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MISO – Motion in the Science Ocean Project Based Learning Using Mobile Devices – Synthesis of Biodiesel by Homogeneous or Heterogeneous Catalysis

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Abstract: Six European schools from very different parts of Europe (Agrupamento de Escolas da Maia - Portugal, Anne-Frank-Schule Bargteheide – Germany, Özel Bilkent Lisesi – Turkey, Sandsli VGS – Norway, Institut Pau Vila – Spain and Liceul Teoretic Iancu C. Vissarion - Romenia, have developed an Erasmus+ project for Exchange of Good Practices, MISO, in order to increase student interest in science, foster the use of ICT with different applications for experiments, share experiences between teachers and students and collaboratively examined new approaches to teaching and learning of science (E-learning Tools). In recent years the automobile industry has been looking for alternatives to reduce the consumption of fossil fuels. One of the solutions can be vehicles containing a normal internal combustion engine that uses the biodiesel as combustion This research study used Project Based Learning as pedagogical methodology, through the use of mobile devices and was done by students of Chemistry of 12th grade. Students aimed to synthesize Biodiesel by transesterification of refined soybean oil with methanol by basic catalysis using laboratory materials. They studied the effect of the amount of catalyst on the synthesis of biodiesel, they evaluated the acidity index of

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biodiesel and they also studied the miscibility of the produts obtained with ethanol and hexane. FT-IR was used to monitor the reaction. Mobile devices were used during the project to take photos and to record videos of the experimental procedure. Different type of APPS (Magisto, Animoto, Popplet and Scapple) were used to report the results. This work showed that transesterification is a simple, easy and economically accessible method of synthesizing biodiesel. This project enabled students to deepen and apply their previous and new learning, develop their critical thinking, their creativity and communication, increase their autonomy, organizational management of work, interpersonal relations and motivation for the learning.

Keywords: Project based learning, Mobile devices, Biodiesel

Introduction

Bearing in mind the priorities established by the European Horizon Strategy 2020 and more specifically the idea of Europe in a changing world, six European schools from very different parts of Europe (Agrupamento de Escolas da Maia - Portugal, Anne-Frank-Schule Bargteheide – Germany, Özel Bilkent Lisesi – Turkey, Sandsli VGS – Norway, Institut Pau Vila – Spain and Liceul Teoretic Iancu C. Vissarion - Romenia, have developed an Erasmus + project for Exchange of Good Practices, MISO – Motion in the Science Ocean.Such a project intended to increase student interest in science, foster the use of ICT with different applications for experiments, share experiences between teachers and students who collaboratively examined new approaches to teaching and learning of science (E-learning Tools).

The potential of multimedia applications, adapted to the contexts of teaching and learning, can be seen as important teaching tools in the different dynamics of the classroom (Lencastre, Bento & Magalhães, 2016). In addition, there is a great popularity and familiarity with mobile devices present features which will enhance potential users (Kukulska-Hulme, 2012). The rise of these resources is a fact that can be explored in the educational process, using the pedagogical model called Mobile Learning (Lencastre et al, 2016; Kukulska-Hulme, 2012). Mobile devices are necessary tools that can be used to facilitate learning. We need them to supplement schools resources, to extend learning process outside the class walls, to prepare students for working life after their graduation (Moraru P. et al, 2018).

Project Based Learning allows students to work independently to build their own knowledge in a dynamic and active learning process. Under the scope of the Erasmus+ project, MISO, 12th grade Chemistry students, working in partnership with the Department of Chemistry and Biochemistry of the University of Porto, used the Project Based Learning methodology to synthesize biodiesel by homogeneous and heterogeneous catalysis.

