

ESTERIFICATION OF FUSEL OIL WITH OLEIC ACID FOR THE PRODUCTION OF POTENTIAL BIOLUBRICANTS

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Abstract: Due to constant concerns about the environment, many researchers have sought to develop alternative products with the aim of reducing the environmental impacts caused by petroleum derivatives. Brazil is the second largest producer of the biofuel called ethanol, produced from sugar cane. However, throughout the ethanol production process, large quantities of fusel oil are generated. In this sense, the objective of this work was to study a possible destination for fusel oil. For this purpose, the fusel oil esterification reaction was carried out with oleic acid, epoxidation of esters, hydrolysis of epoxides and acetylation of hydroxyls to obtain compounds. With successive chemical modifications, different types of potential biolubricants were produced, with viscosities classified as ISO GV7, 10, 22, and SAE 0, 15, 20 and 30W. These results indicated that fusel oil has great potential to be used in the production of biolubricants, and this way, contribute to the range of renewable products that are less harmful to the environment.

Keywords: Fusel Oil, Esterification, Oleic acid, Biolubricant.

INTRODUCTION

On a global scenario, two countries stand out in ethanol production, the United States as the main producer, corresponding to 54.9% of world production, and Brazil, the second largest producer with 27.5% of global volume in the year 2021 [1].

Estimating that ethanol production in a medium-sized plant can reach 1.5 million liters per day and that the average proportion of fusel oil for every 1000 liters of alcohol is 2.5 liters [2], the potential total fusel oil production in the world is estimated at approximately 550 million liters. Of this volume, only the United States and Brazil are responsible for approximately 84% of world production [3,4].

Fusel oil is the product of the transformation of amino acids by yeasts through alcoholic fermentation, essentially consisting of the less volatile fractions obtained during the fuel alcohol distillation process [5]. Its composition contains higher alcohols such as amyl, isoamyl, propyl, butyl alcohols, among others [6,7].

Therefore, fusel oil has great potential to be used as a substrate to produce compounds of industrial interest, such as biolubricants, plasticizers and flavorings [8,9]. Furthermore, this by-product of alcoholic fermentation has been widely applied as a reagent in esterification reactions to produce aromatic compounds such as isoamyl butyrate [10] and isoamyl laurate [11].

Within this context, it was proposed in this work to obtain different fusel oil esters with potential application in the area of biolubricants through the esterification reaction of fusel oil with oleic acid and subsequent structural modification of the ester by chemical reactions.

EXPERIMENTAL PART

FUSEL OIL SAMPLE COLLECTION

The fusel oil sample was provided by the company Renuka Vale do Ivaí S/A – São Pedro Do Ivaí Unit, Paraná, Brazil. It was stored in a 50-liter plastic container before being taken to the UTFPR Campus Curitiba.

PRE-PURIFICATION OF FUEL OIL

600 mL of fusel oil was placed in a 1-liter separatory funnel. Three washes were made with 150 mL of brine solution. Then the organic phase was transferred to a 2-liter Erlenmeyer flask containing approximately 50 g of MgSO₄ where it remained for 24 hours. Subsequently, the fusel oil was filtered and stored in an amber bottle.

FUSEL OIL ANALYSIS BY GAS CHROMATOGRAPHY

The analysis of the fusel oil components was carried out using the Gas Chromatograph with Flame Ionization Detector, Shimadzu, Model 17A, with AT-WAX Column with polyethylene glycol, using 40°C for 1 min., 40°C to 240°C in 10°C/min and 240°C for 3 min, with injector and detector temperatures at 280°C and with N₂ carrier gas. Ethanol, isopropanol, n-propanol, isobutanol, n-butanol, isoamyl alcohol, n-amyl alcohol was used as chromatographic standards with at least 99% purity.

