

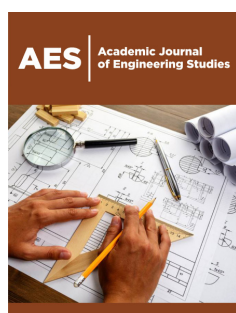
Synthesis of Biodiesel and Biolubricant using Sweet Almond Oil (*Prunus Dulcis*)

Álida Samara Gomes da Silva^{1*}, Dyego dos Santos Souza¹, Dannilo Costa Santos¹, Marcela Ravena Felinto de Souza¹ and José Carlos Oliveira Santos²


¹Laboratory of Biofuels and Environmental Chemistry, Federal University of Campina Grande, Brazil


²Titular Professor, Federal University of Campina Grande, Brazil

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***Corresponding authors:** Álida Samara Gomes da Silva, Laboratory of Biofuels and Environmental Chemistry, Federal University of Campina Grande, Brazil

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Abstract

Air pollution is one of the biggest environmental problems today, intensified by population growth and increased consumption of fossil fuels, which raise pollutant emissions and contribute to global warming. In this context, biofuels and biolubricants emerge as a sustainable alternative, since they are considered carbon-neutral, have gained prominence as biodegradable and low-toxicity substitutes for traditional materials, being produced from raw or modified vegetable oils. In this study, the objective was the production of biodiesel, used as an intermediate in obtaining biolubricants, using sweet almond oil as raw material. The methodology adopted for biodiesel production consisted of transesterification, followed by epoxidation with peracetic acid to obtain biolubricants. The characterization of the samples was carried out considering two distinct routes, methyl and ethyl, for both bioproducts, with these reactions occurring in a basic medium. In the study, biodiesel achieved a yield of 88% via the methyl route and 92% via the ethyl route, while epoxides showed 91.6% and 84.1%, respectively. These products demonstrate potential for reducing environmental impact, although biolubricants still have limitations regarding their application, requiring further studies.

Keywords: Biofuels; Lubricant; Environmental impact; Sustainability

Introduction

The increasing consumption of energy has accelerated the depletion of fossil fuel reserves, such as coal, oil, and natural gas. In this context, there has been a growing interest in the use of renewable and sustainable sources, especially in the form of biomaterials derived from natural resources. These materials present themselves as promising alternatives for the energy transition, contributing to the reduction of greenhouse gas emissions [1]. The production of biofuels from biomass has emerged as a viable strategy to replace, totally or partially, fossil fuels. Although the combustion of these biofuels also releases carbon dioxide, this is partially offset by the absorption of the gas during plant growth, characterizing them as energy sources with a lower net carbon footprint [2-7].

In Brazil, the main liquid biofuels are ethanol, produced from sugarcane, and biodiesel, obtained from vegetable oils, animal fats, or lipid residues [8]. Biodiesel, in particular, stands out as an alternative to fossil diesel, especially in the transport sector, due to its environmental and operational advantages. Studies show that its use can significantly reduce emissions of air pollutants such as carbon monoxide, hydrocarbons, particulate matter, and sulfur dioxide, with average reductions of up to 40% [9]. In addition to biofuels, biolubricants have emerged as sustainable alternatives to petroleum-derived lubricants. These products, generally formulated from raw or chemically modified vegetable oils, exhibit high biodegradability, low toxicity, and performance suitable for industrial applications. Their increasing adoption is associated with both environmental demands and growing awareness of the impacts of conventional products [5-6].

