Jatropha cinerea SEED OIL AS A POTENTIAL NON-CONVENTIONAL FEEDSTOCK FOR BIODIESEL PRODUCED BY AN ULTRASONIC PROCESS

ACEITE DE SEMILLAS DE *Jatropha cinerea* COMO FUENTE POTENCIAL NO CONVENCIONAL DE BIODIESEL OBTENIDO POR ULTRASONIDO

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Abstract

This work demonstrates that *Jatropha cinerea* (*J. cinerea*) seed oil has potential as a new, non-conventional, bio-energy resource. The physical and chemical properties of *J. cinerea* seeds, collected from its natural habit, were evaluated. The length-, diameter- and weight- of seeds were in the ranges of 8 to 12 mm, 7.5 to 11 mm, and 0.2 to 0.7 g, respectively. Additionally, the amount of oil in the seed kernel was 65.77 wt.%, and it contained 15% saturated, 33% monounsaturated, and 51% polyunsaturated fatty acids. The major constituent (50.8 wt%) of crude *J. cinerea* oil was linoleic acid. Based on its content of phorbol esters (0.22 mg g^{-1}), *J. cinerea* was considered to be a non-toxic *Jatropha* species. Iodine, saponification, and acid values of the *J. cinerea* seed oil were similar to those of the *J. curcas* seeds oil; therefore, it was suggested that *J. cinerea* oil had the quality required for biodiesel production from *J. cinerea* seeds oil was produced by a sonotransesterification process, evaluating the effect of the methanol: oil molar ratio (MOR), temperature, and reaction time. The best conditions for biodiesel production were 25ºC, a MOR of 4:1, and a notably short reaction time of 20 s. These conditions were very advantageous as compared to those required by conventional processes, and very promising for the development of a low cost biodiesel production process using *J. cinerea* seed oil as a feedstock.

Keywords: biofuel, biodiesel, Jatropha, *Jatropha cinerea*, ultrasonic process, transesterification.

Resumen

En este trabajo se demuestra que el aceite de las semillas de *Jatropha cinerea* (*J. cinerea*) tienen un potencial como materia prima no convencional para la producción de biodiesel. Se evaluaron las propiedades fisicoquímicas de las semillas *J. cinerea* recolectadas de su hábitat natural en las costas de Sinaloa. Se encontró que la longitud, diámetro y peso característicos de las semillas estuvieron en los intervalos de 8 a 12 mm, 7.5 a 11 mm, y de 0.2 a 0.7 g, respectivamente. Además, la cantidad de aceite en la almendra de la semilla expresada en porciento en peso (%p) fue de 65.8, del cual 15% correspondió a ácidos grasos saturados, 33% a monoinsaturados, y 51% a poliinsaturados; asimismo, se encontró que el compuesto principal de los ácidos grasos del aceite de *J. cinerea* fue el ácido linoleico (50.8 %p). También se determinó que *J. cinerea* se puede considerar como una especie no tóxicas debido a su bajo contenido de ésteres de forbol (0.22 mg g^{-1}). La caracterización del aceite de *J. cinerea* estableció que es adecuado para la producción de biodiesel debido a su alta calidad, fundamentada en los valores de índice de yodo, saponificación y acidez, los cuales fueron similares a los reportados previamente para *J. curcas*. Se evaluó la transesterificación del aceite de *J. cinerea* asistida por ultrasonido, evaluando el efecto de los siguientes parámetros: relación molar metanol: aceite (MOR), temperatura, y tiempo de reacción. En el rango de estudio, las mejores condiciones para la producción de biodiesel fueron 25 ºC, una MOR de 4:1, y un tiempo de reacción de 20 s. Estas condiciones experimentales fueron notoriamente favorables en comparación con las requeridas en procesos convencionales y muy promisorias para la producción de biodiesel de bajo costo a partir del aceite de semilla de *J. cinerea*.

Palabras clave: biocombustible, biodiesel, *Jatropha cinerea*, ultrasonido, transesterificación.

