International Journal of Multidisciplinary and Current Research ISSN: 2321-3124
Research Article Available at: http://ijmcr.com

Project-Based Learning Strategy in the Renewable Energy Education at State University of Jakarta

Desnita

Department of Physics, Universitas Negeri Jakarta, Indonesia

Accepted 06 June 2017, Available online 10 June 2017, **Vol.5 (May/June 2017 issue)**

Abstract

The purpose of the article is to highlight the effectiveness of Project Based Learning (PBL). The present paper presents an eloquent model for implementing the PBL strategy, in a Department of Chemistry, with a course on renewable energy. Students worked cooperatively in teams to conduct a series of laboratory investigations through which they explored the engineering aspects of renewable energy production, properties, characterization, quality control, performance testing and decided the proper strategy with a view to solve the problems at hand. The experiments were designed to be cost effective and transferrable. The laboratory experiments were conducted within the 'how people learn framework'. A survey was used to evaluate the acquisition of specific and generic competences, as well as the students' degree of satisfaction with respect to the use of these learning methodologies. The results of the survey and the perceptions of the lecturers show that PBL encourages students' motivation and improves their results. They not only acquire better technical training, but also improve their transversal skills. It is also pointed out that this methodology requires more dedication from lecturers than traditional methods

Keywords: *Laboratory Experience, Project Based Learning, Renewable Energy*

1. Introduction

In recent years, a transformation in teaching and learning methods involves the transition from an education system based on teaching to a system based on learning, making the student the centre of the educational process. In particular, subjects which have a very technological and systematic nature, are more suited to implement active learning methods such as Project Based Learning (PBL) (Mills & Treagust, 2003). PBL enhances not only the students' acquisition of competencies specific of each subject, but also the development of generic competencies as communication, team work, leadership, etc., that are increasingly valued in the professional field. The core idea of PBL is that real-world problems capture students' interest and provoke serious thinking as the students acquire and apply new knowledge in a problem-solving context. The teacher plays the role of a facilitator, working with students to frame worthwhile questions, structuring meaningful tasks, coaching both knowledge development and social skills, and carefully assessing what students have learned from the experience (David, 2008). PBL can take place both inside or outside the classrooms.

PBL is a learning model that organizes learning around projects. Thomas (2000) lists five aspects that have to be considered in PBL projects which are projects are central, not peripheral to the curriculum, projects are focused on questions or problems that drive students to encounter the central concepts and principles of a discipline, projects involve students in a constructive investigation, projects are student driven to some significant degree, projects are realistic, not school like. The core idea of Project Based Learning is to connect student's experiences with school life and to provoke serious thinking as students acquire new knowledge. The empirical evidence shows that experiential education addresses specific methods and Project Based Learning is one of them. Moreover, PBL methodology emphasizes activities which: are long-term, are student-centred, are based on collaborative team learning, are integrated with real world practices, have productive outcomes, have an impact on skills like self-management, teamwork, leadership, time management, communication and problem-solving and use technology-based tools.

Several authors have pointed out the benefits of this kind of methodology. In particular, PBL contributes to the development of many soft skills with applications to the workplace which apparently will fulfil the needs of the 21st century job market (Musa *et al*, 2012). Luminiţa *et al* (2014) specially in teaching sciences, there must be eliminated the pedagogic practices centred on formalized and excessively generalized presentations and promoted the teaching-learning strategies axed on action, experimentation, scientific investigation and problems solving. Promoting these strategies, and especially Problem- Based Learning, we will help students to develop their cognitive, instrumental and transversal competencies, which will allow them to extend learning at lifelong scale.