Among the various raw materials available, sweet almond oil, extracted from the species *Prunus dulcis*, stands out for its rich composition of unsaturated fatty acids, which favors its

application in chemical processes such as transesterification and epoxidation. The almond tree, belonging to the Rosaceae family, is widely cultivated in Mediterranean climate regions and has significant economic and nutritional importance. Its kernels have a high content of lipids, proteins, fiber, and bioactive compounds, such as vitamin E, and are widely used in the food, cosmetic, and pharmaceutical industries [10]. In addition to its nutritional value, the almond production chain generates several co-products, such as husks, shells, and processing residues, which have potential for use in different applications. These materials can be used in energy production, the manufacture of composites, the production of antioxidant compounds, and the formulation of low-cost materials, contributing to the full utilization of biomass and the sustainability of the production process [11]. In this context, the present study aims to produce and characterize biodiesels and biolubricants via the methyl and ethyl routes from sweet almond oil, using transesterification and epoxidation reactions.

Materials and Methods

Materials

The refined sweet almond oil was purchased from a local supplier and is produced by a Brazilian company in São Paulo. The refined vegetable oil did not require any prior treatment before the reactions it underwent. The reagents for physicochemical analyses were prepared following specific analytical standards using pure reagents for analysis.

Experimental procedure

Synthesis of biodiesels: To obtain methyl and ethyl biodiesels, the molar mass of sweet almond oil was initially calculated from its experimentally determined saponification index. Knowing this molar mass, the quantities of alcohol and catalyst needed for the reactions were calculated. The transesterification reaction was carried out using an oil/alcohol molar ratio of 1:6 and 0.7% catalyst (oil/catalyst), maintaining the temperature at approximately 45°C for 1 hour is recommended because temperatures above the boiling point of alcohol can accelerate the saponification of glycerides by the alkaline catalyst before complete alcoholysis [12-13].

Following the transesterification reaction, the reaction mixture was transferred to a separatory funnel, allowing the separation of the phases: the upper phase containing the methyl or ethyl ester and the lower phase composed of glycerol, soaps, excess base, and alcohol. After the waiting time, the lower phase was removed and stored in a suitable container. Then, the methyl or ethyl ester (biodiesel) was washed with distilled water and a 0.01 M hydrochloric acid solution. Phenolphthalein was used to verify the efficiency of the acid wash.

Synthesis of biolubricants: The synthesis of biolubricants was carried out through an epoxidation reaction of sweet almond oil esters. In a 250mL round-bottom flask, 100 g of the methyl or ethyl ester obtained from sweet almond oil was added, followed dropwise by 140mL of 15% commercial peracetic acid. The mixture was stirred and heated constantly at 45 °C for 1 hour. As this procedure is exothermic, a container with ice water was placed below the round-bottom flask containing the reaction mixture

to maintain temperature stability. The reaction was carried out using a molar ratio of 1:1.1 ester/peracetic acid [5,14]. After the reaction was complete, the mixture was transferred to a separatory funnel, where the lower phase, corresponding to acetic acid, was removed, and the upper phase was washed twice with 10% sodium bicarbonate until all bubbles were released due to the neutralization reaction. With the purification process complete, the epoxides of the methyl and ethyl esters of sweet almond oil were stored in a suitable container.

Physicochemical characterization

The samples were characterized by appearance, acidity index, iodine index, saponification index, soap content, peroxide index, relative density, ash content, moisture and volatile content, and kinematic viscosity.

The biolubricants obtained from methyl and ethyl esters of sweet almond oil were further characterized by means of the hydroxyl index and oxirane oxygen content. All characterizations were performed in accordance with the techniques of the American oil chemist's society described by researchers in the literature [5] and were performed in triplicate.

Result and Discussion

Synthesis of biodiesels and biolubricants

The synthesis of biodiesel showed a yield of 88% for the methyl route and 92% for the ethyl route, demonstrating greater efficiency of the latter. During the purification process, a loss of approximately 12% of the biodiesel mass was observed, attributed to saponification during the washing stage. Short-chain alcohols are widely used in transesterification, and the choice of alcohol is a determining factor for the process yield. Although the literature frequently points to greater efficiency for the methyl route, due to the ease of phase separation, the results obtained in this study indicated better performance of the ethyl route, even with its recognized greater difficulty in separation [15,16].

