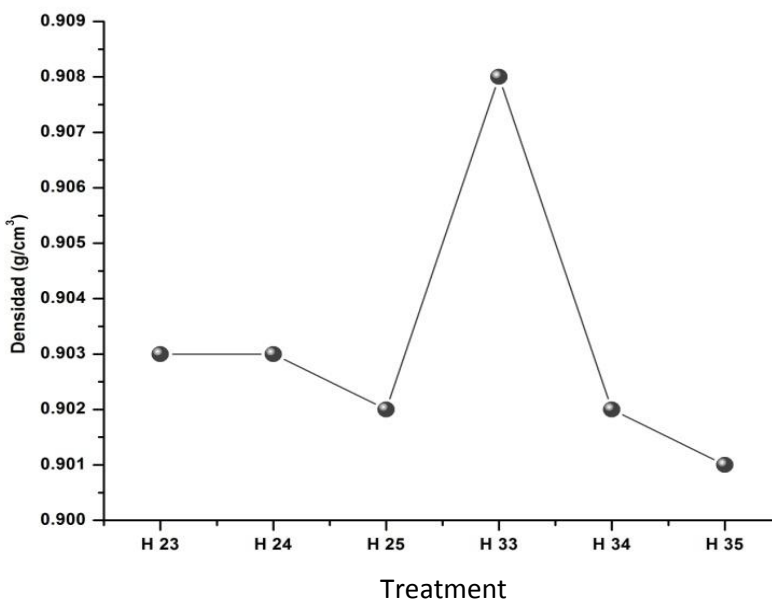


Figure 7. Density of the samples of biodiesel from castor oil

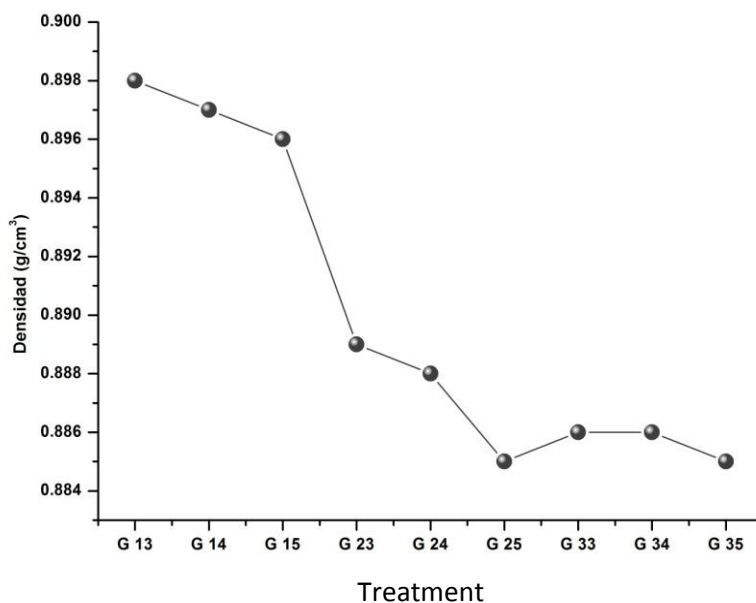


Figure 8. Density of the samples of biodiesel from sunflower oil.

While NaOH concentration increased in all treatments, the density was decreased slightly. This is indicative of the effect of NaOH used as catalyst directly influences the density to obtain biodiesel. Density analysis performed by commercial diesel yielded a value of 0.834 g/cm^3 at 15°C , in accordance with the provisions of PEMEX [26], the value of the density at 15°C should be <1.00 reported in the literature, we can see that there is little difference.

In Table 4, the disclosed values of the densities of the samples of biodiesel obtained from various oils, using different catalysts to conduct transesterification, and their respective reference. Comparing the results obtained in this investigation with respects to the data.

Table 4. Absolute densities obtained in different investigations.