Xiangyun *et al*. (2013) developed a sustainability curriculum using the methodology of Problem and Project Based Learning (PBL) in a Chinese context. The results show that PBL can be an effective and efficient strategy and method for sustainability education. However, the success of the implementation process is highly dependent on its cultural setting. Therefore, a change of the curriculum itself is not enough for educational change; a broader scope of cultural change is needed within the institution, profession, and society (Blewitt, 2004). Jacobo *et al* (2015) describes the innovation activities performed in the field of space education involved implementing Project Based Learning (PBL), as the students learn how to communicate with satellites, how to receive telemetry and how to process the data. PBL methodology enhances students learning and improves not only their confidence about their technical skills, but also transversal skills increasingly in demand in the business world. The results of the study show that PBL encourages students' motivation and improves their results. They not only acquire better technical training, but also improve their transversal skills. It is also pointed out that this methodology requires more dedication from lecturers than traditional method. It also points out the benefits of collaboration among students as they have to learn to work together to find solutions to problems, and how the PBL methodology promotes responsibility and independent learning.

Rowan University has pioneered a progressive engineering program that uses innovative methods of teaching and learning to produce students who have the competencies to operate successfully in a dynamic and competitive global environment. Key features of the program were focusing on the educational process, through collaborative laboratory and course work. Experiential learning is the key factor of acquiring knowledge through experiencing things. It addresses specific teaching methods, which are believed to achieve a beneficial outcome to the learning ability of students. Project Based Learning is such a modern teaching method (Stephanie & Eduardo, 2014).

Musa *et al* (2011) studied relevance of PBL in relation to equip learners with the employability skills required by employers. The findings have shown that students greatly benefit in developing their various skills such as team-work, managing conflicts, decision making, and communication skills. Engaging themselves in these skills has assisted learners to be more independent, confident, and productive in generating and discussing ideas. In the PBL environment, students build their own knowledge by active learning, interacting with the environment, working independently or collaborating in teams, while the teacher directs and guides (Thomas, 2000).

PBL Model

The Project-Based Learning (PBL) consists on valorising the problems of the "real world" in the educational process, in order to facilitate the development of critical thinking, students' problem solving abilities, and the assimilation of the fundamental concepts for the different study disciplines (Duch *et al*., 2001). Using PBL in the instruction demarche, the teacher assumes the role of a coach for his students, orienting them in the research activity, stimulating their interest for an authentic and relevant learning. The PBL model, involves the following stages and sub-stages:

1. Understanding the problem; confrontation with the problem, identification of detained knowledge which might be necessary for the problem approach, definition of the situation/problem, students list the activities/tasks that must be effectuated and the factors which ensure their success.
2. Curriculum exploring: collection of information/documentation, information exchange: students share/disseminate information and it is discussed their relevance for the investigated problem;

Further on, an eloquent model for implementing the PBL strategy, in a Department of Chemistry at the State University of Jakarta with the theme: *Biodiesel - How do we make biodiesel from waste cooking oil* was presented (Table 1).

Table 1 Applying the PBL Model with the Theme: Biodiesel

No	Topic	Specific teaching and learning outcomes
1	Problem Comprehension	• The organization of a learning situation centred upon the presentation of a problem from everyday life, the increasingly apparent climate change, it becomes imperative to use renewable energy in the production of fuel that is environmentally friendly. • The initiation of a dialogue with students, having questions like: *How do we prepare biodiesel from animal fats or vegetable oils*. • The inventorying of anchor knowledge about: source of biodiesel, catalyst, transesterification reaction • Definition of problem-situation–students guided by their teacher, formulate the problem, make a list of the activities/tasks which must be accomplished and of the factors that ensures their success.
2	Curriculum Exploring	• The collection of new information referring to: raw material for biodiesel, catalysts, methods for production of biodiesel, properties and quality of biodiesel, what are the parameters in biodiesel production, how to improve the yields of biodiesel from waste cooking oil; • Exchange of information – students share/disseminate information they collected in their group and discuss their relevance for the investigated problem; • Generation of possible solutions – students synthesize the obtained information in order to generate more possible solutions, in the form of portfolio and projects

3	Project Solving	• Identifying the best solution – students organize the results obtained by their group and select the optimal solution; • Presentation of solution – students present the identified solution to the interested persons (stakeholder) • Reporting – students report the results of the problem, they complete their learning by following the other colleagues' presentations, underlying the assimilated /formed contents and competencies; students will receive confirmation for the assimilated and experimentally verified knowledge, regarding the principles that govern the making of biodiesel from waste cooking oil using microwave heating , and the validation of formed/developed competencies.