In obtaining epoxides (biolubricants), the epoxidation process of esters (biodiesel) resulting from transesterification was used. This process occurs through the reaction of the double bonds (unsaturations) present in triglycerides, which are converted into oxirane rings (epoxide groups), resulting in epoxidized esters as the final product. The substitution of unsaturations by epoxy groups promotes significant improvements in the thermal and oxidative stability of the oil [17], giving the resulting product a high potential for application as a lubricant at high temperatures [18].

The reaction process of the methyl and ethyl routes for obtaining epoxides derived from sweet almond oil used 15% peracetic acid as an oxidizing agent. The yield obtained in this procedure was 91.6% for the methyl route, while the ethyl route showed a yield of 84.1%. Therefore, the reactions of the methyl route are faster and more selective, resulting in a higher yield, while the ethyl routes present greater steric hindrance and lower selectivity, leading to lower yields. Furthermore, methyl esters exhibit greater thermal and oxidative stability, while ethyl esters are more susceptible to secondary reactions, such as oxidation and polymerization, which compromises the yield. The greater solubility of methyl esters

in polar media also favors the homogeneity of the epoxidation reaction, contributing to a more efficient conversion [2].

Physicochemical characterization of biodiesels and biolubricants

The aspect refers to the element evaluated visually, allowing the identification of the presence of impurities, sediments, or even turbidity in the sample, factors relevant to determining the quality and appropriate appearance of a product. These factors may result from the presence of water. If no evidence of contaminants is found, the product is classified as clear and free of impurities. According to the literature [19], this aspect may be related to the molecular characteristics of biodiesel, as well as the handling process during storage. Sweet almond oil presented a clear yellow color, free of visible particles and turbidity, conforming to the standards established by ANVISA (Brazilian National Health Surveillance Agency) for vegetable oils. The esters obtained also met the specifications of ANP (Brazilian National Agency of Petroleum, Natural Gas and Biofuels) for biodiesel, presenting a clear yellow color and absence of impurities, indicating adequate product quality. Regarding biolubricants, methyl epoxide presented characteristics similar to those of the raw material and biodiesel, with a clear color and absence of turbidity. On the other hand, ethyl epoxide presented a cloudy yellow appearance, suggesting the possible presence of impurities or suspended particles [6].

Table 1 presents the results for moisture content and volatile compounds, showing relevant differences between the raw material and the products obtained. Sweet almond oil presented values within the established standards, indicating a low presence of water, a condition favorable to the transesterification process. On the other hand, methyl and ethyl esters presented moisture contents above the recommended limits, indicating the presence of residual water. This factor is undesirable because it can compromise the quality of biodiesel, favoring the formation of soaps, oxidation, and corrosion of metallic components. Furthermore, high moisture content in biofuels and biolubricants can intensify degradation processes, such as microbial growth, formation of solid residues, and wear of metallic surfaces, compromising the efficiency and durability of the systems in which they are applied.

Table 1: Moisture and volatile content of the samples.

Samples	Moisture and Volatiles (%)	Standards/Competent body
Sweet almond oil	0.09	≤0.1/ANVISA
Methyl biodiesel	0.04	0.02/ANP
Ethyl biodiesel	0.07	0.02/ANP
Methyl biolubricant	0.007	Nothing to report
Ethyl biolubricant	0.022	Nothing to report

Esters showed moisture and volatile compound levels above the limits established by the ANP, indicating the presence of residues from the reaction process, such as water and alcohol remaining from the washing stages. These factors may have negatively influenced the subsequent stage of biolubricant production. The presence of contaminants in biodiesel may be associated with both the raw

material and the production process, including compounds such as free glycerin, residual alcohol, catalysts, soaps, and unreacted glycerides [20]. In addition, storage processes can contribute to moisture absorption and oxidative degradation, resulting in the formation of peroxides and carboxylic acids [19]. On the other hand, biolubricants showed lower moisture levels compared to esters and raw material, indicating that the purification process adopted was effective in removing water and improving the quality of the final products [8].