Biodiesel as a sustainable alternative to use on automobile industry

Since traditional fossil fuel resources are limited and greenhouse gas emissions are becoming a great concern, the research is now being directed towards the use of alternative renewable fuels that are capable of fulfilling an increasing energy demand (Ma & Hanna, 1999). Biodisel is a sustainable alternative to use on automobile industry for many reasons: it is made from renewable resources (namely from vegetable oils or animal fat); it is also environmentally friendly (lower dependence on foreign crude oil; limitation on greenhouse gas emissions because of the closed CO_2 cycle; lower combustion emission profile, especially SOx (Dorado et al., 2003); potential improvement of rural economies; low toxicity; biodegradability) and it is technically eficient (it can be used without engine modifications; it has a good engine performance; improved combustion because of its oxygen content; ability to be blended in any proportion with regular petroleum-based diesel fuel) (Jun Yang et al. 2013).

Characteristics of Biodiesel

The biosidesel has many important characteristics: high oiliness; yellow colour; high boiling point; slightly flammable; it is neither toxic nor corrosive when purified, but it should not be ingested, nor inhaled. It can be used in diesel engines and in oil heaters; it´s composed by molecules with long carbon chains and hydrogen atoms and, at the end of the chain, it contains an ester functional group (-COOR). Finally, it is obtained from triglycerides, which exist in vegetable oils or animal fat.

Biodiesel Synthesis

The most common and most used reaction for biodiesel production is transesterification, in which the triglyceride molecules react with a small chain alcohol (methanol or ethanol), which is in excess in the reaction, forming biodiesel (methyl or ethyl esters) and a by-product (glycerol). Basicly it is a method of converting primary fats (triglycerides) to esters of alcohols (methyl or ethyl esters). These reactions are often catalyzed by the addition of a catalyst. The catalyst is a substance that aims to accelerate the speed of a chemical reaction, without interfering with the final reaction result (so that the mass of the catalyst is not consumed during the process, with the possibility of recovering it at the end of the reaction). If the catalyst is in the same physical state as the reactants, the catalysis is called homogeneous. If the catalyst is in a different physical state from that of the reactants, it is called heterogeneous catalysis. Heterogeneous catalysis was invented to replace the homogeneous catalysis in order to overcame some disadvantages associated to the biodiesel production through this method. Each of the previous catalysis may use both acid and base catalyst. The base catalysts most used in homogeneous catalysis are sodium hydroxide (NaOH) and potassium hydroxide (KOH), whilst the most used acid catalyst is sulfuric acid (H_2SO_4). The base catalyst most used in homogeneous catalysis are barium oxide (BaO) and calcium oxide (CaO), whilst the most used acid catalyst are Amberlyst 15 and NAFION (figure 1).

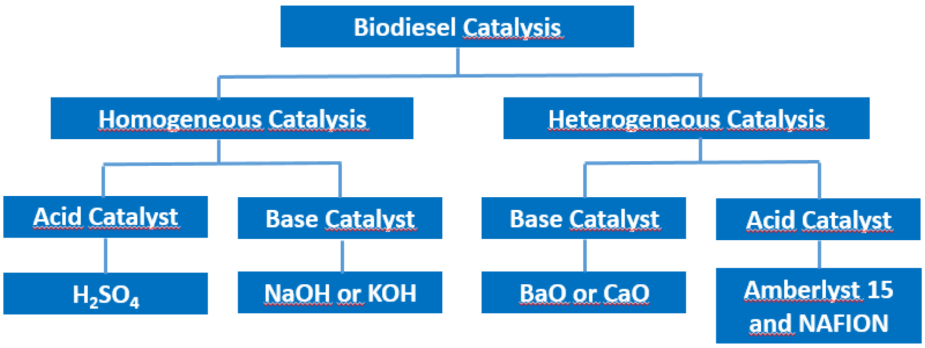

Figure 1. Catalysts used for biodiesel production

Methodology

During this project teachers used Project Based Learning as pedagogical methodology. Students had to design and develop an investigative path to answer the problem question: How to produce a Biodiesel from used soy oil? The realization of this project went through the following phases:
- Used soybean cooking oils, at home and / or at the school canteen collection in appropriate containers,
- Method research to obtain biodiesel;
- Identification of the different stages of the process, with a sequential diagram of the operations to be performed, using the mind map Popplet and Scapple;
- Identification of the chemical transformations involved and writing out the respective chemical equations;
- Laboratory work planning, including material, equipment, reagents and safety issues;
- Accomplishment of the laboratory work, to obtain the final product.
- Reuse of oils

Homogeneous Catalysis

In the homogeneous catalysis, biodiesel was synthesized from the transesterification of filtered soy oil with methanol catalyzed by potassium hydroxide. Different amounts of catalyst (KOH) were used: 0,5% (m/m) KOH, 1% (m/m) KOH and 5% (m/m) KOH. The experiment was performed at room temperature. The transesterification reaction lasted 1 hour (Rinaldi R. et al., 2007).

