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Artigo Original

Biodiesel produced from seed oils treated with sanitary effluent

Biodiesel produzido a partir de óleos de sementes tratadas com efluente sanitário

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Abstract

Oils from *Jatropha curcas L.* and *Ricinus communis L.* can be transformed into biodiesel through the transesterification reaction. The plants J. curcas and R. communis are of great importance in northeastern Brazil and has been considered an alternative energy source to fossil fuels. Wastewater can be used to irrigate these plants as it contains nutrients such as nitrogen and phosphorus. This study aimed to evaluate the productive aspects of fertile Jatropha and Ricinus that has been grown with treated domestic sewage. For the Jatropha were used three systems: an anaerobic digester and filter, an anaerobic filter, and a Upflow Anaerobic Sludge Blanket (UASB) reactor. For the Ricinus was used a UASB reactor, an anaerobic lagoon, polishing tank and 4 drains with the planting of castor. Using these systems, the chemical and biochemical oxygen demands were reduced by 93.6, 91.92, and 94.84%, and 98.2, 91.92, and 92.31%, respectively. The average pH in the three treatment systems was 7.0. The oil content of the Jatropha and Ricinus seeds were of 14 – 35% and 46-70% yield, respectively. The acidity of the Jathopha oil was 18.88 mg KOH/g, with a density of 0.911 g/cm^3 and kinematic viscosity of 31.49 cSt and the acidity of Ricinus communis was of 0.0003 mg KOH/g, with a density of 0.940 g/cm^3 and kinematic viscosity of 248.65 cSt. The esters of oleic and linoleic acid constituted 45.83 and 30.60% of the oil of Jatropha and Ricinoleic acid was of 79.9% in composition of fatty acids. These results show that Jatropha oil and Ricinus oil treated with domestic sewage has great potential for biofuel production.

Keywords: Biodiesel; Jatropha; Ricinus; Vegetable oils; UASB

Resumo

Óleos de *Jatropha curcas L.* e *Ricinus communis L.* podem ser transformados em biodiesel através da reação de transesterificação. As plantas J. curcas e R. communis são de grande importância no nordeste do Brasil e têm sido consideradas uma fonte alternativa de energia para combustíveis fósseis. Águas residuais podem ser usadas para irrigar essas plantas, pois contém nutrientes como nitrogênio e fósforo. Este trabalho teve como objetivo avaliar os aspectos produtivos de Jatropha e Ricinus fértirrigados que foram cultivados com esgoto doméstico tratado. Para o pinhão-manso foram utilizados três sistemas: um digestor anaeróbico e um filtro, um filtro anaeróbico e um reator de manta de lodo anaeróbio de fluxo ascendente (Upflow Anaerobic Sludge Blanket - UASB). Para o Ricinus foi utilizado um reator UASB, uma lagoa anaeróbica, tanque de polimento e 4 drenos com plantio de mamona. Usando esses sistemas, as demandas química e bioquímica de oxigênio foram reduzidas em 93,6, 91,92 e 94,84%, e 98,2, 91,92 e 92,31%, respectivamente. O pH médio nos três sistemas de tratamento foi de 7,0. O teor de óleo das sementes de Jatropha e Ricinus foi de 14 a 35% e 46 a 70% de rendimento, respectivamente. A acidez do óleo de Jathopha foi de 18,88 mg KOH / g, com uma densidade de 0,911 g / cm^3 e viscosidade cinemática de 31,49 cSt e a acidez de Ricinus communis foi de 0,0003 mg KOH / g, com uma densidade de 0,940 g / cm^3 e viscosidade cinemática de 248,65 cSt. Os ésteres do ácido oléico e linoléico constituíram 45,83 e 30,60% do óleo de Jatropha e ácido Ricinoleico foi de 79,9% na composição de ácidos graxos. Estes resultados mostram que o óleo de Jatropha e o óleo de Ricinus tratados com esgoto doméstico têm grande potencial para a produção de biocombustíveis.