Biodiesel obtained from:	Test method	Bulk Density g/cm^3	Reference
Crude palm oil, Methanol/NaOH.	ASTM D1298	0.8729	[23]
Corn oil (Burnt cooking), methanol / sulfuric acid.	ASTM D1298	0.8766	[24]
Canola oil (Burnt cooking), methanol / sulfuric acid.	ASTM D1298	0.8776	[24]
Cottonseed oil, Methanol / NaOH.	ASTM D1298	0.875	[13]
Castor oil, methanol and NaOH.	ASTM D1298	0.9261	[23]
Sunflower oil, methanol and NaOH.	EN ISO 3675	0.8781	[28]
Castor oil, Methanol / NaOH.	ASTM D1298	0.915	[29]
Sunflower oil Methanol / NaOH.	EN ISO 3675	0.8631	[30]

3.7 Elemental Analysis (EA) of the biodiesel obtained

The results of elemental analysis (EA), expressed as% w / w of carbon, hydrogen and nitrogen are shown in Table 5. It can be seen that for biodiesel obtained from sunflower oil (G), the average was 76.90% carbon, hydrogen (H) and 12.55% nitrogen (N) 0.09%.

Table 5. Analysis results percentage (% m/m) of elements C, H and N in the biodiesel obtained by treatment

Samples	weight	Carbon	Hidrogen	Nitrogen
G13	3.288	77.17	12.69	0.09
G14	2.890	77.35	12.46	0.14
G15	3.983	77.35	12.69	0.04
G23	4.467	77.55	12.84	0.06
G24	2.846	76.59	12.67	0.07
G25	3.710	75.07	12.08	0.07
G32	3.695	77.37	12.73	0.11
G34	4.480	77.11	12.72	0.06
G35	2.379	76.57	12.08	0.15
Average Sunflower	3.526	76.90	12.55	0.09
H23	4.071	73.51	12.48	0.04
H24	3.729	73.41	12.50	0.03
H25	1.817	73.17	12.16	0.17
H33	3.488	73.40	12.40	0.07
H34	3.045	73.97	12.50	0.08
H35	4.650	73.96	12.56	0.08
Average Castor oil	3.467	73.57	12.43	0.08

Unlike biodiesel from castor oil, the contents in C were lower (73.57%), in terms of the contents of H (12.43%) and N (0.08%), no significant differences were observed with respect to biodiesel sunflower oil. These results are similar to those reported by Tirado et al [31] and that found in the biodiesel from the pinion (*Jatropha curcas* L.), 77.06% C, 11.57% H and 0.05% N.

3.8 Study of Infrared Spectroscopy (FTIR)

Performing infrared spectroscopy study of the castor and sunflower oils were identified some of the functional groups that form such oils. In Figures 9 and 10 shows the FTIR spectra of the biodiesel obtained from sunflower oil and castor respectively. The bands, a, d and e, in 3008, 1243 and 725 cm^{-1} , corresponding to vibrations of elongation and roll out of plane deformation of the functional group $-\text{C}=\text{C}-$ in the cis position, respectively. The band b, 1745 cm^{-1} , corresponding to a stretching vibration of $-\text{C}=\text{O}$ group of the ester group. The d band at 1438 cm^{-1} , corresponding deformation vibration of $-\text{O}-\text{CH}_3$ group of methyl ester. The band f at 1178 cm^{-1} corresponds to a stretching vibration $-\text{CO}-$ group of methyl ester.