CALCULATION OF % CONVERSION IN ESTERIFICATION REACTIONS

The Acidity Index of the samples was obtained using the AOCS Cd 3d-63 method. Conversion percentages were determined using equation 1 where: A_i is the acid number of commercial oleic acid (OA) and A_f is the acid number of the sample [12]. All analyzes were performed in duplicate.

$$\% \text{ conversion} = (A_i - A_f / A_i) \times 100 \quad (1)$$

PHYSICO-CHEMICAL ANALYSIS

The iodine index (I.I.) was determined with the AOCS Cd 1-25 method. The percentage of oxygen oxirane (%O.O.) was determined using the ASTM D 1652 method. The relative density was determined using a pycnometer at 20 °C. Kinematic viscosity and viscosity index were determined using ASTM 445 and ASTM D2270 standards. All analyzes were performed in duplicate.

PREPARATION OF COMPOUNDS

ESTERIFICATION REACTIONS

A total of 32 experiments were carried out. In general, 10 g of oleic acid (OA), fusel oil (molar ratios 1:3 or 1:6) and the catalyst (p-toluenesulfonic acid - APTS or H₂SO₄ in a mass/mass ratio of 1 or 3 %) were added to a 100 mL round-bottom flask. The balloon was connected to a ball condenser. The mixture was heated in a silicone bath and remained under stirring and heating (80 or 100 °C) until the end of the reaction (1 or 2 hours).

The obtained products were transferred to a 125 mL separation funnel. Three washes were carried out with 25 mL of water at 30 °C, two washes with 25 mL of 0.1 M NaHCO₃ solution and one wash with 25 mL of brine solution. The organic phase was dried with MgSO₄, vacuum filtered and transferred to a vacuum distillation system (5 mmHg), containing a silicone bath at 100 °C to remove fusel oil alcohols that were not esterified. These reactions provided esterified oleic acids (EOA).

To produce a larger quantity of EOA, a reaction was carried out in a 5-liter reactor, containing 1.7 kg of commercial OA, 1.5 kg of fusel oil and 51 g of concentrated H₂SO₄. An OA/fusel oil ratio of 1:3, 3% concentrated H₂SO₄, stirring at 300 rpm, temperature of 100 °C for 2 hours was used.

EOA EPOXIDATION REACTIONS

32 experiments were carried out. In general, 15 g of EOA and commercial acetic anhydride were added to a three-necked round-bottom flask. Then, 30% H₂O₂ was added drop by drop (molar ratio acetic anhydride/30% H₂O₂, 3:2, 3:3 or 3:4). The mixture was stirred and heated at 40 or 50 °C for 5 or 7 hours after the complete addition of 30% H₂O₂. After completion of the reaction, the mixture was transferred to a separatory funnel. Three

washes were carried out with 25 mL of water and two washes with 25 mL of 0.1 M NaHCO₃. The organic phase was dried with MgSO₄ and vacuum filtered to obtain epoxide oleic acid esters (EEOA).

For larger quantity production, a molar ratio of acetic anhydride/ H₂O₂ 30% of 3:2 was used, 40 °C temperature and 7 hours of reaction using 900 g of EOA, 1.9 kg of acetic anhydride and 1.344 kg of H₂O₂ 30 %.

EEOA OXIRANE RING OPENING REACTIONS

A total of 10 g of EEOA and water or alcohol (in different molar ratios) were added to a 250 mL three-neck round-bottom flask coupled to a reflux system. Then the Fe₂(SO₄)₃ catalyst was added (3 or 5% by weight in relation to EEOA). The mixture was kept under stirring and heated for 2 hours, in a silicone bath, at temperatures of 80 °C using Methanol and ethanol, 90 °C with propanol and 100 °C for water.

After completion of the reaction, the mixture was transferred to a separatory funnel. Three washes were carried out with 25 mL of water and two washes with 25 mL of 0.1 M NaHCO₃. The organic phase was dried with MgSO₄, vacuum filtered and placed in a rotary evaporator coupled to a vacuum pump, to remove excess alcohols that were not removed in the washing process.