Palavras-chave: Biodiesel; Jatropha; Ricinus; Óleos vegetais; UASB

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1 Introduction

Concern for the environment and the search for alternative energy sources are of great importance for humanity. The development of alternatives to conventional energy sources such as coal, oil, and natural gas has increased in recent years (SHEEHAN; DUNAHAY; BENEMANN, 1998). Another major issue is the usage of water as shortages have hit several parts of the world; an alternative to water rationing is re-use, which can be applied in irrigation (CERQUEIRA et al. 2008, DAVIS et al., 2015).

Biodiesel is among the proposed alternative sources of energy; it is a renewable fuel obtained through a chemical process called "transesterification." The raw materials used in the production of biodiesel can be of vegetable (such as soybean, castor bean, canola, palm, sunflower, or peanut) or animal origin (bovine, swine, and poultry) (VIEIRA et al., 2018, DIAS et al., 2013). Vegetable oils have been proposed as an alternative to diesel fuels as they widely available from a variety of sources and renewable (BOEHMAN, 2005; EL DIWANI; ATTIA; HAWASH, 2009, AMIN et al., 2016).

Brazil has great potential in the production of biodiesel (MASIERO, 2011). However, the selection of an oil seed should consider the oil contaminent of the plant, agricultural yield, and availability for harvest in each region (PINTO; SILVEIRA; CARVALHO, 2005). Jatropha (*Jatropha curcas*) can grow in arid and semi-arid areas with low precipitation levels of 200 mm/year and high precipitation levels of 900 to 1,200 mm/year (VIRGENS; CASTRO; LOUREIRO; FERNANDEZ, 2017). Engineering tests have found that that unmodified J. curcas oil can replace 40 to 50% of diesel.

The castor bean, known scientifically as *Ricinus communis L*, can grow in places with low water tolerance but needs of heat and luminosity (SOUZA et al., 2010). The Brazilian northeast has climatic conditions for the development of these plants (EMBRAPA, 2013). The amount of oil from castor oil seeds contents from 46 to 55%, whose commercial standard is 45% (CHEAH; YUSUPA; CHUAH; BOKHARI, 2016).

J. curcas produces a non-edible oil; it is cultivated in northeastern Brazil and irrigated with treated wastewater, which reduces the level of freshwater consumption – this is a major environmental action considering the recent constant reduction of the availability of water. In addition, wastewater contains high levels of nutrients (nitrogen and phosphorus) that can meet crop requirements, which significantly reduces, and sometimes eliminates, fertilization costs (LEITE; JÚNIOR; DE SOUSA, 2005).

The fruits of *J. curcas* and *R. communis* contains a viscous oil that can be used in the cosmetics industry, as a substitute for kerosene, and in the manufacture of soap and diesel fuel (VIRGENS; CASTRO; LOUREIRO; FERNANDEZ, 2017). Using this non-edible oil for biodiesel production could render this process economically feasible (EL DIWANI; ATTIA; HAWASH, 2009). In addition, the use of wastewater further reduces the costs of advancing wastewater treatment. Biodiesel production must be technically feasible, economically competitive, environmentally sustainable, and readily available (ATABANI et al., 2012). Therefore, it is necessary to explore methods of reducing the biodiesel production cost and minimizing the cost of raw materials is of particular interest.

The purpose of this study is to evaluate the domestic sewage effluent crude in two small cities of the Brazilian northeast (Ibimirim - PE and Pesqueira - PE) and oil and biodiesel obtained from Ricinus communis and Jatropha curcas plants. Thus presenting, a way of producing biofuel with low cost and with possibility of being an alternative to replace fuels derived from petroleum.