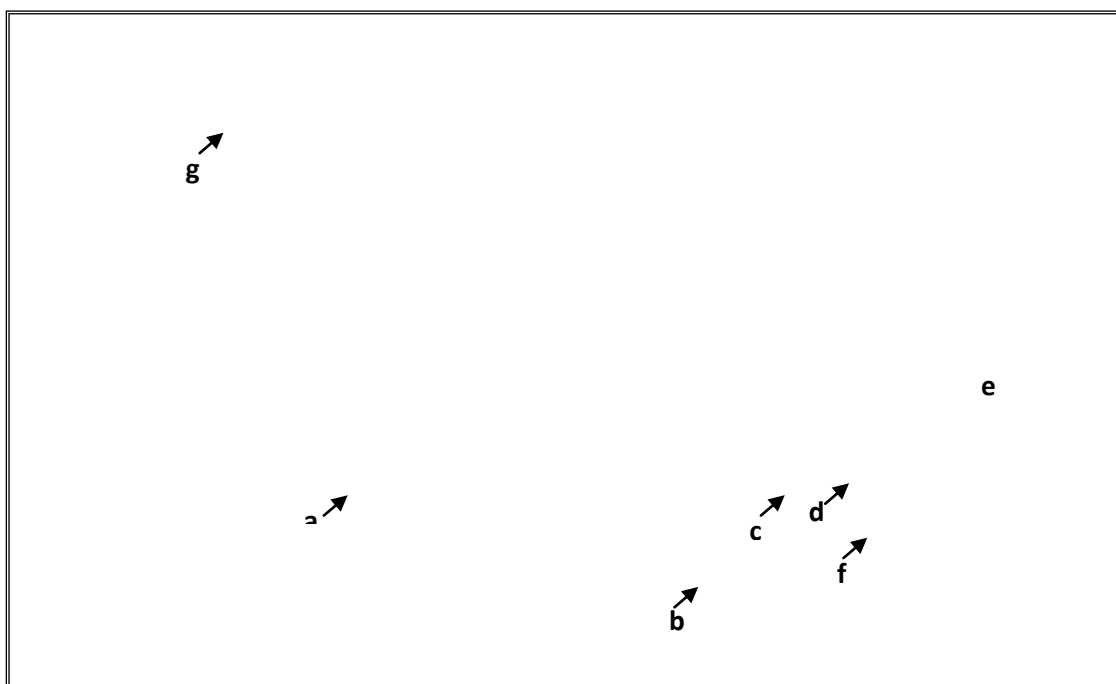


Figure 9. FTIR spectrum of biodiesel obtained from sunflower oil

The band c, in 1569 cm^{-1} , corresponding to a stretching vibration of CO_2^- group, carboxylic acid salt [32-33]. As shown all bands are present in the products obtained starting from both biodiesel oils (sunflower and castor), ie in the FTIR spectra in both figures 9 and 10. However it should be noted that the band g appears at 3450 g cm^{-1} , being more intense in Figure 10 (castor oil biodiesel) in Figure 9. This indicates that due to the presence of the two -OH groups of the ricinoleic acid (free one at position 12 in Figure 1 and another carboxylic acid group), the majority in this product, with respect to a single -OH group belonging to linoleic acid amide majority in sunflower oil.