These reactions produced hydroxylated oleic acid esters (EHOA), named EHOA-1 EHOA-2, EHOA-3 and EHOA-4 when water, methanol, ethanol and propanol were used, respectively, in the process of opening the oxirane ring.

EHOA ACETYLATION REACTIONS

100 g of EHOA and 12 mL of pyridine were added to a 250 mL three-necked round-bottom flask. 16 mL of acetic anhydride was added dropwise into the mixture under stirring. The

reactions were carried out under heating at 80°C and stirring for 2 hours. For EHOA-1, a larger amount of acetic anhydride (32 mL) was used because there are two hydroxyls. After completion of the reaction, ice cubes were added and the mixture was transferred to a separation funnel. Three washes were carried out with 25 mL of water and two washes with 25 mL of 0.1 M NaHCO₃. The organic phase was dried with MgSO₄, vacuum filtered and placed in a rotary evaporator coupled to a vacuum pump, to remove excess acetic anhydride and acetic acid that were not removed in the washing process.

These reactions produced esters of acetylated oleic acids (EAOA), named EAOA-5 EAOA-6, EAOA-7 and EAOA-8 when water, methanol, ethanol and propanol were used, respectively, in the process of opening the oxirane ring.

RESULTS

CHARACTERIZATION OF FUSEL OIL

The results of gas chromatography analyzes indicated the presence of five alcohols in the composition of the fusel oil. Isoamyl alcohols (79.6%) and isobutyl alcohols (12%) were the majority. The other three alcohols were propanol (2.8%), 2-methyl-1-butanol (1.9%) and ethanol (1.7%). These results are similar to those found in the literature, which indicated the preponderance of isoamyl and isobutyl alcohols in fusel oil [13].

After characterizing the fusel oil, it was possible to obtain an average molar mass of 84.59 g/mol for the fusel oil, based on the weighted averages of the molar masses of the alcohols present in the mixture.

REACTIONS CARRIED OUT TO OBTAIN BIOLUBRICANT POTENTIALS

Figure 1 shows the reactions involved in obtaining the compounds studied in this work. The first reaction consisted of the esterification of oleic acid (OA) with fusel oil to produce oleic acid ester (EOA). Subsequently, the EOA epoxidation reaction was carried out to obtain the epoxidized oleic acid ester (EEOA). Next, the oxirane rings of EEOA were hydrolyzed with different alcohols to obtain hydrolyzed oleic acid esters (EHOA). Finally, acetylation of the EHOA hydroxyls was carried out to obtain acetylated oleic acid esters (EAOA).

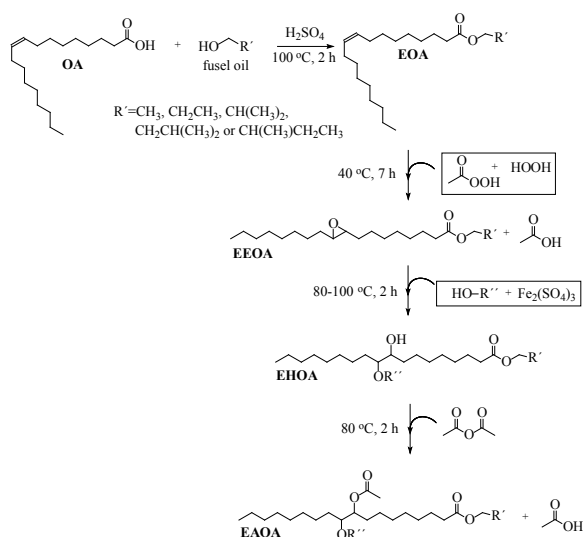


Figure 1. Reactions carried out to obtain the EOA, EEOA, EHOAs ($R''=H$, **1**; $R''=CH_3$, **2**; $R''=CH_2CH_3$, **3** e $R''=CH_2CH_2CH_3$, **4**) and of EAOAs ($R''=COCH_3$, **5**; $R''=CH_3$, **6**; $R''=CH_2CH_3$, **7** e $R''=CH_2CH_2CH_3$, **8**).