Research Methodology

Pre Laboratory Project

The pre-laboratory session began with a motivating problem that would be explored during the experiment, helping students to organize their body of knowledge (knowledge-centred). During the pre-lab the in-class discussion provided formative feedback to both the students and the lecturer. The lecturer was able to assess the accuracy and quality of students' pre-existing knowledge and linkages to new conceptual understanding, and to provide relevant formative feedback to the students.

The hands on activities were also reviewed by the instructor before the students left the laboratory, and formative feedback was given regarding accuracy and quality of the investigation and analysis. The course was community-centred in the use of in-class breakout groups for brainstorming and discussion, followed by whole-class discussion. Students worked in teams of 3–4 throughout the project with cooperative learning structures employed to promote positive interdependence and individual accountability. Teams were formed at the beginning of the semester, considering the criteria of student schedule (compatible), ethnicity/race and gender (minorities not isolated), academic performance (heterogeneous), and commitment level (similar) which have been found to be important in student learning (Layton *et al*., 2010). A team size of four students was formed based on the nature of the laboratory tasks.

Implementation of PBL in Biodiesel

At the beginning of the semester, all the students participate in classes focused on renewable energy. In these classes they work in groups with the support of a lecturer who helps and guides them. Students participating in the PBL methodology are organized in groups of 4 members to develop a project in laboratory for preparation of renewable energy.

All of the experiments for the project were conducted during the weekly laboratory meetings. A graduate assistant or technician set up the laboratory in advance, and this task typically took between 30 and 60 min. The laboratory was set up such that all glassware, chemicals and supplies were in a common area. Students assembled the necessary experimental apparatus before conducting each experiment. The instructor and assistant were both present during the laboratory meetings. The experimental procedures were straight forward enough that student teams could work independently, but questioning was encouraged. The basic laboratory procedure was provided in a handout that was distributed to students in advance of the laboratory experiment. Students were given some flexibility in the design of their process, for example, teams chose their own feedstock, catalyst, parameters in biodiesel production, method for improving the yields of biodiesel and were allowed to share data in order to assess how the choice of these affected the product properties. Other variations included the choice of transesterification reaction temperature, choice of distilled or tap water for washing, and power loads used in performance testing. Teams were also responsible for developing measurement techniques. The project used standard laboratory glassware and supplies to the maximum extent possible in order to minimize the overall cost.

Transesterification Procedures

All experiments were carried out in a 200 ml round-bottom flask equipped with a magnetic stirrer and a water-cooled condenser. The transesterification reaction was performed with various amounts of catalysts and different methanol/oil molar ratios. The waste cooking oil and catalyst were charged into the flask and stirred. When the required temperature was reached, methanol was added into the reactor through the constant press dropper. After the reaction, the mixture was separated by the centrifuge, resulting in the formation of an upper phase consisting of methyl esters and a lower phase containing glycerine. Excess methanol in the methyl ester phase was evaporated by heating. Then catalyst was removed by adding silica gel and the impurities were removed by water which resulted in the production of biodiesel. The methyl ester contents in the upper layer were quantified using a GC-2010 gas chromatograph (Shimadzu, Japan). Heptadecanoic acid methyl ester was used as an internal standard. The biodiesel yield was calculated from the equation below:

$$\text{Biodiesel Yield (\%)} = \frac{Total\ amount\ of\ methyl\ ester\ (mol)}{Charge\ amount\ of\ triglycerides\ (mol)} \times 100\%$$

Properties and Quality Testing

Physical properties including pH, viscosity, specific gravity, acid number and cloud point were measured either directly or indirectly. The pH of the wash water, oil, acidity or alkalinity of the sample and biodiesel were measured using full range and narrow range pH meter. Viscosity of oil and bio diesel was evaluated by measuring the time required to drain 12 ml from a 20 ml plastic disposable syringe without a needle. The viscosity was calculated using the Hagen–Poiseuille Equation.