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1   Introduction

Eminent fossil fuel depletion has motivated the search for alternative fuels such as biodiesel, which is obtained from vegetable or raw animal products (Nieves-Soto, *et al.*, 2012). An important question regarding the feasibility of biofuels production is the availability of land to meet the potential demand of biomass as a feedstock. It is also important to keep in mind that despite several advantages that support and promote the development of biofuels, the use of biomass has originated several concerns related to possible side environmental impacts, including a loss of biodiversity and food security (Pandey *et al.*, 2012). To overcome these concerns, the use of non-edible or residual biomass has been suggested. Accordingly, the genus *Jatropha* and, especially, *J. curcas*, has recently received considerable attention as a strong candidate for the production of second-generation biofuel because it is a stress-tolerant ruderal that is drought-resistant. This small non-edible oil-bearing tree is well-adapted to tropical climates, semi-arid regions, and marginal lands and therefore grows pantropically (Jain and Sharma, 2010; Kesava *et al.*, 2012; Fresnado-Ramirez and Orozco-Ramirez, 2013). It has also been shown that *J. curcas* does not compete for conventional agricultural land or natural ecosystems; however, it suffers immediately from frost and waterlogging. Importantly, *J. curcas* is a relatively cheap seed that may have multiple applications such as feedstock for biofuels production and high protein flour used in animal feed e.g. sheep, shrimp, and quail (Escoto *et al.*, 2013; Rodríguez *et al.*, 2012). However, for the purpose of extensive crop production in the northwestern region of Mexico, *J. curcas* needs to be assisted by irrigation system, therefore, it is necessary to explore new alternative biomass feedstocks to support the development of biofuels to an industrial level with limited concerns and economic benefits.

In this context, Mexico is considered to be the center of diversity and endemism for the *Jatropha* genus. According to the literature, 50 of the 186 known *Jatropha* species are found in Mexico, and 39 of them are endemic (Govaerts *et al.*, 2012; Steinmann, 2002). These species are distributed between seven groups according the eco-geographic regionalization of Mexico. The group localized in the northwest of Mexico is characterized by growing in such habitats as tropical and subtropical deciduous forests, dry broadleaf forests, and semi-arid and hot deserts (xeric scrubs). A recent report (Fresnedo-Ramírez and Orozco-Ramírez, 2013) stated that the most represented species in the region of interest were: *J. cinerea, J. cuneata, J. cordata, J. cardiophylla*, and *J. malacophylla*. However, these species have not been studied as a potential feedstock for biofuels production. Interestingly, *J. cinerea* grows in a land with a high salinity level where the growth of *J. curcas* is very limited. As such, the aim of this work was to determine the potential of *J. cinerea* seed oil as a novel feedstock for the production of biodiesel and other byproducts. To this purpose, a physical-chemical characterization *J. cinerea* seeds oil was carried out to evaluate its composition, toxicity, and oil quality. In addition, its potential as a fuel feedstock was evaluated by performing the transesterification of the *J. cinerea* oil by using an ultrasonic process following a methodology recently reported (Nieves-Soto *et al.*, 2012).

2   Experimental

2.1   *J. cinerea seed collection*

Fruit collection was carried out from selected shrubbery localized on the coast of northwestern Mexico with the following coordinates: 24° 39' 08.49" north latitude and 107° 55' 54.92" west longitude. This site is characterized by briarwood vegetation and saline and sandy soils, according to the classification of Rzedowski (2006). Fruit collection was carried out from August to October due to the fruiting period of this *Jatropha* species (Maya and Arraiga, 1996). Afterwards, the pulp was removed and the seeds were placed under solar radiation for 15 days.

2.2   *Physical-chemical characterization of J. cinerea seeds*

Ripe seeds of *J. cinerea* were cleaned, and then hundreds of them were randomly selected to determine the average physical dimensions, *e.g.*, diameter, length, and weight. The moisture content in the seed was determined after a constant weight was obtained when drying the seeds at 100 ºC for up to 24 h. Next, seeds were de-shelled and the kernel was ground to a powder using a grinder. Protein, lipid, moisture, and ash content of the seeds kernel were determined using standard methods (979.09, 920.050, 925.10, and 923.03 respectively) of the Association of Official Analytical Chemists (AOAC, 2005). Likewise, carbohydrate was determined for

difference considering protein, lipid, moisture, and ash content per gram of dry biomass.