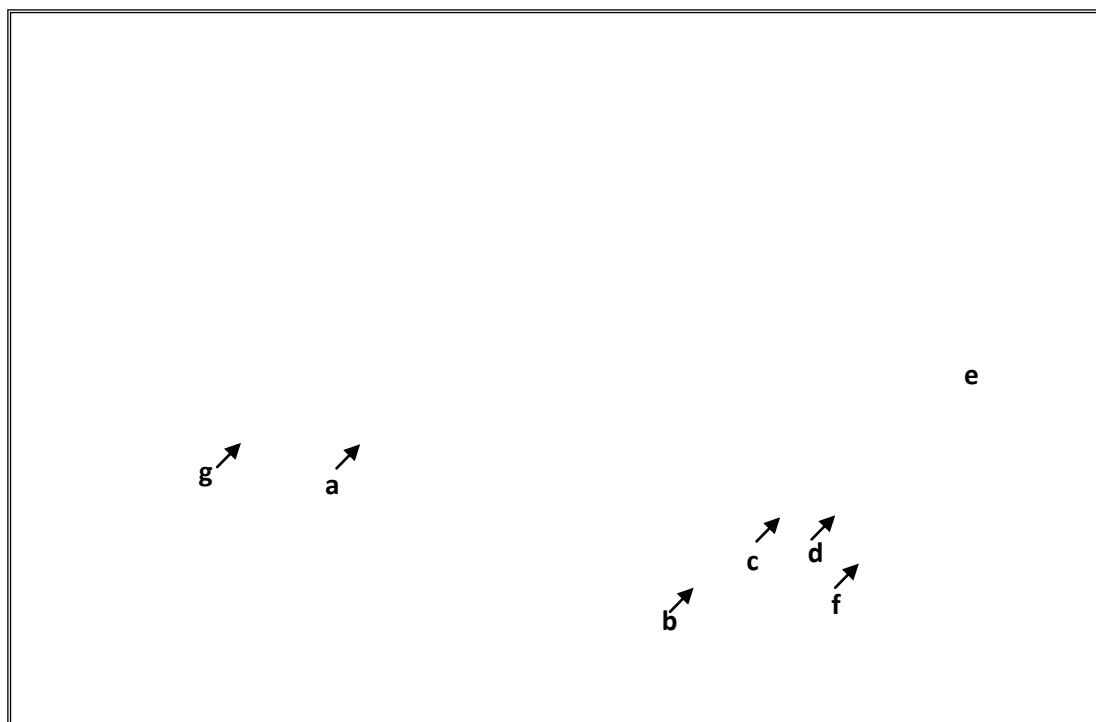


Figure 10. FTIR spectrum of biodiesel obtained from castor oil

Particularly the band at 3008 cm^{-1} showed transmittance rates that ranged from 36-54% depending on the concentrations of methanol (10, 20 and 30% v/v) and the most intense band of the ester group (1745 cm^{-1}) presented transmittance between 5-9% for biodiesel from sunflower oil and slightly higher (6-10%) in the castor oil biodiesel.

3.9 UV-Vis Studio

UV-Vis spectroscopy has corroborated the presence of conjugated double bonds (polyene) present in the respective FAME biodiesel obtained. In Figures 11 and 12 show the corresponding spectra of each of the obtained samples.

It is appreciated that the signals 260, 254 and 248 nm are the same in the two products without significant variations correspond to transitions $\pi - \pi^*$ between 250-260 nm of the double bonds and n-transitions of the presence π^* of the carboxylic acids. The most significant variation between both products is shown in Figure 13 where two signals are noted at 228 and 224 nm which can be explained by transitions $\pi - \pi^*$ of carboxylic acids λ and unsaturated β [34].