2 Materials and Methods

2.1 Characterization of the sewage treatment system

For the two regions (Ibimirim - PE and Pesqueira - PE) the water samples were analyzed using the standard methods for the examination of water and wastewater (American public health association (APHA), 2005). The experimental unit of the Demonstration Station for Treatment of Sewage and Hydrous Reuse, located in the district of Mutuca-Pesqueira/PE is located in a rural community in the semi-arid region, 230 km from Recife, capital of the state. The other station works in the Municipality of Ibimirim, Microregion of the Sertão do Moxotó, 340 km from Recife. The samples were collected about between 0 - 1 meter deep and were performed in triplicates. The mean values were used to show the results of this work. The parameters adopted for characterizing the crude and treated effluents were pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), conductivity, total phosphorus, total nitrogen, chlorides, sodium, and potassium. To calculate the percentage or efficiency of pollutant removal for the respective efficiency of the treatment systems, the model proposed by Von Sperling (2005), which is expressed in Equation 1.

$$E (\%) = [(S_0 - S/ S_0) * 100] \quad (1)$$

E - treatment efficiency of the parameter studied - Crude effluent

S - value of the studied parameter - Treated effluent

S_0 - value of the parameter studied - Gross effluent

2.2 Extraction of oil by extraction and degumming

The oils of Jatropha and Ricinus were extracted following the Soxhlet method, based on procedures adapted from the analytical standards of the Adolfo Lutz Institute (PREGNOLATO; PREGNOLATO, 1985). The seeds were selected and ground in a multiprocessor (Multimix II model, Zaitec), they remained homogeneous and the contact surface area with the solvent was increased.

After grinding, the samples were placed in an oven at 60 °C for 30 min. The samples were extracted for 2 h at 80 °C. The oil was extracted, and the solvent was removed through a rotary evaporator, thereby creating a yellow coloration (QUEIROZ; ZAIDAN; SILVA, 2017).

For the Jatropha oil, the oil underwent the degumming process, which involves the addition of 3% (m/m) of water to the oil heated at 70 °C and subsequent agitation for 30 min. In this study, the oil contained a large number of phosphatides, so the water ratio was increased to 5% and then 8% in relation to the oil mass, which was appropriate for gum removal. The oil was separated from the gum using a separatory funnel and then dried at 105 °C for 1 h (MANDARINO, 2001). This degumming process was not necessary in castor oil.

2.3 Acidity of oil and biodiesel production

The acidity index was determined following the American Society for Testing and Materials (ASTM) D 664 standard, which involves the determination of the number of milligrams of potassium hydroxide required to neutralize the free acids of one gram of the sample (MORETTO; FETTI 1989). The sample was dissolved in a solvent (ether + alcohol) and titrated with a 0.1-N sodium hydroxide solution. Acidity analysis is important because, if the oil has a high acid content, a reaction may occur before the transesterification reaction to produce biodiesel. The transesterification reaction was carried out at a temperature of 58 ° C, alcohol / oil molar ratio of 8/1; 0.5% sodium hydroxide to the oil mass and constant stirring for one hour. After the reaction, there was phase separation with glycerol (lower phase) and biodiesel (upper phase) due to the low solubility of glycerol in the esters. This separation was performed on a separation funnel after two hours. The biodiesel was heated for evaporation of the excess alcohol and then subjected to the washing step with water to remove the remaining catalyst, soap, salts, alcohol and glycerine free from the biodiesel. The conversion of free fatty acids was calculated by the acid number, and the ester content after transesterification was determined through gas chromatography.

2.3.1 Transesterification reaction

Transesterification requires one mole of triglyceride and three moles of alcohol. During the reaction, the triglycerides transform into the monoesters of fatty acids that constitute biodiesel. In addition, a glycerin emerges as a byproduct (FERREIRA et al., 2015). This process is used to reduce the viscosity of triglycerides. The transesterification of triglycerides produces fatty acid alkyl esters and glycerol (EL DIWANI; ATTIA; HAWASH, 2009), with diglycerides and monoglycerides as intermediates. The transesterification mechanism is described as follows (2):

When methanol is used for transesterification, R/ is CH_3 and the process is referred to as methanolysis. The methanolysis of *Jatropha* oil and *Ricinus* oil requires three moles of methanol, and can be represented by the following equation (3):