2.3 Oil characterization

2.3.1 Oil extraction

The oil content of the powdered seeds kernel was determined by extracting thoroughly with *n*-hexane (60-80 °C), in a Soxhlet extractor, for 6 h. To recover the oil, the solvent was removed under vacuum at 40 °C with a rotary evaporator (Emil *et al*., 2009) (Figure 1).

2.3.2 Phorbolesters production

Phorbolesters were determined as a measure of toxicity using the method of Makkat *et al*. (2007). The sample was extracted with methanol and an aliquot was loaded in a PerkinElmer High-Performance Liquid Chromatograph (model FLEXAR) equipped with a UV-Vis photodiode array (DAD) detector. A calibration curve was obtained using phorbol-12-myristate 13-acetate as standard; detection was made at 280 nm.

2.3.3 Acid value (AV)

The AV of the *J. cinerea* seed oil was determined according to the AOAC official method Cd 3a- 63. Percentage of free fatty acids (FFAs) was calculated using oleic acid as standard.

2.3.4 Iodine value (IV)

The IV of the *J. cinerea* seed oil was determined according to the AOAC official method 993.20 (AOAC, 2005).

2.3.5. Saponification value (SV)

The SV was determined according to the AOAC official method 920.160 (AOAC, 2005).

2.3.6 Fatty acid composition

The fatty acid profile of *J. cinerea* seed oil was determined from the composition of fatty acid methyl esters (FAME). The FAME analysis was carried out with an Agilent gas chromatograph (GC) (model 6890N) coupled to a selective mass spectrometer (MS) detector (model 5973). To prepare the sample, 25 mg of FAME were dissolved in 1 mL of hexane. Then, 1

μL of this mixture was injected via an auto sampler from Agilent Technologies (series 7683), using a split ratio of 50:1 and helium as carrier gas. An omega wax 250 column was used. For the analysis, the column temperature was initially maintained at 150 °C for 5 min, then the temperature was increased to 240 °C at 7 °C min^{-1} and, finally, the column was kept at 230 °C for 10 min.