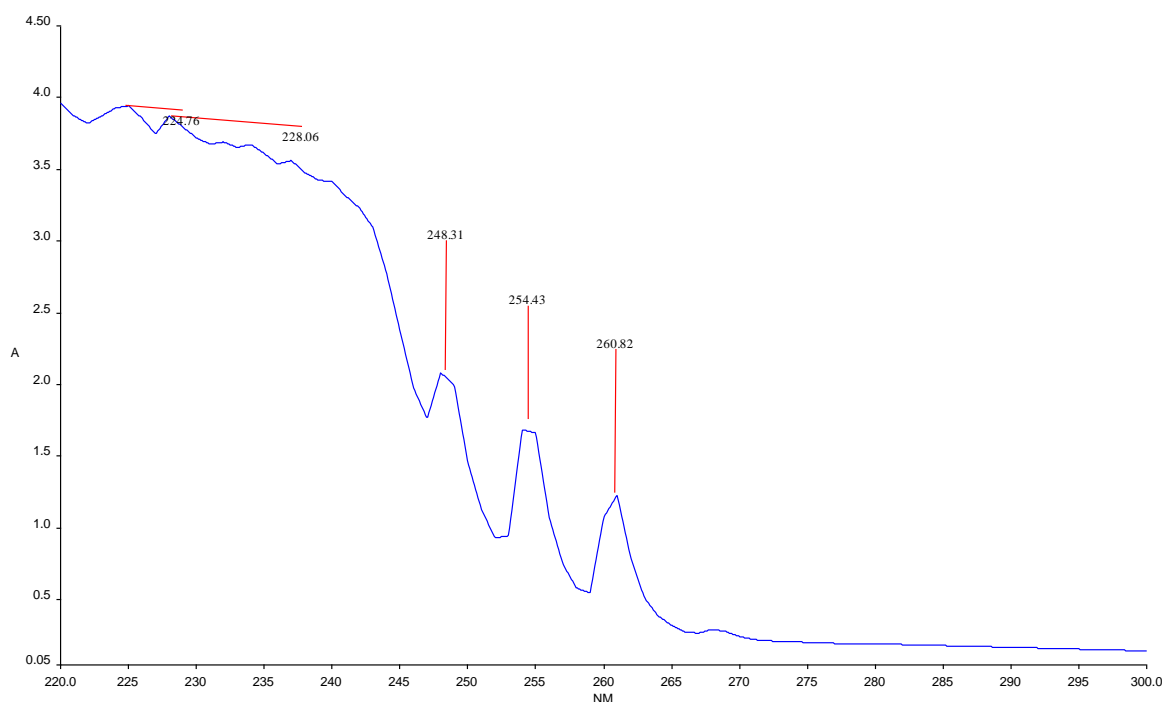


Figure 11. UV-Vis spectra of the samples of biodiesel obtained from castor oil

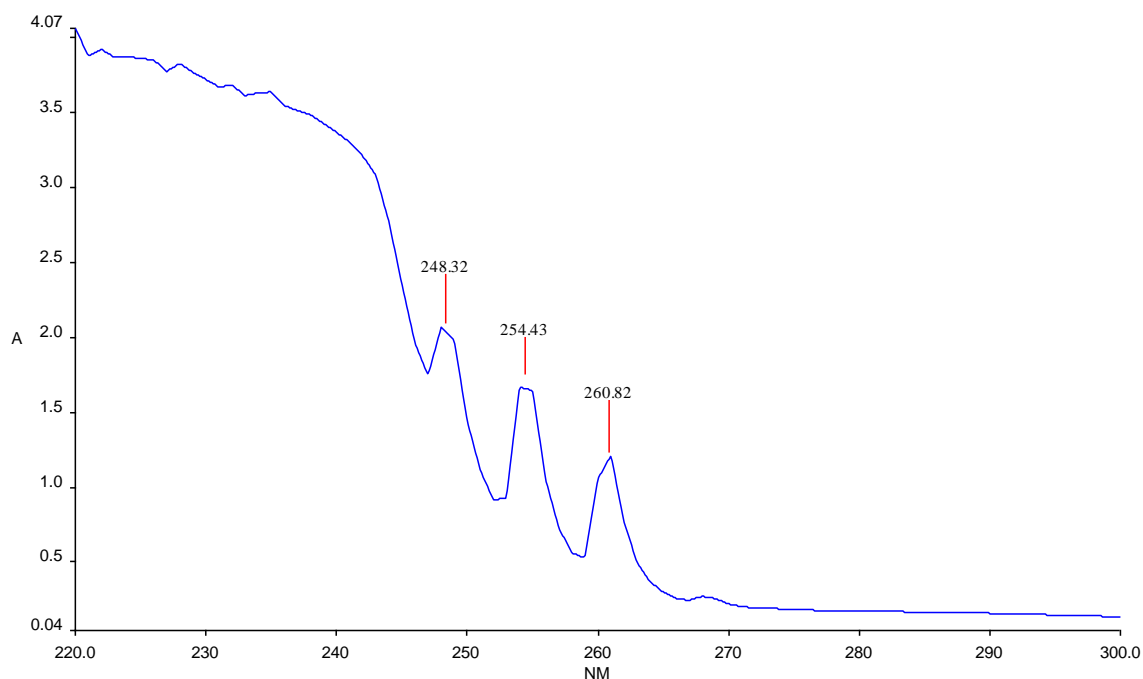


Figure 12. UV-Vis spectrum of biodiesel samples obtained from sunflower oil

4.0 Conclusions

Biodiesel obtained from the transesterification reaction of the oil, both of *Ricinus communis*, *Helianthus annuus* as grown in Tabasco, Mexico, presents yields between 78-91%. As characterizations results observed in the best quality is biodiesel oil obtained from *Helianthus annuus*, however achieved in performance, biodiesel oil *Ricinus communis* is higher (86.1% - 91.0% yield). Both products characterized by instrumental techniques confirm their high quality. It was felt that it is better to use oil *Ricinus communis* for easy production and is not used or marketed in the State of Tabasco.