Assessment of Knowledge Gain

To evaluate the impact of this project on student learning, specific assessment tasks: (a) work assignments, written tests and b) specific component related to the project, such as oral presentations, project reports, prototypes etc. were used. Each of these two main components have a weightage of 60% and 40%, respectively, on students' individual classification. The students' feedback was based on the filling in the assessment questionnaire of the research questions such as What are the advantages and difficulties of PBL ?, and can PBL help in developing skills for professional practice?

Results and Discussion

The students' feedback - after implementation of PBL is presented in the Appendix I. The hands on activities were designed for course of renewable energy entitled "Biodiesel Project ; An educational experience converting waste cooking oil to biodiesel".

Difficulties and Challenges of PBL

In the end of this course, a survey was conducted to obtain the feedbacks from students. Here are excerpts from several students.

"I think the project theme of each group is too much different, which means the workload and difficulty of each group is also different. Time is not enough. This course needs much time in order to develop our technical and soft skills. But whatever be the challenge this course is perfect. The resources in the lab are not adequate, some special tools are unavailable, and the administrative procedures are too complex"

"There is not enough time available in advance for ordering and machining designed parts, resulting in delay in assembly and debugging of the final physical system"

"I had to stay at the university to work all afternoons! And when I wasn't working on the project, I had to study for the tests. The subject content that we applied on the project wasn't even enough to study for tests"

Students identified the heavy workload which the project entails as one of the main constraints of this approach to learning

Developing Skills for Professional Practice

Students highlighted that one of the most positive aspects of PBL was teamwork. It provides the opportunity for students to develop transversal skills such as problem solving, time management, oral and written communication skills, amongst others. Students identified the benefits of working with people with different skills, ideas and perspectives, which allowed them to feel as if they were working in a real engineering environment. These findings are also consistent with the professional skills required for today's engineers. The development of these important skills can be seen in the following examples referred by students:

" the course timeline is across the whole semester, it is not uncommon to work very ''loose'' at beginning and very ''tight'' when approaching the end. The closer to the end, the more problems to solve.

"I also learned how to work as a team, how to solve problems within the group members so that these would not interfere with the progress of the project."

"I learned how to make an effective project report. In sum, we learned about things that we had never even thought about but they are going to be very important for our future."

"I think participating in PBL was a positive experience because it allowed us to develop several competencies." Teamwork was the most important amongst all, as it will be very useful in our future professional practice."

"My hands-on skills were improved, and I hope we can get more help from our instructors. This is a very good course, and our practical solving ability was enhanced greatly"

The lecturers also consider PBL as a good example of what awaits students in their future professional practice".

Conclusions

As PBL represents an educational method that uses *real world* problems like an important context, in order for the pupils to think critically and to achieve skills for solving the proposed problem, the results obtained in the frame of bio diesel project emphasized that the quality of the communication between teachers and students is very important, the teacher being perceived as a partner, as an active participant, during the training activities. Students in the introductory physics and chemistry department worked on a semester-long biodiesel project which introduced engineering skills and topics related to biodiesel production and use: reaction, purification, properties characterization and quality testing, and performance testing.

Drawing on the findings from this study, it is possible to recognize the importance of PBL to improve student learning and prepare graduates for professional practice. Both students and teachers identified a set of benefits of PBL, such as teamwork skills, increased student motivation, articulation between theory and practice, problem solving, amongst others. The difficulties and disadvantages of PBL are identified by students such as the fact that the students' final grade does not depend on a group and the workload is also much less, leaving students with more free time. Learning outcomes, teaching strategies and assessment methods need to be clearly aligned with the educational philosophy adopted. Thus, it is important to ensure diversity in teaching and learning methodologies and provide students with rich and challenging projects, that will engage them in learning and in achieving the essential skills required for their future professional practice.