2.4 Biodiesel production

Figure 1 shows the experimental sequence proposed in this study for the production of biodiesel from *J. cinerea* seeds oil. The figure highlights the extraction and characterization steps indicated in the previous section for the *J. cinerea* oil. This extracted oil was then converted to biodiesel by transesterification with methanol, catalyzed by KOH. In subsequent steps, methanol and KOH are recovered from the reaction products; finally, the last step was the refinery of the FAME, which was analyzed to determine the extent and yield of the process. Transesterification of *J. cinerea* oil was enhanced by means of an ultrasonic process. To this purpose, a highly efficient Hielscher Ultrasonic processor, model UP200S, was used to generate mechanical vibrations by means of the reversed piezoelectric affect (electric excitation) with a frequency of 24 kHz and a control range of 1 kHz. An acoustic power density (N) of 65 Wcm-2 was used, as suggested by Nieves-Soto *et al*. (2012). The effect of sonication time (reaction time), methanol:oil molar ratio (MOR) and reaction temperature on FAME content were evaluated at ambient pressure, using 0.85 wt. % of KOH as catalyst. Anhydrous methanol (Sigma-Aldrich, 99.8%,) and KOH reagent grade (Sigma-Aldrich, 90%) were used for all experiment of this study. After a given sonication time, the glass reactor was suddenly immersed to a plastic container at 0º C, for 15 min, to quench the reaction. Subsequently, the unreacted methanol was removed under vacuum at 40 °C with a rotary evaporator from Yamato (model RE-300); glycerol layer was carefully removed by decantation. Next, the catalyst and the partially converted triglyceride were removed from the FAME phase by means of adsorption, using Megasol D600R as absorbent. This adsorption process was conducted at 120 ºC, for 1 min, and using 1 wt. % of D600R. This process was sequentially repeated until the density of the biodiesel phase was within the range of 0.85 to
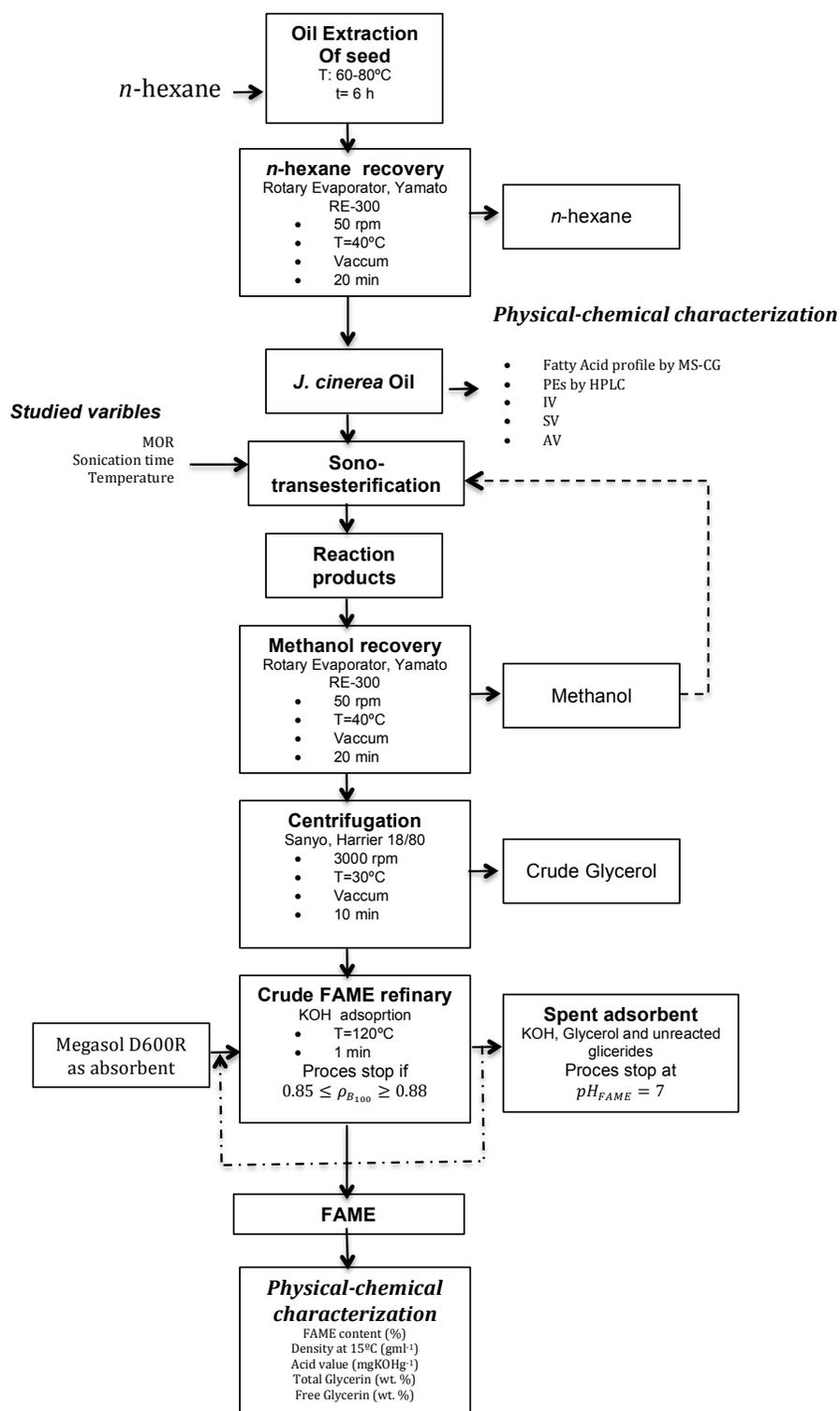
Fig. 1. Biodiesel flow diagram for oil characterization and sonotransesterification process.