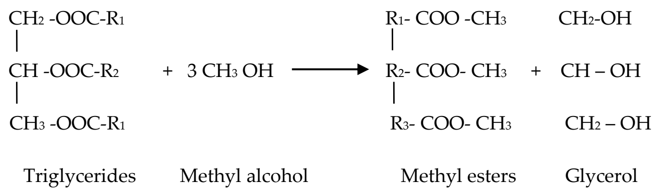
Triglycerides + R′ OH ⟷ Diglycerides + RCOOR′

Diglycerides + R′ OH ⟷ Monoglycerides + RCOOR′

Monoglycerides + R′ OH ⟷ Glycerol + RCOOR′

Mechanism of transesterification

(2)



Transesterification of Triglycerides

(3)

where R_1, R_2, R_3 are three moles of the fatty acid constituents of *Jatropha* oil and/or *Ricinus*. The methanolysis of *Jatropha* and/or *Ricinus* fatty acids uses 100% of the excess methanol to force the reaction in the forwards direction, producing the corresponding fatty acids of the methyl esters and releasing glycerol (HAILEGIORGIS; HASRAFF; KHAN; AYOUB, 2016).

2.4 Physicochemical characterization of Jatropha oil, Ricinus Oil and biodiesel

The physicochemical parameters of the oil samples that were obtained after transesterification and purification were determined according to ASTM standards (ASTM D 445 – 1997; ASTM D 4052 – 1996). The specific mass or oil density at 20 °C were determined according to ASTM D 4052 and measured using an Anton Paar GmbH DMA 4500. The kinematic viscosity at 40 °C was determined following ASTM D 445 and measured using a Cannon-Fenske.

2.5 Quantification of fatty acids

The chemical composition of the oils was determined using a CG Master gas chromatograph with a PEG 530 µm × 60 m capillary column, which shows the percentage of fatty acids. The stationary phase used was polyethylene glycol, and the entrainment gas (H2) was used at a flow rate of 5 mL/min. The temperatures of the detector and injector were maintained at 260 °C and 240 °C, respectively, and the split mode was employed with a ratio of 1:50. The fatty acids were quantified by area normalization. The biodiesel was also characterized in the same manner, and flashpoint analysis was conducted according to ASTM D6751 (analytical method ASTM D93) using a Herzog, model HFP 360.

3 Results and discussion

3.1 Water and soil conditions

Table 1 shows the performances of the respective effluent treatment systems of Pesqueira - PE with values in the entrance and exit of effluent. Table 2 show the performances of the respective effluent treatment systems of Ibimirim - PE: anaerobic digester plus filter, UASB, and anaerobic filter only. These results were calculated used to calculate the efficiencies of the systems.

Table 1 shows the parameters in the Pesqueira – PE region. It was observed that there was a decrease, the COD average was 464,02 mg/L at the entrance of the effluent and 151 mg/L in the final, this decrease indicated that had a high concentration of organic matter that will lead to its degradation, consumption of the dissolved oxygen present in the receiving bodies. The mean BOD found was 99,94 mg /L and posteriorly was of 30,29 mg/L, this mean that this demand is enough to consume all the dissolved oxygen from the water, which conditions the death of all aerobic organisms' underwater breathing. The other parameters as phosphorous, electrical conductivity and nitrogen had a decay showing that these parameters indicate their retention in the soil and absorption by the plants. It is important to comment on toxicity because the most toxic elements in wastewater are boron, sodium and chlorine. In our work the presence of sodium and chlorine concentrations were observed, but the values are within tolerated limits of 0,5 g/L and 13 meq/L (ALMEIDA, 2010). According VALDEZ-AGUILAR; REED, (2010), the electrical conductivity can conduct electric current, as a function of ionic concentration mainly by nutrients such as calcium, magnesium, potassium, sodium, carbonate, sulfate and chloride. The pH ideal is between 6,0 and 8,6, according VON SPERLING (2005) pH values far from neutrality can affect aquatic life and the microorganisms responsible for the biological treatment of the effluent, these values corroborate with this work. The significant reduction of COD and BOD showed the efficiency of the treatment, as maximum efficiency obtained from 83,25%.