THE OA ESTERIFICATION

Through the results presented in Table 1 it can be seen that the most important variables were the amount of catalyst and temperature. The higher the values for these variables, the better the conversions to OAE. For example, analyzing experiments 5 and 6 it can be seen that increasing the amount of catalyst from 1 to 3% increases the conversion from 73 to

92% using APTS and from 82 to 89% using H_2SO_4 concentrated.

Analyzing experiments 2 and 6, despite the amount of catalyst being the same (3%), there was an increase in conversion, increasing the temperature from 80 to 100 oC, from 75 to 92% using APTS and from 85 to 89% using H_2SO_4 .

Experiment	% of catalyst	OA/fusel oil molar ratio	% Conversion with APTS	% Conversion with H_2SO_4
1	1	1:3	50 ^a	64 ^a
2	3	1:3	75 ^a	85 ^a
3	1	1:6	48 ^a	61 ^a
4	3	1:6	64 ^a	76 ^a
5	1	1:3	73 ^b	82 ^b
6	3	1:3	92 ^b	89 ^b
7	1	1:6	65 ^b	74 ^b
8	3	1:6	82 ^b	89 ^b
9	1	1:3	67 ^c	70 ^c
10	3	1:3	85 ^c	87 ^c
11	1	1:6	58 ^c	73 ^c
12	3	1:6	76 ^c	83 ^c
13	1	1:3	79 ^d	79 ^d
14	3	1:3	91 ^d	93 ^d
15	1	1:6	69 ^d	82 ^d
16	3	1:6	88 ^d	91 ^d

Table 1. Reaction conditions evaluated to obtain the % conversion of EOA from the reaction of OA and fusel oil.

^a 1 hour and 80 °C, ^b 1 hour and 100 °C, ^c 2 hours and 80 °C, ^d 2 hours and 100 °C.

When analyzing the effect of the molar ratio, it was observed that increasing the molar ratio generally decreases the conversion to OAE. For example, analyzing experiments 14 and 16, increasing the molar ratio from 1:3 to 1:6 decreases the conversion to EOA from 91 to 88% using APTS and from 93 to 91% using concentrated H_2SO_4 .

The best reaction conditions found using APTS and H_2SO_4 were those presented in experiments 6 and 14, respectively. Both catalysts provided excellent results. The

reaction conditions of experiment 14, using H_2SO_4 as catalyst, were used for the production of EOA and the next compounds (Figure 1).

EOA EPOXIDATION

Table 2 presents the results for the in-situ epoxidation reactions of EOA to produce EEOA. The lowest results for I.I. were found under the conditions of experiments 2 (5h and 50 oC) and 5 (7h and 40 oC) indicating that in these cases the double bonds were reduced to close to zero.

The best results from %O.O. were found in experiments 1 (5h and 40 oC) and 6 (7h and 40 oC). These experiments provided 8.42 and 9.64%. These results indicate that reactions at 40 oC favor the formation of oxirane rings more than at temperatures of 50 oC. They show that at higher temperatures, there is a reduction in the saturations present in the EOA, however, they generate a reduction in the %O.O. values, that is, they cause an early opening of the oxirane rings. This can be observed, for example, in experiment 1 where the values of %O.O. reduce from 8.42 to 1.19% by changing the temperature from 40 to 50 oC [14].

Therefore, the reaction conditions that provided good I.I. and %O were experiments 4 (7h and 40 oC) and 5 (7h and 40 oC) with molar ratios of acetic anhydride: 30% H_2O_2 of 3:2 and 3:3, respectively (Table 2).

The result of %O.O. to be considered effective it must be greater than 6.3% [15]. Thus, experiment 4 (7h and 40 oC) was defined for the production of EEOA.

OPENING OF THE EEOA OXIRANE RING AND ACETYLATION OF HYDROXYLS

The oxirane ring opening reactions were carried out between EEOA with water, methanol, ethanol or propanol using the $Fe_2(SO_4)_3$ how to catalyze to produce the

hydroxylated oleic acid esters EHOA-1, EHOA-2, EHOA-3, and EHOA-4 (Figure 1).