0.88 g mL^{-1}. After purification process, the quantity of FAME was determined following the method EN 14111, according to the European Standard EN 14214 (2008). The method EN 14111 requires the calibration of all FAME components by relative response to a single compound, methyl heptadecanoate, as internal standard (ISD). The FAME content (wt. %) after the purification process was calculated according eq. (1).

$$FAME = \frac{\Sigma A - A_{ISD}}{A_{ISD}} \times \frac{C_{ISD} V_{ISD}}{m} \times 100 \quad (1)$$

Where ΣA is the total peak area from the C$_{14:00}$ to C$_{24:1}$ FAME m the mass of sample, A_{ISD} and V_{ISD} are, respectively, the peak area and the volume of ISD. The parameters of the mass spectroscopy- gas chromatography (MS-CG) analysis were similar to those used to obtain the FAME profile previously described. Finally, a 37-component FAME Mix standard from Supelco was used to determine the calibration factor and the retention time of each component in the mix. Moreover, the determination of the free and total glycerin in FAME was carried out following the volumetric method proposed by Pisarello *et al*. (2010).

3 Results and discussion

The *J. cinerea* seeds collected for this study were more spherical than the *J. curcas* seed, which are more elongated. Table 1 shows that the average mass of a *J. cinerea* seed was 0.35 g seed^{-1}, which was slightly less than for *J. curcas* (0.20-70 g seed^{-1}) (Karaj *et al*., 2008). However, the *J. cinerea* seed kernel had a total oil content of 65.8 wt. % after oil extraction, and the residual kernel cake had a chemical composition of 20.51 wt. % carbohydrates, 12.57 wt. % lipids, 6.07 wt. % ash, 4.24 wt. % moisture and 56.8 wt. % proteins (Table 1). These results highlighted the great potential of *J. cinerea* not only for biofuel production but also as rich-protein source for animal feed. For the later application, a special attention was placed in the potential toxicity of *J. cinerea* that might limit industrial applications. It should be notice that toxicity in *Jatropha* species, e.g. *curcas*, has been related to the presence of antinutritional factors including phytate, trypsin inhibitors, saponin, tannin and lectin and other toxic factors (e.g., curcin and PEs) among these, PEs are considered to be the most toxic constituents in *Jatropha* cake and meal (1- 6 mg g^{-1}; Devappa *et al*., 2013). As shown in Table 1, the content of PEs in *J. cinerea* kernel was 0.22 mg g^{-1}; therefore, it

could be classified as non-toxic resource in agreement with Makkar *et al*. (2007). This result suggests that *J. cinerea* could be a good candidate to be used as a rich-protein source for animal feed.

On the other hand, Table 2 shows the basic physical and chemical characteristics of *J. cinerea* oil that determine the quality of oil used for biodiesel production. *J. cinerea* oil revealed an IV of 120 cg I$_2$ g^{-1}, which is within the specified value for biodiesel according to the EN 14111 standard method. It is reasonable to associate this IV to the high content of unsaturated fatty acids measured by MS-GC, such as oleic acid and linoleic acid (see Table 3). It should also notice that this IV was higher than that observed for *J. curcas* (100- 105, as determined by Emil *et al*., 2009) due to the higher content of linoleic acid in *J. cinerea*. Moreover, is noteworthy the fact that a higher IV indicates a higher degree of unsaturation of oils (Emil *et al*., 2009) leading to oxidation and viscosity problems however, *J. cinerea* still kept good quality for biodiesel production purposes, as indicated by the SV, which was 150 mg g^{-1} (Table 2). This SV suggested that *J. cinerea* seed oil was high in triglycerides and, therefore, very useful in the production of biodiesel due to its low FFA content (ca. 0.9 wt.%). Moreover, the AV of 1.4 mg KOH g^{-1} shown in Table 2 was very different from the reported values for crude *J. curcas* oil, which were between 10 and 14 mg KOH g^{-1} (Lu *et al*., 2009). As a result, crude *J. cinerea* seed oil can undergo direct transesterification without a pretreatment, contrary to the case of *J. curcas* oils containing higher amount of FFAs, that requires an additional esterification step in the biodiesel production process (Lu, *et al*., 2009).