5.0 References

- Kyoto Protocol. (1997). Kyoto Protocol to the United Nations Frameworks convention on Climate Change. Kyoto, December 1997.
- ADEME. (2000). Changement Climatique: Un défi majeur.
- Amado, E.; Villamizar, A.; Gafaro, A. (2005). Evaluación del proceso de producción de biodiesel a partir de grasas amarillas con altos contenidos de ácidos grasos. *Bistua: Revista de la Facultad de Ciencias Básicas*, Vol.3(1), p.54-60.
- Tickell, J., Tickell, K. (2005). *From Fryer to the Fuel Tank, The complete Guide to Using Vegetable Oil as an Alternative Fuel* (3a. ed.) New Orleans, Louisiana. Roman K.
- Aguilar, J.L. Biodiesel, ejemplo notable de combustible alternativo. http://www.energiaadebate.com.mx/Articulos/febrero_2006/jorge_luis_aguilar.htm. Consultado en Diciembre, 2010
- Balat M, Balat H. (2008). A critical review of bio-diesel as a vehicular fuel *Energy Convers Manage* 49, 2727-2741.
- Torres, F. Diseño, Construcción y Pruebas de un Prototipo para la Producción de Biodiesel a Partir de Aceites Provenientes de Recursos Renovables. Tesis de Maestría en Ciencias. Centro Nacional de Investigación y Desarrollo Tecnológico. Cuernavaca, México. (2008).
- Al-Zuhair S. (2005). Production of biodiesel by lipasecatalyzed transesterification of vegetable oils: A kinetics study. *Biotechnol Progress* 21, 1442-1448.
- Hanna, M.A. (1999). Biodiesel production: a review. *Bioresource Technology*.