Table 2 shows the water and soil parameters in the Ibimirim Region. Most parameters exhibited high values in the raw effluent, which decreased due to the applied treatments. Here, we use the removal efficiencies of COD and BOD, and the sodium and potassium parameters as examples. According to the results, COD was significantly reduced, demonstrating the efficiency of the treatment systems. The maximum removal efficiency was 96%, indicating the quality of the digester plus filter and UASB reactors, which reduced the pollution indices of the raw and treated effluents. The BOD also reduced in the digester plus filter and UASB reactors, demonstrating the efficiency of the process. The removal efficiencies by the reactor that solely contained a filter were lower than those of the previous two treatments. It is important highlight that no significant levels were detected for the metals zinc, manganese, iron and copper in the samples. Is possible that the concentrations of these metals in the samples can be well below the detection level of the equipment.

Table 1- Medium values of the characterization of the exit of the Pesqueira - PE treatment plant

	Entrance of effluent (±0,2)	Exit of effluent (±0,2)
pH	7,59	7,78
COD (mg/L)	464,02	151,01
BOD (mg/L)	99,94	30,29
Conductivity (uS/cm)	2547,50	2012,25
Total phosphorous (mg/L)	22,18	38,12
Total nitrogen (mg/L)	41,96	29,45
Chlorides (mg/L)	397,68	281,53
Sodium (mg/L)	262,86	252,81
Potassium (mg/L)	89,49	66,53

Table 2 – Medium values of the 4 systems applied at Ibimirim - PE station

	Raw Effluent (±0,2)	Digester + filter (±0,2)	UASB (±0,2)	Filter(±0,2)
pH	7,03	7,34	7,14	7,10
COD(mg /L)	1968,27	384,58	395,48	694,88
BOD (mg /L)	335,59	47,30	36,05	65,03
Conductivity (uS/cm)	1658,50	1984,73	2137,70	1884,25
Total phosphorous (mg/L)	10,16	8,68	10,25	9,39
Total nitrogen(mg/L)	68,85	60,18	62,13	66,36
Chlorides(mg/L)	179,88	159	171,10	186,20
Sodium(mg/L)	2479,35	116,58	99,10	111,65
Potassium(mg/L)	123,68	42,43	43,58	53,63

Table 3 – Maximum and minimum values of process removal efficiencies in Pesqueira -PE station

Efficiency	COD	BOD
Entrance and exit of effluent	62-83%	68-96%

Table 4 – Maximum and minimum values of process removal efficiencies in Ibimirim -PE station

Efficiency	COD	BOD
Digester + filter	66–96%	51–98%
UASB	45–94%	77–92%
Filter	40–92%	62–85%

The COD and BOD removal efficiencies from the treatment systems are shown in Table 3 and 4.

3.2 Characterization of Ricinus comunnis oil and Jatropha oil

Irrigated Jatropha seeds have a mean weight of 0.81 g, with a standard deviation of 0.033, as shown in Fig. 1, which also shows the 95% confidence interval. The seeds consist of 36.7% bark and 63.3% albumen. The seeds were extracted following the Soxhlet method. On average, 26,41% of the oil could be extracted, as shown in Table 5.

The oil contents expressed in mass fraction are presented in Table 5. The amount of fertigated castor oil is greater than the amount of oil of the jatropha and ricinus oil plants.

These results show that there is a variation between 40% and 49% in oleo content extracted from irrigated and fertirrigated castor bean seeds. Thus, the influence of irrigation by domestic sewage is verified from the yield of the extraction process, where a quantity of oil was verified (QUEIROZ; ZAIDAN; SILVA., 2017).