Fatty acid composition was another important parameter because the chain length and the number of double bonds determine the physical and chemical characteristics of both fatty acids and triglycerides (Thomas, 2000). Figure 2 shows the fatty acid profile of *J. cinerea* oil which was similar to the fatty acid profile of other vegetable oils, such as sunflower, corn and soybean oils. The predominant fatty acids in the *J. cinerea* oil used in this study were polyunsaturated (50.8%), monounsaturated (34%) and saturated fatty acids (15.23%) (Table 3). The degree of monounsaturation of *J. cinerea* seed oil was comparable to other vegetable oils such as palm, soybean and corn oils, but lower than *J. curcas* oil (Emil *et al*., 2009). Meanwhile, the polyunsaturated fatty acid content was similar to that of soybean oil (Demirbas, 2008).

Table 1. Characterization of *Jatropha cinerea* seeds

Parameter	Value ± SD
Seed per kg	2 300 ±30
Diameter[1], mm	9.20 ±0.2
Length[1], mm	10.16 ±0.4
Weight[1], g	0.35 ±0.1
Oil content of kernel[2], wt%	65.77 ±2
Moisture[3], %	4.24 ±0.002
Protein[3], wt%	56.58± 3.9
Carbohydrate[3], wt%	20.51±7.12
Ash content[3], wt%	6.07±0.02
Phorbolesters (PEs), mg g^{-1}	0.22 ± 0.02

[1] Average value obtained from 1000 randomly selected seeds
[2] Total lipid content including 12.57 wt% of the residual kernel
[3] Obtained after the oil extraction process

Table 2. Characterization of *Jatropha cinerea* seed oil

Parameter	Value
Acid value (AV), mg KOH g^{-1}	1.40 ± 0.09
Iodine value (IV), cg I$_2$g^{-1}	122 ± 0.08
Saponification value (SV), mg g^{-1}	150 ± 1.98
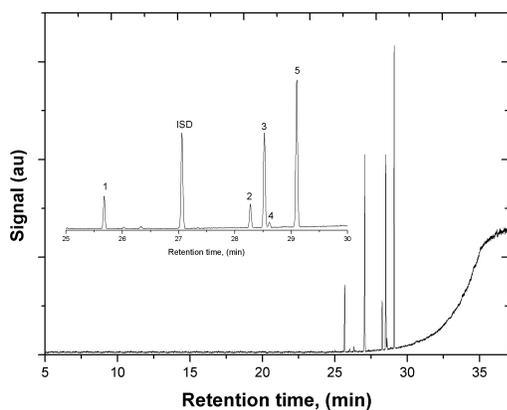
Fig. 2 MS-GC chromatogram for identification of fatty acid profile of *J. cinerea* seed oil and the FAME content of the sonotransesterification reactions: (1) palmitic acid methyl ester (C$_{16:00}$), (2) Stearic acid methyl ester (C$_{18:00}$), (3) Oleic acid methyl ester (C$_{18:1}$), (4) 11-octadecenoic acid methyl ester (C$_{18:1}$), (5) linoleic acid methyl ester (C$_{18:02}$), and heptadecanoic acid methyl ester as internal standard (ISD).

Table 3. Fatty acid composition of *Jatropha cinerea* oil

Fatty acid	Structure	wt %
Palmitic	16:00	8.78 ± 0.08
Stearic	18:00	6.44 ± 0.10
Oleic	18:01	33.99 ± 1.09
Linoleic	18:02	50.78 ± 0.5
Σ Saturated		15.23
Σ Monounsaturated		33.99
Σ Polyunsaturated		50.78

Hence, according to the MS-GC results, the major fatty acids in *J. cinerea* seed oil were oleic, linoleic, palmitic and stearic acids. Linoleic acid was the largest fatty acid component at 50.8% followed by oleic acid, which amounted for approximately 34% of the fatty acids (Table 3). Thus, *J. cinerea* seed oil can be classified as an oleic-linoleic oil. Compared to other vegetable oils, *J. cinerea* seed oil has a higher oleic acid content than soybean, coconut, corn, and sunflower oils (Demirbas, 2008).