Acknowledgments

The authors thank Universitas Negeri Jakarta for financial support and Analytical Chemistry Laboratory of State University of Jakarta for using their facilities and quality testing.

References

[1]. Blewitt, J. (2004). Sustainability and lifelong learning. In: Blewitt, J., Cullingford, C.(Eds.), The Sustainability Curriculum e the Challenge for Higher Education. Earthscan: London, pp. 24-42.

[2]. David, J. L. (2008). What Research Says About/Project-Based Learning. .Educational Leadership Teaching Students to Think, 65(5), 80-82

[3]. Duch, B. J., Groh, S. E., & Allen, D. E. (2001). "Why Problem-Based Learning? A case study of institutional change in undergraduate education". In Duch, B. J., Groh, S. E., Allen, D. E. (Eds.) The Power of Problem-Based Learning –(pp. 3-13). Stylus Publishing, 2001, Sterling, Virginia,USA.

[4]. Faridah, M., Mufti, N., Latiff, R. A., & Amin, M. M. (2012). Project-based learning (PjBL): inculcating soft skills in 21st century workplace . Procedia - Social and Behavioral Sciences, 59, 565-573

[5]. Musa, F., Mufti, N., Latiff, R.A., & Amin, M.M. (2011). Project-based Learning: Promoting Meaningful Language Learning for Workplace Skills Procedia Social and Behavioral Sciences. 18 :187-195

[6]. Rodrı´guez, J., Lavero´n-Simavilla, A., M. del Cura, J., Ezquerro, J.M., Lapuerta, V., & Cordero-Gracia, M. (2015). Project Based Learning experiences in the space engineering education at Technical University of Madrid. Advances in Space Research

[7]. Drăghicescu, L.M., Petrescu, A.M., Criste, g.C., Laura, Gorghiu, M., & Gorghiu, G. (2014). Application of Problem-Based Learning Strategy in Science lessons. Examples of Good Practice. Procedia - Social and Behavioral Sciences 149 :297-301

[8]. Layton, R.A., Loughry, M.L., Ohland, M.W., & Ricco, G.D., 2010.Design and validation of a web-based system for assigningmembers to teams using instructor-specified criteria. Adv.Eng. Educ. 2 (1): 1-28

[9]. Mills, J., & Treagust, D. 2003. Engineering Education – is problem-based or project-based learning the answer? Australasian Journal of Engineering Education. Available online at http://www. aaee.com.au/ journal/2003/ mills_treagust03.pdf

[10]. Cavanagh, S.F.E. (2014). Biodiesel production, characterization, and performance: A hands-on project for first-year students. education for chemical engineers, 9 : 21-31

[11]. Thomas, J. W. (2000). A review of research on project-based learning San Rafael, CA: Autodesk Foundation

[12]. Du, X., Su, L., & Liu. J. (2013). Developing sustainability curricula using the PBL method in a Chinese context. Journal of Cleaner Production, 61: 80-88

Appendix 1

Biodiesel Project: An educational experience converting waste cooking oil to Biodiesel

The Goal of the Program

To teach students of physics, chemistry and mechanical engineering, competencies and renewable energy. Furthermore, the school intends to produce, on campus, biodiesel produced from locally procured waste cooking oil. The full spectrum of planning, development, implementation, and quality control will serve as an experiential learning

Project Objectives

1. Define the chemical process required to convert waste cooking oil into usable biodiesel
2. Develop a standardized procedure to convert waste cooking oil into biodiesel
3. Classifying a catalyst that will implement the procedure
4. Develop a method to evaluate the quality of the biodiesel produced