The oil content extracted from the seeds of irrigated Jatropha varied between 14.5 and 34.5%, with an average of 26.41%. This variation is due to losses during the extraction process, extraction time, humidity, and other factors that influence the oil yield that are currently being

Figure 1 - Weight of seeds of *Jatropha*

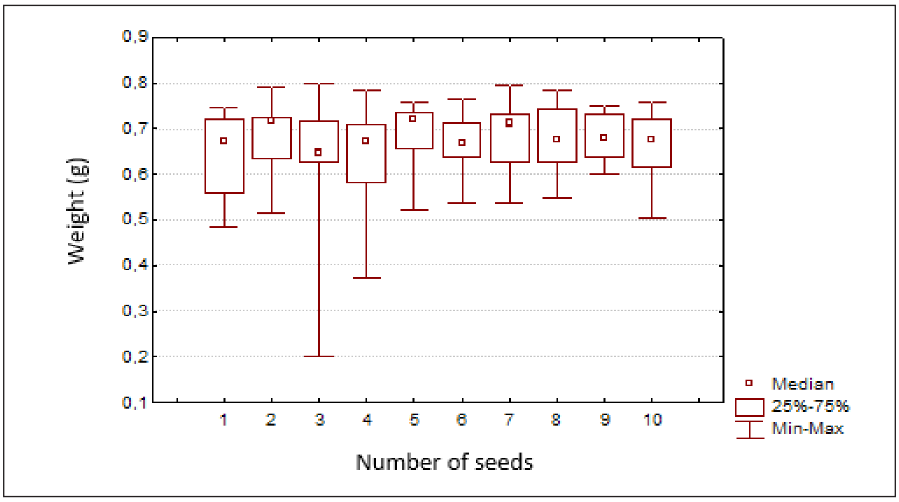


Table 5 – Oil content of *Ricinus* and *Jathopha*

SAMPLE	OIL CONTENT FERTIGATED CASTOR (%)	OIL CONTENT IRRIGATED CASTOR (%)	OIL CONTENT IRRIGATED JATROPHA (%)
1	53,6 ± 0,1	38,9 ± 0,1	34,4 ± 0,1
2	39,9 ± 0,1	47,1 ± 0,1	14,2 ± 0,1
3	49,2 ± 0,1	40,4 ± 0,1	22,67 ± 0,1
4	53,6 ± 0,1	38,8 ± 0,1	25,91 ± 0,1
5	45,6 ± 0,1	35,8 ± 0,1	34,84 ± 0,1
AVERAGE	48,4 ± 0,1	40,2 ± 0,1	26,41 ± 0,1

Table 6 – Results of the characterization analyses

ANALYSIS	UNITS	Ricinus Oil Fert irrigated	Ricinus Oil irrigated	Jatropha oil irrigated
Oil acidity index[1]	(mg KOH/g)	0,0003	3,18	18,82
Specific oil mass[2]	(kg/m^3)	940	961	911,5
Kinematic oil viscosity[3]	(cSt)	248,65	262,5	31,49

(1)astm d664[2]; (2) astm d4052[3]; (3) astm d445[4]; (4) astm d93[5]

Table 7 – Result of the acidity analysis of neutralized *Jatropha* oil

ANALYSIS	UNITS	VALUE
Acidity index of the neutralized oil[1]	(mg KOH/g)	0,9624

analyzed for possible correction.

The results of the acidity index, specific mass (density), and kinematic viscosity analyses are presented in Table 6, and Table 7 shows the acidity index of neutralized oil.

The oils underwent transesterification, and the biodiesel quality and fatty acid composition for both types of irrigation were quantified and analyzed using the area percentage. Depending on the raw material, the biodiesel may contain more or fewer unsaturated fatty acids that are susceptible to oxidation reaction, which would be accelerated by exposure to oxygen and high temperatures; these conditions are relevant to engine operation (PRAMANIK, 2003).