Figure 3 shows the effects of reaction time, MOR and temperature on the FAME content after the products purification of the sonotransesterification process. It had been demonstrated elsewhere by Nieves-Soto *et al.* (2012) that with proper optimization of the sonochemical conditions, transesterification can be performed at very high reaction rates, with a typical reaction time of 30-60 s at 25 °C, as compared to a few hours and higher temperature required for other conventional transesterification processes (González-Brambila *et al.*, 2014). In this study, we observed no significant statistic difference in the FAME content when using a MOR of 4:1 and 6:1, but there was a noticeable difference for a MOR of 3:1. For experiments conducted with MOR of 4:1 and 6:1, at 25 ºC, and a reactant volume of 50 mL (Figure 2 A), the FAME content was around 97-99.5 wt.%. Meanwhile, for experiments with a MOR of 3:1, under the same reaction conditions, the FAME content was within 88- 97%. These results suggested that only a small excess of methanol (i.e., MOR of 4:1) over the theoretical stoichiometric requirement (i.e., MOR of 3:1) was sufficient to enhance the formation of FAME. It is noteworthy that neither the range of reaction time (Figure 2A) nor the range of temperature (Figure 3B) used in this study, had a significant statistic difference in the FAME content. The higher FAME content (up
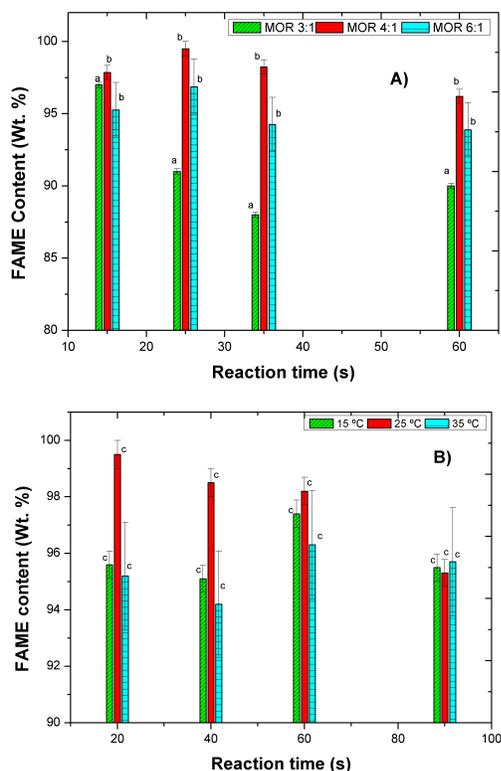
Fig. 3. FAME content after purification process of product of transesterification reaction using an acoustic power density of 65 Wcm^{-2}. A) Effect of sonication time and the methanol: oil molar ratio (MOR) at 25 ℃. B) Effect of sonication time and temperature at a MOR of 4:1. Data were obtained by triplicated; similar letters on the results bar means no significant differences according to ANOVA statistical analysis.

99.5%) was obtained in the experiment conducted at 25℃, with a MOR of 4:1, indicating that 90% FAME yield was reached. This is a significant high yield due to the high reaction efficiency; it should be noted that the theoretical FAME yield from *J. cinerea* oil is 91.4% (defined as FAME mass/reactant mass) and also that the FFA and the unreacted triglyceride content in *J. cinerea* oil was 0.9 and 0.5 wt.%, respectively. Moreover, for longer reaction times, the FAME content was slightly diminished to 96 % after 90 s. The slight effect of sonication time in the decrease of overall FAME content is not fully understood yet. However, it is important to notice that the positive effect of ultrasound to accelerate the transesterification process is related to the mass transfer limitations typically found in biphasic reactions systems. Ultrasound is a means of cavitation, which involves the formation, growth and implosion of bubbles in a liquid subjected to ultrasound; therefore, ultrasound favors a notably fine dispersion of methanol in the oil that, in turn, increase the interface area up to 67 times (Kumar *et al.*, 2012). As a result, there is a drastic decrease of the typical diffusional problems found in transesterification reactions and also an increase of the local temperature; both phenomena may have a beneficial effect on the overall reaction rate. In the same context a possible explanation of the effect of sonication time could be that a higher sonication time induces a higher local temperature due to hot-spot formed during the sonication process (Kyuichi, *et al.*, 2004). This local temperature allows the equilibrium condition to be reached much faster since the kinetic of transesterification reaction follows the Arrhenius's Law, according to the recently stated by González-Brambila (2014) and, therefore, if the product is not removed from the reaction mixture, a slightly lower conversion might be observed. On the other hand, the improved kinetic conditions of the sonotransesterification process may contribute to require a lower MOR for a high conversion of the *J. cinerea* oil. The higher FAME content observed in this study was found for a MOR of 4:1 and, as it was previously indicated, this MOR was slightly higher than the stoichiometric amount (3:1) but significantly lower than the typical MOR of 6:1 used in other conventional transesterification processes. The lower amount of alcohol has practical implications in the overall process, because it reduces the cost of raw materials as well as the energy required in the separation of the reaction products.