Background

Bio Diesel is an attractive and cleaner burning alternative biofuel for diesel engines. The main advantages of biodiesel over fossil diesel are (1) availability and renewability (2) lower emissions (3) biodegradability and (4) increased lubricity (Yusuf *et al*., 2011). The most common way to produce biodiesel is by transesterification, in which a catalysed reaction between vegetable oil or animal fat and an alcohol yields fatty acid alkyl esters (biodiesel) and glycerol. The advantages and disadvantages of different methods of biodiesel production have been extensively explored (Balat and Balat, 2010). An alkali catalysed reaction was chosen for this project mainly for safety considerations. This reaction is shown below where the vegetable oil feedstock is a mixture of triglycerides, and biodiesel is a blend of fatty acid methyl esters (FAME) (Hoekman *et al*., 2012). After the transesterification reaction, the glycerine and biodiesel are phase separated, and purification is required prior to use in an engine. Two common techniques for crude biodiesel purification are water washing and adsorption (Gerpen, 2005). In the first year biodiesel project, students explored both water washing and adsorption as separation techniques. A number of standards have been established for biodiesel quality, most notably in Europe through the European Committee for Standardization (CEN) and in the U.S. through the American Society of Testing and Materials (ASTM). These standards ensure the quality of the product in several important aspects such as flash point, water and sediment content, free and total glycerine content, kinematic viscosity, acid number, density and cloud point (Methanol Institute, 2006). The relevance of these quality standards is described elsewhere. (Gogo *et al*., 2010). In this project the students use several simple property test methods in conjunction with semi-quantitative and threshold testing to characterize the fuel and ensure its quality prior to testing in a generator. These simplified test methods were chosen because they are more cost–effective and less time consuming than most standardized methods, and they are appropriate for the learning goals of the project. Biodiesel has a lower reported heat of combustion than fossil diesel, which results in a higher rate of fuel consumption at a constant power load (or a lower power output for a fixed fuel injection volume) (Andrade *et al.*, 2011). Biodiesel combustion results in reduced emissions in comparison with fossil diesel fuels. Carbon monoxide and carbon dioxide emissions are lower for biodiesel fuels, and nitrogen oxides are either slightly higher or lower depending on the engine family and testing procedures (Demirbas, 2007). Further, biodiesel CO_2 emissions are biogenic which reduces the impact of total biodiesel emissions to the environment, relative to fossil diesel. In this project, students compared the biodiesel and fossil diesel fuels on the basis of heat of combustion. Emissions were compared on a mass and energy basis

Biodiesel Production

Biodiesel fuel was produced using waste cooking oil from local fast food restaurants. The waste cooking oil was pre-treated prior to reaction. Approximately 1.0 L of waste oil were first filtered to remove solid food particles, heated to remove water (10 min at 100^0C and 10 min at 130 ^{0}C, longer if necessary as indicated by splattering sound of water present in oil), and neutralized with sodium hydroxide to eliminate free fatty acids using phenolphthalein as an endpoint indicator. The biodiesel was produced via a transesterification reaction between oil and excess methanol with CH_3ONa. NaOH, CaO/Zeolite, CaO/TiO_2 catalyst. 1 L of oil was heated to 55^0 C. 3.5 g sodium hydroxide was added to 200 ml methanol, and agitated until dissolved. This solution was added to the heated oil. The transesterification reaction was carried out in a 2-L beaker for 30min at $50–55^0$ C and then transferred to a 2-L separator funnel and allowed to settle until the next laboratory period. After settling, the biodiesel phase the glycerine (by product) phase were separated. The crude biodiesel from was purified using gentle agitation washing with 500 ml water to remove residual methanol, soap, sodium hydroxide and glycerine. After washing, the biodiesel and water phases were allowed to settle and were then separated. The wash cycle was repeated two additional times. The masses of the biodiesel and water phases were recorded before and after each wash.