According to the analyzes presented in Table 6, a low acidity index (0,0003mg KOH/g) is observed for the fertirrigated castor oil sample and a high acidity index (3,18 mg KOH/g) was observed for the sample of castor oil irrigated with fresh water. According Ribeiro et al (2012) the oil of castor oil irrigated with fresh water has a high acidity index increasing the loss of the neutralization and indicating the inferior quality of the seeds, when compared to the fertirrigated. The samples of fertirrigated castor oil a very low acidity index and can be classified as type 1 because it has a value lower than 1% (IJAZ et al.,2016).

The specific mass is also an important fluid-dynamic characteristic of the fuel, because together with the viscosity, it is important for the proper functioning of the diesel cycle engines. For biodiesel, this property is similar to that of diesel, except for castor bean biodiesel that has a high viscosity and high specific mass of 0,959 kg/L (NOBRE et al., 2012, RIBEIRO et al., 2012).

As can be observed, there is a variation between 14,5% and 34,5% in the content of oil extracted from irrigated jatropha seeds at an average of 26,41%. This value is considered below the percentage of the Jatropha oil of the literature, which is about 35%, this is due to losses during the process, time of extraction, humidity, among other factors that are influencing the oil yield, which already being analyzed for possible correction.

The analysis of the specific mass of the oil sample was 911,5 kg / m^3, a value consistent with the standard of the oil of jatropha is observed. The kinematic viscosity of the oil sample was 31.49 cSt, also consistent with the characteristics of the oil.

3.3 Analysis of fatty acids

The oils were characterized following the chromatographic method to determine the percentage composition of fatty acids. The Ricinus oil fertirrigated the esters of unsaturated fatty acids appear in greater quantity with oleic (C 18: 1), linoleic (C 18: 2) and ricinoleic (C 18: 2) esters in higher proportions, 6.3%, 8.5% and 79.9%, respectively. The methyl esters of palmitic (C16: 0) and stearic (C18: 0) acids were found at lower levels. With the irrigation of pure water, the analysis of fatty acids showed that ricinoleic acid presented a lower level with 69%.

For the Jatropha oil irrigated with pure water the esters of unsaturated fatty acids are more abundant, with the oleic (C18:1) and linoleic (C18:2) esters exhibiting higher proportions of 45.83 and 30.60%, respectively. The methyl esters of the palmitic (C16:0), palmitoleic (C16:1), and stearic (C18:0) acids were present at 15,87%, 0,71% and 6,99%, respectively.

When analyzing the biodiesel of jatropha was verified that the esters of unsaturated fatty acids are more abundant, with the esters of oleic (C18:1) and linoleic acid (C18:2) constituting proportions of 44,75 and 30,34 %, respectively. The methyl esters of palmitic (C16:0), palmitoleic (C16:1), and stearic (C18:0) acids were recorded at lower levels. For the biodiesel of ricinus oil, the esters of ricinoleic (C18:2) had a proportion of 84%.

The purity of each biodiesel produced was calculated following the European method using their fatty acid compositions, and the biodiesel produced from irrigated *Jatropha* had a purity of 71% and the biodiesel from the fertirrigated ricinus presented a purity of 78,1%, while the irrigated ricinus oil had a purity of 47,1%.

4 Conclusion

Using the data obtained from the water and soil analysis of the Pesqueira - PE and Ibimirim - PE Region, we can conclude that irrigation using a digester and UASB are feasible for treating raw effluent. The high concentrations of sodium and potassium in the wastewater indicate high salinity, however, these values decreased after treatment. The influence of irrigation using domestic sewage was verified through analyzing the *Ricinus* and *Jatropha* seeds obtained in the extraction process. According to the physicochemical characterization, the oils had values of the acidity, density and the viscosity in agreement with the works of the literature and showed a good-quality of oil produced. The chromatographic analysis of the fatty acid composition of the *Jatropha* oil, *Ricinus* oil and biodiesel of both showed that unsaturated fatty acids were more abundant; oleic and linoleic acid and ricinoleic, respectively. And bigger values in fertirrigated samples. Through this work it is possible to point out that there are already many places in Brazil that have the reuse of water for agricultural purposes, but it is necessary to institutionalize, regulate and prepare legislation for better development and dissemination.

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