Ash content is directly related to the presence of inorganic residues, such as salts and metallic oxides, which can cause the formation of deposits and abrasive wear in engines, as highlighted by researchers [7]. The results obtained for the raw material, esters and biolubricants allowed us to evaluate the presence of these contaminants throughout the process stages, highlighting the influence of the synthesis and purification procedures on the final quality of the products (Table 2).

Table 2: Ash content of the samples.

Samples	Ash content (%)	Standards / Competent body
Sweet almond oil	0.02	---/ANVISA
Methyl biodiesel	0.006	0.02/ANP
Ethyl biodiesel	0.014	0.02/ANP
Methyl biolubricant	0.13	Nothing to report
Ethyl biolubricant	0.036	Nothing to report

Table 3: Relative density of the samples.

Samples	Density (g/cm ³)	Standards / Competent body
Sweet almond oil	0.956	0.915 - 0.925/ANVISA
Methyl biodiesel	0.937	0.850 - 0.900/ANP
Ethyl biodiesel	0.949	0.850 - 0.900/ANP
Methyl biolubricant	0.94	Nothing to report
Ethyl biolubricant	0.954	Nothing to report

The ash content of the raw material was 0.020%, indicating a low presence of inorganic compounds and adequate quality of the sweet almond oil. For esters, the values obtained were within the established limits, demonstrating the efficiency of the purification process in removing inorganic residues. High ash values are associated with the presence of metallic oxides from catalysts and impurities in the raw material, which can cause abrasive wear and damage to engine components [2]. Biolubricants showed higher levels than esters, especially methyl epoxide (0.13%) and ethyl epoxide (0.036%). These results may be related to the limited washing step and the presence of residues from the reagents used in epoxidation [3]. Regarding density, this property depends on the fatty acid composition and temperature, exhibiting behavior inversely proportional to the thermal increase [20]. The values obtained for the raw material and the synthesized products allowed us to evaluate the structural modifications that occurred throughout the process, with density being an important parameter in the characterization and quality control of biofuels and biolubricants (Table 3).

Sweet almond oil showed a higher density than expected, possibly associated with the presence of impurities. This behavior may influence its application as a raw material, since denser oils tend to have a higher energy content [20]. Methyl and ethyl esters showed densities lower than that of the raw material, but still above the established limits, which may be related to the structure of the esters formed, the degree of unsaturation of the fatty acids, and the presence of residual impurities. Biolubricants showed the highest density values, attributed to the formation of the epoxy group, which increases molecular polarity and intensifies dipole-dipole intermolecular interactions. The values obtained were close to those reported in the literature, indicating consistency of the experimental results.

The acidity index is directly related to lipid degradation, resulting from the hydrolysis of ester bonds, a process favored by the presence of water and catalyzed by enzymes such as lipase, leading to the formation of free fatty acids. This parameter is widely used to assess the state of preservation of oils, being associated with rancidity and the decomposition of glycerides, intensified by factors such as heat and light. In addition, acidity influences important properties such as thermal stability, volatility behavior, and corrosion resistance. In biodiesel production processes, high acidity indices can compromise the efficiency of transesterification by basic catalysis, reducing yield and favoring undesirable reactions such as saponification [21].

The acidity index of sweet almond oil was below the established limit, indicating good quality and adequate state of preservation, enabling its direct use in biodiesel production by basic catalysis (Table 4). The esters obtained also presented values within the required standards, demonstrating the efficiency of the transesterification process and the purification step, in addition to minimizing the occurrence of saponification reactions. On the other hand, the biolubricants presented acidity values higher than those observed for the esters and the raw material, suggesting the presence of free fatty acids or residual water. This increase may be associated with incomplete conversion during epoxidation. High acidity values are undesirable because they can cause corrosive wear on metallic surfaces and compromise product performance [8].

Table 4: Acidity index of the samples.