Methanol and KOH was added to an Erlenmeyer flask. Its top was covered with aluminum foil, and the stirring was started. After the complete dissolution of KOH, it was added the soy oil. The Erlenmeyer flask was, covered again and shake for 30 minutes. After that, the content of the Erlenmeyer flask was transferred to a decanter ampoule and the phase separation was followed for 1 hour (figure 2) (Rinaldi R. et al., 2007).

Figure 2. Homogeneous Catalysis procedure

Heterogeneous Catalysis

In the heterogeneous catalysis, Biodiesel was synthesized at 117 ºC, from the transesterification of filtered soy oil with methanol catalyzed by Amberlyst tm 45, a macroporous sulfonic acid polymer designed for use in high-temperature heterogeneous catalysis. A research group of FCUP/REQUINTE works in the development of new catalysts for the production of biofuels and bio-oils and provided one of its catalysts for these experience. A magnetic stirrer was put into a round bottomed flask. Then, the catalyst was added to it and after mixing the soy oil with the methanol, it was transferred to the flask. The mixture was placed in a preheated silicone bath at 117 degrees, the water was opened from the condensation system and the reaction occurred for about 2 hours. During those 2 hours, samples were taken to control the change of reagents into Biodiesel. At the end, the Biodiesel was decanted to make sure that no residue is left and the catalyst was recovered and cleaned with ethanol (figure 3).