In general, all reactions presented very low values of %O.O. (Table 3) indicating that the oxirane rings were broken. Increasing the amount of catalyst: $Fe_2(SO_4)_3$ of the alcohol: EEOA molar ratio did not indicate an improvement in results.

Experiment	Alcohol	Alcohol molar ratio: EOAE	% O.O.
1	Methanol	1:3	0,31 ± 0,02 ^a
2	Methanol	1:3	0,37 ± 0,02 ^b
3	Ethanol	1:3	0,23 ± 0,01 ^a
4	Ethanol	1:3	0,19 ± 0,05 ^b
5	Propanol	1:3	0,15 ± 0,01 ^c
6	Propanol	1:3	0,15 ± 0,02 ^d
7	Methanol	1:6	0,23 ± 0,02 ^a
8	Methanol	1:6	0,24 ± 0,01 ^b
9	Ethanol	1:6	0,36 ± 0,03 ^a
10	Ethanol	1:6	0,30 ± 0,01 ^b
11	Propanol	1:6	0,13 ± 0,03 ^c
12	Propanol	1:6	0,15 ± 0,10 ^d
13	Water	1:6	0,29 ± 0,01 ^e
14	Water	1:9	0,33 ± 0,04 ^e

^a 3% of $Fe_2(SO_4)_3$ at 80 °C, ^b 5% of $Fe_2(SO_4)_3$ at 80 °C, ^c 3% of $Fe_2(SO_4)_3$ at 90 °C, ^d 5% of $Fe_2(SO_4)_3$ at 90 °C and ^e 5% of $Fe_2(SO_4)_3$ at 100 °C.

Table 3. Reaction conditions evaluated using % O.O., to obtain the EHOA compounds (1-4).

Acetylation of the hydroxyls of EHOA-1, EHOA-2, EHOA-3, and EHOA-4 produced the acetylated oleic acid esters EAOA-5, EAOA-6, EAOA-7, and EAOA-8 (Figure 1).

PHYSICAL-CHEMICAL ANALYSIS OF OLEIC ACID (OA) AND PRODUCED COMPOUNDS

The results of the physicochemical analyzes of OA, EOA and EEOA are presented in Table 4.

Experiment	Acetic anhydride molar ratio: H ₂ O ₂ 30%	I.I.	I.I.	% O.O.	% O.O.
1	3:2	19,69 ± 0,31 ^a	0,97 ± 0,06 ^c	8,42 ± 0,01 ^a	1,19 ± 0,02 ^c
2	3:3	3,90 ± 0,45 ^a	0,01 ± 0,04 ^c	6,50 ± 0,03 ^a	5,80 ± 0,01 ^c
3	3:4	4,81 ± 0,02 ^a	5,49 ± 0,04 ^c	7,42 ± 0,01 ^a	7,77 ± 0,01 ^c
4	3:2	0,37 ± 0, 01 ^b	9,27 ± 0,10 ^d	8,22 ± 0,02 ^b	0,82 ± 0,05 ^d
5	3:3	0,01 ± 0,09 ^b	6,58 ± 0,08 ^d	7,54 ± 0,01 ^b	4,60 ± 0,22 ^d
6	3:4	4,65 ± 0,08 ^b	19,52 ± 0,27 ^d	9,64 ± 0,02 ^b	4,00 ± 0,01 ^d

Table 2. Reaction conditions evaluated to obtain EEOA from the EOA epoxidation reaction with acetic anhydride/30% H₂O₂.

^a 5 hours at 40 °C, ^b 7 hours at 40 °C, ^c 5 hours at 50 °C and ^d 7 hours at 50 °C.