Finally, Table 4 shows the properties of biodiesel obtained after the refinery process schematically shown in Figure 1, for an experiment conducted at 25 C, MOR of 4:1, during 20 s. As a comparison, a conventional approach for biodiesel production, recently reported by González-Brambila (2014), indicated that for an experiment conducted at 60 ℃, MOR of 6:1 and after 1 h, a maximum yield 79% of biodiesel was reached. Thus, these results clearly demonstrates that with the operationing conditions and purification sequence proposed in this study, *J. cinerea* seeds oil could be a convenient feedstock for biodiesel production, fulfilling the main regulations indicated by EN 14214. In summary, the selected experimental conditions for the conversion of *J. cinerea* oil in biodiesel enhanced by the ultrasonic phenomenon are very suitable for industrial

Table 4. Physical chemical properties of biodiesel obtained from J. cinerea seed oil at 25 ºC, 20 s and MOR 4:1.

Parameter[a]	Value
FAME content (%)	99.5
Density at 15ºC (gml-[1])	0.84
Acid value (mgKOHg^{-1})	0.5
Total Glycerin (wt. %)	0.18
Free Glycerin (wt. %)	0.017

[a]After purification process

application, because a very fast reaction rate leads to a drastic decrease in reactor size, as well as to a set of milder reaction conditions for the transesterification process.

Conclusions

The potential of *J. cinerea* seed oil from northwestern Mexico as a biodiesel feedstock was probed. In addition, results of this study showed that *J. cinerea* can be classified as a non-toxic *Jatropha* species with a high protein content, which also makes *J. cinerea* a good feedstock for animal food production. The composition analysis of *J. cinerea* oil showed that it is rich in linoleic and oleic acids, and it could be classified as an unsaturated oil, thus explaining its potential as feedstock for biodiesel production. The major advantages of the *J. cinerea* sonotransesterification process found in this study include operational simplicity, mild reaction conditions (25 ºC and atmospheric pressure), short reaction time (20 s), low MOR (4:1), and high overall oil conversion (up 99.5%). Notoriously, ultrasonication decreases the transesterification reaction time to a few seconds as compared to 1-6 h required for conventional transesterification processes. The experimental findings of this study, in addition to the fact that *J. cinerea* grows on lands with a high salinity level not suitable for agriculture, demonstrate that *J. cinerea* seed oil has a strong potential as raw material for industrial biodiesel production.

Acknowledgments

Nomenclature

A	peak area
AOAC	association of official analytical chemists
AV	acid value
AV	acid value
C	FAME concentration
DAD	UV-Vis photodiode array detector
FAME	fatty acid methyl esters
FFAs	free fatty acids
HPLC	High-Performance Liquid Chromatograph
IV	iodine value
IV	iodine value
J. cinerea	*Jatropha cinerea*
J. curcas	Jatropha curcas
MOR	Methanol: Oil molar ratio
MS-GC	mass spectroscopy -gas chromatography
N	acoustic power density
PEs	phorbolesters
SV	saponification value
Wt%	weight percentage
Subscripts	
ISD	internal standard
XX:YY	carbons number in the fatty acid chain: numbers of unsaturation

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