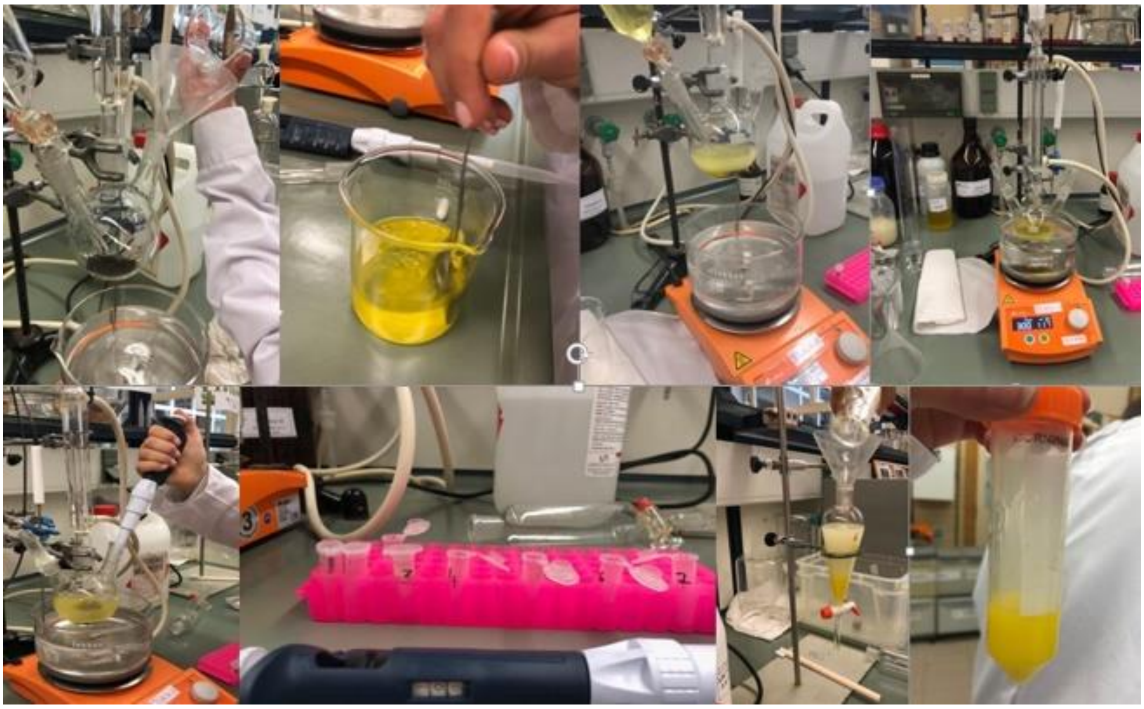

Figure 3. Heterogeneous Catalysis procedure

Determination of Acidity index for both catalysis

The acidity of the biodiesel obtained in both catalysis was also analyzed by acid-base titration (figure 4). It was added isopropanol to the biodiesel and then the mixture was titrated with KOH using phenolphthalein as indicator (Pinheiro I. et al., 2009).

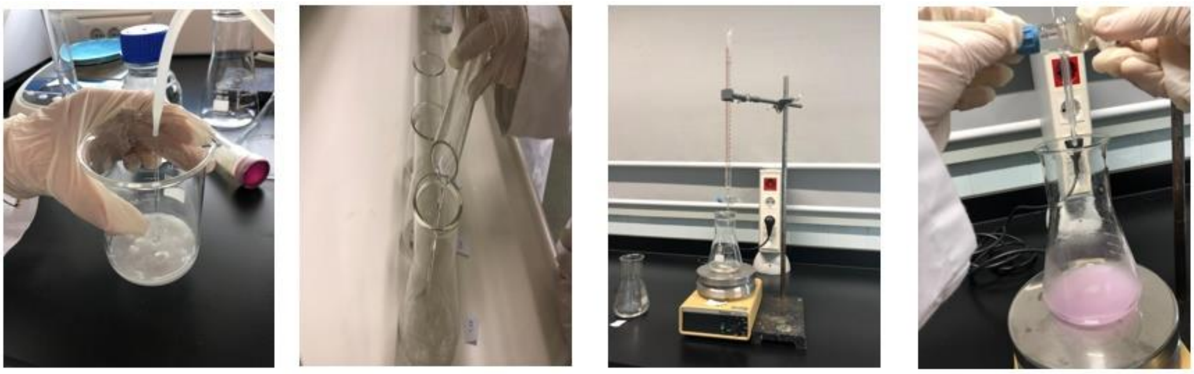

Figure 4. Determination of the acidity index of biodiesel

Miscibility Test

For the miscibility test (figure 5), 2 mL of the lower phase and 2 mL of the upper phase were transferred to two beakers each, so that the miscibility of these phases could be analyzed with ethanol and hexane. The top phase corresponded to the Biodiesel

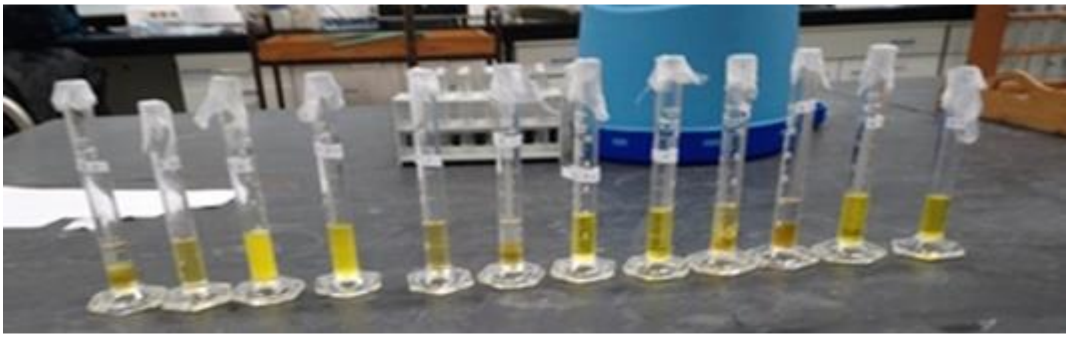

Figure 5. Miscibility test

Results and Discussion

The APP`s Magisto (figure 6) and Scapple (figure 7) were used to do the lab report as well as the video of the procedure of the homogeneous catalysis. The APP`s Popplet (figure 8) and Animoto (figure 6) were used to do the lab report as well as the video of procedure of the heterogeneous catalysis.