Samples	Acidity index (mg KOH/g sample)	Standards / Competent body
Sweet almond oil	0,34	≤0.6/ANVISA
Methyl biodiesel	0,34	≤0.5/ANP
Ethyl biodiesel	0,17	≤0.5/ANP
Methyl biolubricant	0,67	Nothing to report
Ethyl biolubricant	1,01	Nothing to report

The iodine value is a measure of the degree of unsaturation of fatty acids present in oils and fats. This parameter is based on the addition reaction of halogens to double bonds, and is widely used in the classification and quality control of these materials [7]. The values obtained for the iodine value in the analyzed samples allowed us to evaluate the level of unsaturation throughout the process steps, as shown in Table 5.

Table 5: Iodine value of the samples.

Samples	Iodine Value (g I ₂ /100 g sample)	Standards/Competent body
Sweet almond oil	118.7	96 - 115/ANVISA
Methyl biodiesel	108.6	Annotate/ANP
Ethyl biodiesel	113.4	Annotate/ANP
Methyl biolubricant	126.7	Nothing to report
Ethyl biolubricant	109.5	Nothing to report

Sweet almond oil showed an iodine value higher than the established limit, indicating a high degree of unsaturation, with a value also higher than that reported in the literature for bitter almond oil. After transesterification, the methyl and ethyl esters showed a reduction in iodine value compared to the raw material, evidencing a decrease in unsaturations and indicating process efficiency. Compared to studies in the literature, the values obtained were lower, suggesting greater conversion of double bonds in this research. For the biolubricants, an increase in iodine value was observed compared to the esters, especially in the methyl route. This behavior may be associated with incomplete epoxidation, maintaining some of the unsaturations, in addition to the contribution of the epoxy rings, which still react during titration. Compared to other studies, the values obtained were higher, indicating lower efficiency in the total conversion of double bonds during epoxidation [8].

The soap content is related to the quantification of compounds formed during the neutralization of the alkaline catalyst and the free fatty acids present in the system. This parameter is important for evaluating the efficiency of the purification process and the presence of undesirable residues in the products [21]. The results obtained for sweet almond oil, esters, and epoxides allowed for the analysis of soap formation throughout the process steps, contributing to the evaluation of the final quality of the synthesized products (Table 6).

Table 6: Soap content of the samples.

Samples	Soap content (ppm of sodium oleate)	Standards/Competent body
Sweet almond oil	0.121	≤10 / ANVISA
Methyl biodiesel	0.426	--- / ANP
Ethyl biodiesel	0.500	--- / ANP
Methyl biolubricant	0.304	Nothing to report
Ethyl biolubricant	0.819	Nothing to report

Sweet almond oil showed a soap content of 0.121 ppm of sodium oleate, in accordance with established limits, indicating a low presence of alkaline residues. Esters showed values higher than the raw material, suggesting the presence of residues from the basic catalyst used in transesterification. Although there are no specific limits established, these values indicate greater alkalinity and a possible influence on product quality. For biolubricants, distinct behavior was observed between the routes: the methyl route showed a reduction in soap content, indicating greater efficiency in the purification step, while the ethyl route showed an increase, suggesting incomplete removal of alkaline residues [20]. The

formation of soaps is undesirable because it reduces conversion to esters, increases catalyst consumption, and hinders separation and purification steps, in addition to favoring the formation of emulsions and increasing the viscosity of the system.

The saponification index is an important parameter for characterizing oils and fats, being defined as the amount of potassium hydroxide required to saponify the fatty acids present in 1 g of the sample. This index is inversely related to the average molecular weight of the fatty acids, allowing the evaluation of the material's composition [21]. The values obtained for sweet almond oil, esters, and epoxides allowed for the analysis of the structural modifications that occurred throughout the process, contributing to the characterization of the products and the evaluation of their quality (Table 7).

Table 7: Saponification index of the samples.