- Darnoko, D., Cheryan, M. (2000). Kinetics of palm oil transesterification in a batch reactor, Journal of the American Oil Chemists Society.
- Benavides, A.; Benjumea, P.; Pashova, V. (2007). El biodiesel de aceite de higuera como combustible alternativo para motores diesel. Dyna, Año 74, No. 153, p 141-150
- Cardona, S. M.; González, R.; Franco, A.; Cardeño, F.; Ríos, L. (2010). Obtención de monoglicéridos de aceite de ricino empleando glicerina refinada y cruda. Estudio de las principales variables del proceso. Vitae. Vol.17, n.2, p. 128-134.
- Diaz, A. (2009). Diseño estadístico de experimentos. Colombia. Editorial Universidad de Antioquia.
- Limachi, I.; Farfan, O.; Sterner, O.; Giménez, A. (2009). Preliminary studies about the chemical characterization of fatty acids from *Bertholletia excelsa* fruit's oil by gas chromatography. BIOFARBO, Vol.17, no.1, p.47-53. ISSN 1813-5363.
- ASTM (American Society for Testing Materials). (2008).
<http://www.astm.org/DATABASE.CART/HISTORICAL/D6751-08.htm>. Consultado en Enero, 2012.
- CEN. European Committee for Standardization. (2002).
- Ogunniyi, D. (2006). Castor oil: A vital industrial raw material. Bioresource Technology, 97, pp. 1086-1091.
- Meneghetti, S., Meneghetti, M., Wolf, C., Silva, E., Lima, G. (2006). Ethanolysis of castor and cottonseed oil: A systematic study using classical catalysts. J. Am. Oil Chem. Soc., 83, pp. 819-822.
- Hincapié, G.; Moreno, A.; López, D. (2011). Transesterificación de aceite de higuera crudo utilizando catalizadores heterogéneos - estudio preliminar. Dyna, año 78, Nro. 169, pp. 176-181.
- Forero, M. C.; Gnecco, M. J.; Torres, M. A. (2003). Producción de biodiesel de Moriche (*Mauritia flexuosa*) como alternativa energética para las regiones apartadas de la Orinoquia Colombiana. Orinoquia Vol.7(1-2);59-69.
- Arancibi, Y. A., Calero, T.A. (2011), Obtención de biodiesel a partir del aceite de semillas oleaginosas de la provincia de Chimborazo. Tesis de Licenciatura. Escuela Superior Politécnica de Chimborazo. Riobamba, Ecuador.
- Guerrero, C. A.; Osorio, I. D.; Sierra, F. E. (2010). Evaluación del efecto de la temperatura en la producción de biodiesel con aceite de higuera. Ingeniería e Investigación Vol. 30 No. 2, p.52-61.
- Benjumea, P.; Benavides, A.; Pashova, V. (2004) Estudio experimental de las variables que afectan la reacción de transesterificación del aceite crudo de palma para la producción de Biodiesel. Scientia Et Technica. Vol. X. núm. 24, Mayo 2004. Universidad Tecnológica de Pereira, Colombia.
- Velasco, M. A., Arriaga, L. E., Niño, A., Sampiere, A., Pérez, A. (n d). Obtención de biodiesel a partir de aceite quemado de cocina por el método ácido-base.
http://www.buap.mx/potal_pprd/work/sites/red_ambiental/resources/pdfcontent/26/obtencióndebiodiesela partirdeaceitequemadodecocinaporelmetodoacido.pdf. Consultado en Diciembre, 2011.
- Kac, A. Método ácido-base para producir biodiesel. Conversión de ácidos grasos libres en ésteres. Journey to forever. Biocombustibles y desarrollo sostenible. <http://es.journeytoforever.org/biocombustibles/biodiesel-proceso-acido-base.cgi>. Consultado en Enero, 2011.
- PEMEX (Petróleos Mexicanos). Hoja de Datos de Seguridad de Sustancias. (2008).
- Antelo, et al. (2007). Biodiesel: Barriers, potentials and impacts. Sistemas de Energía y Medio Ambiente, University of Strathclyde, Glasgow. Inglaterra.
- Pasqualino, J.C.; Meneses, M.; Abella, M.; Castells, F. (2009). LCA as a Decision Support Tool for the Environmental Improvement of the Operation of a Municipal Wastewater Treatment Plant. Environmental Science & Technology, 43 (9), 3300-3307. ISSN: 0013-936X
- Delgado, A. E.; Aperador, W.; Silva, J. R. (2011). Influencia del porcentaje de mezcla del aceite de higuera en la obtención de combustible alternativo para motores diesel. Rev. Fac. Ing. Univ. Antioquia, n.58, pp. 46-52.
- Quezada, J. C. (2007). Evaluación de la energía de combustión y otros parámetros físico-químicos del biodiesel obtenido a partir de cinco aceites vegetales. Tesis de grado. Universidad Zamorano, Honduras.
- Tirado, J. A.; Trejo, F.; Sotelo, R. (2010). Conversión del aceite de piñón a biodiesel. V Simposio de Tecnología Avanzada 24 - 29 de junio de 2010. CICATA-IPN. MEXICO D. F, ISBN: 978-607-414-180-1.
- Socrates G. 1997. Infrared Characteristic Group Frequencies (Tables and Charts), John Wiley & Sons, 2nd Ed. (England).
- Lambert J. B., Shurvell H. F., Lightner D. A., Cooks R. G. 2001. Organic Structural Spectroscopy, Prentice Hall (USA).
- Lu, H.; Liu, Y.; Zhou, H.; Yang, Y.; Chen, M.; Liang, B. (2009). Production of biodiesel from *Jatropha curcas* L. oil. Computers & Chemical Engineering, 33 (5), 1091-1096.