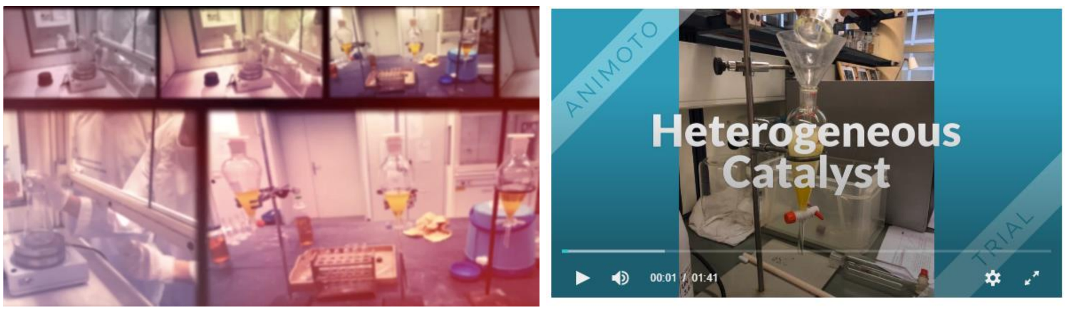

Figure 6. Apps (Magisto and Animoto) used to make the video

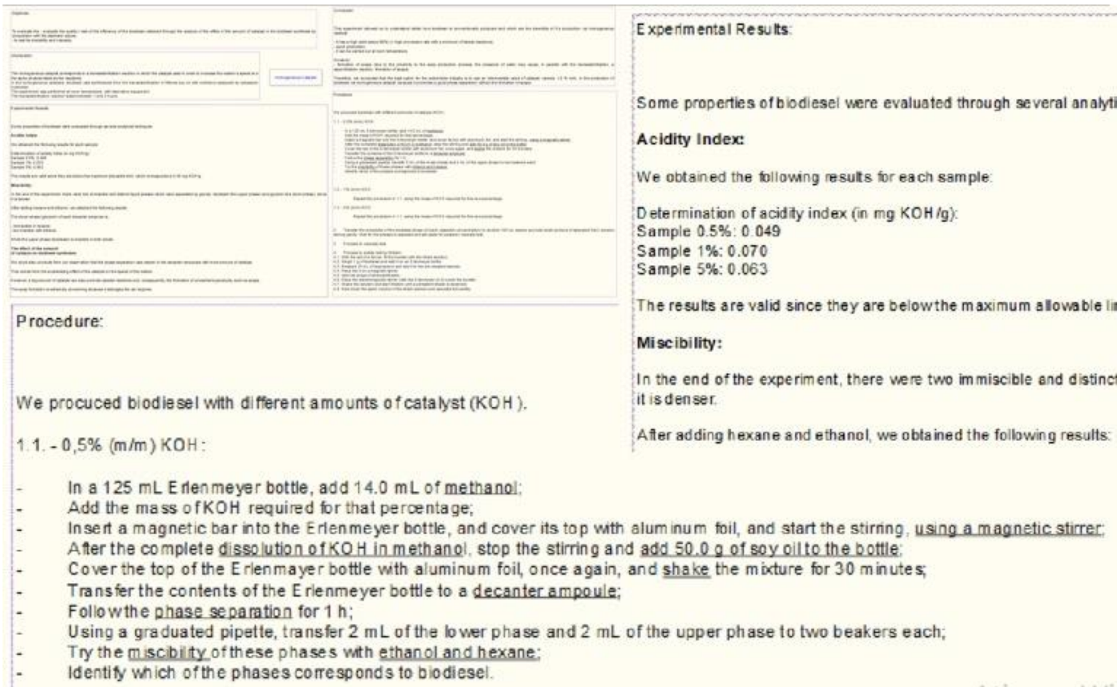

Figure 8. Lab report – Mind Map Scapple

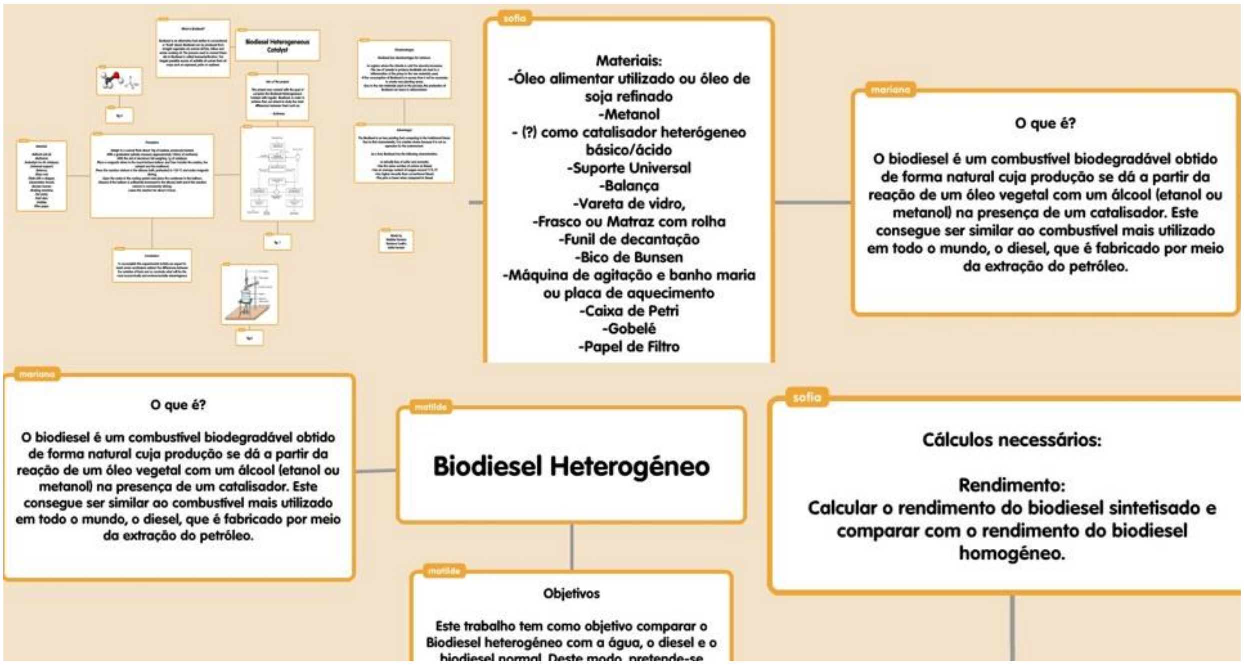

Figure 8. Lab report – Mind Map Popplet

Study of the miscibility

At the end of the experiment, there were two immiscible and distinct liquid phases which were separated by gravity: biodiesel (the upper phase) and glycerol (the down phase), since it is denser. After adding hexane and ethanol, the following results were obtained: the down phase (glycerol) of each decanter ampoule is immiscible in hexane but miscible with ethanol (figure 9), while the upper phase (biodiesel) is miscible in both solutes (figure 9).

0,5% (m/m) KOH	0,5% (m/m) KOH	1% (m/m) KOH	1% (m/m) KOH	5% (m/m) KOH	5% (m/m) KOH
Upper phase	**Upper phase**	**Upper phase**	**Upper phase**	**Upper phase**	**Upper phase**
Ethanol	Hexane	Ethanol	Hexane	Ethanol	Hexane
Miscible (light yellow)	Miscible (light yellow)	Miscible (light yellow)	Miscible (light yellow)	Miscible (light yellow)	Miscible (light yellow)
Lower phase	Lower phase	Lower phase	Lower phase	Lower phase	Lower phase
Ethanol	Hexane	Ethanol	Hexane	Ethanol	Hexane
Miscible Bottom - dark Top part - yellowish	Immiscible Bottom - dark Top - colorless	Miscible Bottom - dark Top part - yellowish	Immiscible Bottom - dark Top - colorless	Miscible Bottom - dark Top part - yellowish	Immiscible Bottom - dark Top - colorless

Figure 9. Study of the miscibility of the upper and lower phase with ethanol and hexane

Effect of the Catalyst amount on the production of biodiesel:

By the observation it is concluded that the phase separation was clearer in the decanter ampoules with more amount of catalyst. This is due to the accelerating effect of the catalyst on the speed of the reaction. However, a big amount of catalyst might also promote parallel reactions and, consequently, the formation of unwanted, such as soaps.