Samples	Saponification index (mg KOH/g sample)	Standards/Competent body
Sweet almond oil	166.6	189 - 195 / ANVISA
Methyl biodiesel	121.7	--- / ANP
Ethyl biodiesel	110.0	--- / ANP
Methyl biolubricant	14.02	Nothing to report
Ethyl biolubricant	22.44	Nothing to report

Sweet almond oil showed a saponification index below the established range, indicating possible variations in the fatty acid composition or the presence of non-saponifiable compounds. After transesterification, the esters showed a significant reduction in this parameter compared to the raw material, suggesting a decrease in impurities and structural changes resulting from the process. The biolubricants showed even lower values, evidencing a further reduction of compounds susceptible to saponification and indicating greater purity of the products obtained. Compared with literature data, the results demonstrate greater efficiency of the process employed in removing contaminants and modifying the chemical structure of the samples [20].

Table 8: Peroxide index of the samples.

Samples	Peroxide index (mEq/kg)	Standards / Competent body
Sweet almond oil	0.018	≤10 / ANVISA
Methyl biodiesel	0.005	--- / ANP
Ethyl biodiesel	0.015	--- / ANP
Methyl biolubricant	0.078	Nothing to report
Ethyl biolubricant	0.074	Nothing to report

The peroxide index is a parameter used to evaluate the degree of oxidation of oils and fats, indicating deterioration processes that affect characteristics such as odor and taste. This method is based on the reaction of peroxides with iodide ions, promoting the release of iodine, which is subsequently titrated with sodium thiosulfate. The amount of titrant consumed is proportional to the peroxide content present in the sample, with the result expressed in milliequivalents of active oxygen per unit mass [7]. The values obtained for this parameter allowed us to evaluate the oxidation

level of the samples throughout the process, as shown in Table 8.

Sweet almond oil showed a peroxide index within the established limits, indicating low oxidation and good stability, possibly associated with adequate extraction and storage conditions. For the esters, although there is no specific limit, the values obtained indicated a higher presence of peroxides compared to the raw material, suggesting greater susceptibility to oxidation. The biolubricants showed reduced peroxide values when compared to literature data, evidencing better oxidative stability of the epoxides obtained from sweet almond oil [3].

Viscosity is an essential parameter for lubricant performance, as it is directly related to resistance to flow and efficiency in lubricating mechanical systems. Inadequate values can compromise the functioning of components, favoring wear, injection failures, and the accumulation of residues. This parameter depends on the dynamic viscosity and density of the fluid, and is used to evaluate the applicability of oils and derivatives under different operating conditions [3]. The results obtained for sweet almond oil, esters, and biolubricants allowed for a comparison of the rheological behavior of the samples, as presented in Table 9.

Table 9: Kinematic viscosity at 40°C of the samples.

Samples	Kinematic viscosity (mm ² /S)	Standards / Competent body
Sweet almond oil	63.2	--- / ANVISA
Methyl biodiesel	4.75	3.0 - 6.0 / ANP
Ethyl biodiesel	4.63	3.0 - 6.0 / ANP
Methyl biolubricant	8.32	Nothing to report
Ethyl biolubricant	32.28	Nothing to report

The raw material showed higher viscosity than other vegetable oils described in the literature, highlighting characteristics specific to the composition of sweet almond oil. After transesterification, the biodiesels showed a significant reduction in viscosity, with values within established standards, indicating process efficiency and better suitability for fuel application. On the other hand, the biolubricants showed increased viscosity compared to the esters, a behavior attributed to the presence of unsaturations, residual glycerides, and hydroxyl groups formed during the epoxidation process. These factors favor intermolecular interactions, such as hydrogen bonds, hindering flow. Despite this, higher viscosity values can be advantageous for lubricant applications, as they contribute to greater thermal stability, better lubricity, and reduced mechanical wear, although they may limit performance under conditions of wide temperature variation. The results obtained were compatible with data from the literature, indicating experimental consistency [6].