Analytics	OA	EOA	EEOA
Acidity level ^a	183,00±0,01	12,00±0,87	---
I.I.	109,83±0,65	98,64±0,04	9,37±0,02
Moisture Content ^b	0,07±0,10	0,09±0,00	0,24±0,01
Relative density ^c	0,897±0,001	0,988±0,001	0,9913±0,001
% O.O. ^d	---	---	8,28±0,16
Kinematic viscosity ^e	19,36±0,87	7,18±0,96	11,27±0,96
Kinematic viscosity ^f	6,06±0,35	2,57±0,70	3,06±0,60
Viscosity Index	299	236	135

^a mg KOHg⁻¹, ^b in % H₂O, ^c at 20 °C (g.mL⁻¹), ^d in percentage, ^e at 40 °C em mm².s⁻¹ and ^f at 100 °C in mm².s⁻¹.

Table 4 - Physicochemical analyzes of OA, EOA and EEOA.

The acid value value of OA was 183 mg KOHg-1. The OA esterification reaction with fusel oil generated EOA with a significant decrease in the acid number to 12 mg KOHg-1 (Table 4). These results show that the percentage of OA converted into OAE was 93%.

Analyzing the I.I. values, it was observed that there was a slight decrease in the OA value for the EOA, going from 109.83 mg I2.g-1 to 98.64 mg I2.g-1. The value of the I.I. for EEOA it was much lower (9.37 mg I2.g-1) than that of EOA (98.64 mg I2.g-1), which indicates that the amount of double bonds decreased

due to the formation of oxirane rings.

This observation can be confirmed by analyzing the %O.O. which presented a value of 8.28 (Table 4) for EEOA, which is within the expected range for efficient epoxidation reactions [15]. The %O.O. of EHOA compounds 1-4 obtained after epoxide ring opening were very low (Table 5), indicating that ring cleavage in the epoxide was satisfactory.

The density values changed, going from 0.897 g.mL⁻¹ for OA to 0.988 g.mL⁻¹ for EOA, reaching 0.9913 g.mL⁻¹ for EEOA (Table 4), indicating that the increase in the chain carbon dioxide of the compounds, changes the packaging of the molecules and, therefore, the mass of the product in relation to its volume.

Comparing the density of EEOA with compounds EHOA 1-4, the greatest increase occurred for compound EHOA-1 (0.9930 g.mL⁻¹) followed by compound EHOA-3 (0.9923 g.mL⁻¹). Compounds EHOA-2 (0.9921 g.mL⁻¹) and EHOA-4 (0.9918 g.mL⁻¹) presented density values similar to EEOA (Table 5). For the acetylated compounds (Table 6), the density values had a slight increase, where the EAOA-5 compound presented the highest value (0,9940 g.mL⁻¹).

Analytcs	EHOA-1	EHOA-2	EHOA-3	EHOA-4
Moisture Content ^a	0,22 ± 0,02	0,19 ± 0,02	0,18 ± 0,02	0,07 ± 0,01
Relative density ^b	0,9930 ± 0,0001	0,9921 ± 0,001	0,9926 ± 0,0001	0,9918 ± 0,0001
%O.O. ^c	0,08 ± 0,03	0,08 ± 0,06	0,08 ± 0,01	0,08 ± 0,04
Kinematic viscosity ^d	52,78 ± 0,91	17,69 ± 0,72	22,39 ± 0,81	19,39 ± 1,02
Kinematic viscosity ^e	11,20 ± 0,88	3,80 ± 0,20	6,11 ± 0,14	5,35 ± 0,60
Viscosity Index	212	105	246	237

^a in % H₂O, ^b at 20 °C (g.mL⁻¹), ^c in percentage, ^d 40 °C in mm².s⁻¹ and ^e 100 °C in mm².s⁻¹.

Table 5. Physicochemical analyzes of HAOE (1-4).

For kinematic viscosity values, the viscosity index was high in all cases (Tables 5 and 6), above 100. These values indicate that the effect of temperature on the flow of these compounds is not as pronounced [16,17].