Infrared Spectrum of the Biodiesel

FT-IR is being employed for monitoring the reaction of biodiesel production. Bands above 3007 cm^{-1} indicate the presence of methanol. Bands at 1467 and 1436 cm^{-1} show the presence of methyl esters. (Baroi C. et al., 2009) In homogeneous catalysis, it is possible to visualize the specific areas of oil absorption by soy oil, methanol and biodiesel formed (figure 10). The higher is the catalyst amount, the higher is the efficiency to convert oil in biodiesel.

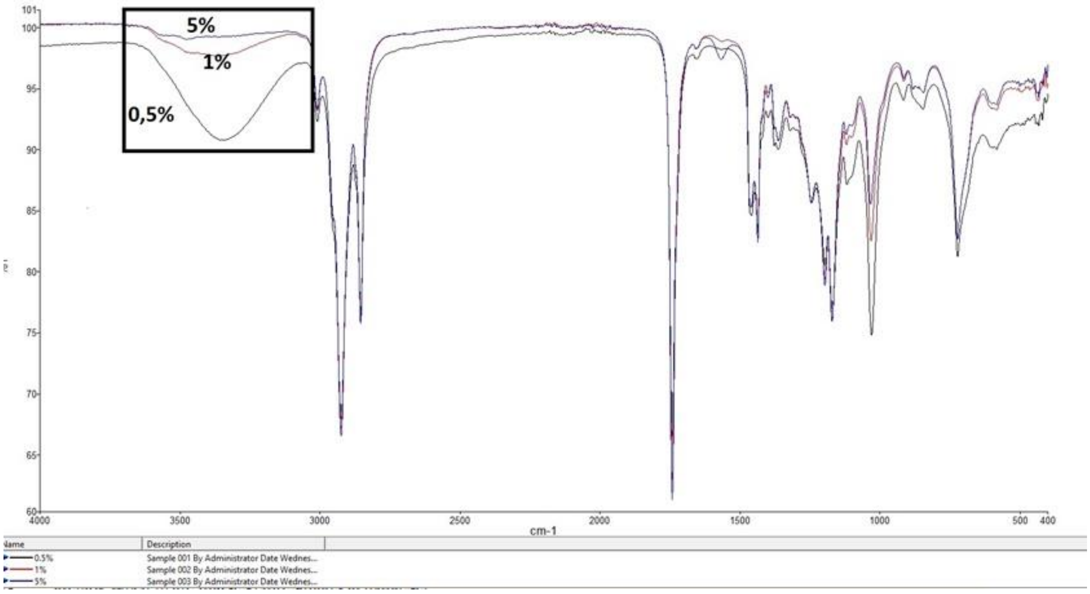

Figure 10. FT-IR of biodiesel – Homogeneous Catalysis

Conclusion

With this project, we may conclude that the transesterification corresponds to a simple, easy and economically accessible method of synthesizing Biodiesel. Homogeneous catalysis can be carried out at room temperature but there is the production of sops by catalyst consumption. On the other hand, the heterogeneous catalyst has no soap formation and the catalyst can be recovered because it is in a different physical state of the reaction elements, so it is easily separated from the final product.

By carrying out this project, students developed personal competencies/skills, the ability of dealing with the unknown as well as facing a challenge, always with the perspective of solving a problem. They developed social skills through teamwork and contact with the entrepreneurial world. Contacting with a research environment, they were led to the development of their ability to structure and analyse complex problems that require multidisciplinary skills as well as executing all tasks relating to each stage of the project in a lab environment. The teacher had a more tutorial role, intervening whenever requested.

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