The hydroxyl index is a parameter that quantifies the amount of hydroxyl groups present in the sample, being especially relevant for the characterization of oil derivatives, such as epoxidized biolubricants. Its determination is based on the esterification reaction with acetic anhydride, followed by titration of the excess reagent, allowing the calculation of the hydroxyl content from the difference between the blank and the sample [3]. The values

obtained for this index make it possible to evaluate the degree of chemical modification of the epoxides formed, as shown in Table 10.

Table 10: Hydroxyl Index of Biolubricants.

Samples	Hydroxyl Index (mg KOH/ g oil)	Standards / Competent body
Methyl biolubricant	13.5	Nothing to report
Ethyl biolubricant	17.8	Nothing to report

The formation of epoxides can be confirmed by the reduction of iodine and oxirane indices, associated with an increase in the hydroxyl index, indicating the occurrence of epoxy ring opening and the formation of hydroxyl groups. The results obtained demonstrated that both biolubricants underwent hydrolysis of the oxirane ring, with this effect being more pronounced in the ethyl route, which showed a higher degree of hydrolysis. Compared to the literature, the values obtained for the methyl route were lower, while the ethyl route showed higher values, highlighting differences in reaction behavior. This result may be related to the high concentration of peracetic acid used in the epoxidation, favoring the formation of hydroxyls and, consequently, byproducts such as acetic acid [3].

The oxiran oxygen content is a physicochemical parameter for biolubricants, in which the percentages of oxiran oxygen found in the sample are measured [21]. Table 11 below shows the results obtained for the epoxides of the aforementioned routes. The epoxidized biolubricants showed similar oxirane oxygen values for both routes, indicating the formation of epoxy rings from the addition of oxygen to the double bonds of fatty acids. The values obtained are within the recommended limit to ensure the effectiveness of the process, suggesting that epoxidation occurred adequately. Compared to data from the literature, higher values are observed in other studies, indicating a greater degree of epoxidation, although the results obtained in this work are satisfactory for the formation of biolubricants [21].

Table 11: Oxirane Oxygen Content of Biolubricants.

Samples	Oxirane Oxygen (%)	Standards / Competent body
Methyl biolubricant	2.58	Nothing to report
Ethyl biolubricant	2.78	Nothing to report

Conclusion

This study, which used sweet almond oil as a basis for the production of biolubricants, employing transesterification as an intermediate step to form biodiesel, demonstrates the potential for broad applications of these biolubricants, provided that specific tests are conducted for each application. It is noteworthy that sweet almond oil shows the greatest potential for application in the cosmetic and pharmaceutical sectors, although its viability depends on complementary analyses, such as toxicity tests and other evaluations that enable its use in the formulation of cosmetic products. The reaction steps used to obtain the oil proved satisfactory. The transesterification reaction, for example, achieved good ester conversions, reaching 88% for the methyl route and

92% for the ethyl route. These results are in accordance with the parameters established by regulatory agencies.

However, some indices showed high values, mainly in the epoxides when compared to the esters, highlighting the acidity, iodine content, and kinematic viscosity, which proved inadequate for lubrication purposes. In this sense, it becomes necessary to employ additional chemical modifications to adapt these products for use as biolubricants, allowing for new reaction steps, such as a different type of catalyst, and new purification processes, taking care not to reduce the sample yield. The high iodine levels in the esters indicate the need for another reaction step, while the high acidity content in the epoxides makes their applicability in equipment unfeasible. The epoxidation reaction, in turn, was efficient, showing yields of 91.6% for the methyl epoxide and 84.1% for the ethyl epoxide. It should also be noted that the increase in viscosity is related to the presence of hydroxyl molecules in the epoxidized samples. However, the high cost of the raw material, while allowing for the production of biodiesel, makes its large-scale production economically unfeasible. But this raw material also allows for the production of biolubricants for different applications. This study proved effective, demonstrating a new possible application for sweet almond oil, which is already widely used in different areas. The research also highlighted its potential for the production of biofuels, presenting satisfactory results and reinforcing its versatility as a raw material.

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