The kinematic viscosity values at 40 oC were higher for the EHOA-1 compounds (52,78 mm².s⁻¹, Table 5) and EHOA-5 (46,83 mm².s⁻¹, Table 6). The other compounds in Tables 5 and 6 presented intermediate values. The EOA and EEOA compounds presented low values (7,18 mm².s⁻¹ and 11,27 mm².s⁻¹, Table 4).

The kinematic viscosity values at 100 oC were lower than those at 40 oC, as expected. Again, the highest values were for the EHOA-1 (11,20 mm².s⁻¹, Table 5) and EAOA-1 (11,08 mm².s⁻¹, Table 6). The other compounds in Tables 5 and 6 presented intermediate values and the EOA and EEOA compounds presented low values. (2,57 mm².s⁻¹ and 3,06 mm².s⁻¹, Table 4).

The higher value of kinematic viscosity at 40 and 100 oC for EHOA-1 in relation to compounds EHOA-2 to 4 demonstrates that the type of branching of the compound chain can change its viscosity, the presence of hydroxyls in a molecule increases the viscosity due to intermolecular hydrogen bonds [18].

Analytcs	EAOA-5	EAOA-6	EAOA-7	EAOA-8
Moisture Content ^a	0,05 ± 0,01	0,07 ± 0,04	0,06 ± 0,03	0,04 ± 0,03
Relative density ^b	0,9940 ± 0,0002	0,9929 ± 0,0001	0,9936 ± 0,0001	0,9926 ± 0,0001
Kinematic viscosity ^c	46,83 ± 0,19	18,82 ± 0,96	22,40 ± 2,14	18,89 ± 0,76
Kinematic viscosity ^d	11,08 ± 0,85	5,25 ± 0,45	5,93 ± 0,70	5,42 ± 1,37
Viscosity Index	239	239	233	254

^a in % H₂O, ^b at 20 °C (g.mL⁻¹), ^c at 40 °C in mm².s⁻¹ and ^d at 100 °C in mm².s⁻¹.

Table 6. Physicochemical analyzes of EAOA (5-8).

The viscosity index values were higher for compounds EAOA-8 (254, Table 6) and EHOA-3 (246, Table 5). The compounds EOA, EHOA-4, EAOA-6, EAOA-7 and EAOA-5 presented lower values, but very close to each other (Tables 5 and 6). Compounds EHOA-2 and EHOA-1 had lower values (105 and 212, Table 5).

According to Rudnick [19], the higher the Viscosity Index, the better the lubricant, as it will not present sudden variations in flow with changes in temperature.

According to the ISO 3448:1992 classification, EOA could be classified as ISO GV 7. with the potential to be used for the lubrication of measuring instruments, guide systems, hinges, metal cables and chains. EEOA could be classified as ISO GV 10, with potential for lubrication of friction bearings, slides, levers and chains in the food industry.

EHOA-3 and EAOA-7 could be classified as ISO GV 22. EHOA-4, EAOA-6 and EAOA-8 would also be close to this classification. These compounds have the potential to be used as a lubricant in metalworking machining, such as cutting and molding tools, as they allow high cutting speeds, reduced application of force and longer service life between parts.

Another way to classify lubricating oils by viscosity is through the standards established by the Society of Automotive Engineers (SAE). In the SAE rating, the EHOA-2 would be at the minimum rating for 0 W, the EAOA-6 and EAOA-8 would be at the 10 W rating, the EHOA-3 at 20 W, EHOA-4 and the EAOA-7 at 15 W, the EHOA-1 and EAOA-8 as 30 W. Lubricating oils within the 30 W rating can be used in car crankcases [20].

CONCLUSIONS

With the analysis of the results of this work, it can be concluded that different types of potential biolubricants were produced, with viscosities characteristic of some lubricants with classifications, such as ISO GV7, 10, 22, and SAE 0, 15, 20 and 30W. These results indicate that fusel oil, a by-product of the sugar and alcohol industry, has great potential to be used in the production of biolubricants, and this way, contribute to the table of renewable products that are less harmful to the environment.

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