Result and Discussion

Experimental Results

This section presents students' results that reflect typical results obtained by teams in the class. Since each team used a different feedstock and had some flexibility in determining the experimental protocol, there was variation in the properties and performance of the biodiesel products. In this section we present the results from student-produced batch of biodiesel.

Effects of Catalyst Type and Amounts of Catalyst on the Yield of Biodiesel

Experiments were carried out using different catalysts in order to investigate their influence on yield. CaO/zeolite, CaO/TiO_2, NaOH and CH_3ONa were used as the catalysts. The fractions of the catalysts were 0.50, 1.00, 2.00, 3.00, and 4.0 wt%, respectively. As shown in Figure 1, the yield decreased with increasing amount of catalyst. The yields of biodiesel with CH_3ONa catalyst were higher than those for NaOH catalyst. Similarly, Rashid *et al*. Found that CH_3ONa catalyst was the most efficient catalyst tested, followed by NaOH, CH_3OK, and KOH [69].

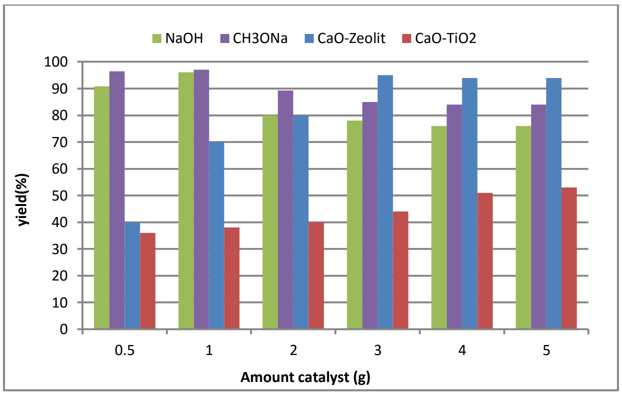

Figure 1 Effects of catalyst type and amounts of catalyst on the yield of Biodiesel

Properties and Quality Testing of the Biodiesel Samples

The results of the characterisations of the biodiesel samples, are presented in Table 1.

Table 1: Characterisations of Biodiesel Samples

No	Biodiesel sample	Acid number (mgKOH/g)	Alkalinity (ppmNa/g)	Glycerol(%)
1	A	0.16	76.5	0.004
2	B	0.11	27.9	0.006
3	C	0.12	58.8	0.007
4	D	0.10	54.6	0.007
5	E	0.10	62.4	0.008

The acidity index indicates the amount of fatty acids existing in biodiesel, that the acidity index showed good results for all samples within the limit established by the ASTM standards, i.e., below 0.50 mg KOH/g of biodiesel. It is an important factor to be determined, since free fatty acids favour the process of fuel degradation and compromises the life of the motor causing corrosion, deposit formation and fouling.

The alkalinity is an indirect measure of the amount of sodium in the biodiesel. The sodium contamination is caused by the use of catalysts in the biodiesel production process in the form of NaOH. This sodium in the form of ions causes the formation of insoluble soaps which generate engine deposits.

The glycerine concentration is an important quality parameter of biodiesel. The free glycerine in biodiesel associated with the presence of tri-, di- and monoacylglycerols is responsible for the formation of carbon deposits in the engine due to its incomplete combustion. Furthermore, according to the temperature and storage time, the glycoside present in the biodiesel tends to precipitate

The density of the cooking oil was 905 kg/m3, and after transesterification the density of the biodiesel is 874 kg/m3. This density difference reflects adequate conversion of the transesterification reaction. The density of fossil diesel is lower, 855 kg/m3. The kinematic viscosity of the cooking oil is 73.2mm^2/s; after transesterification- cation, the biodiesel has a kinematic viscosity of 4.20mm^2/s. The fossil fuel had a slightly lower kinematic viscosity of 2.95mm2/s. The higher kinematic viscosity of the waste vegetable oil in comparison to the biodiesel is one of the main disadvantages of using unconverted waste cooking oil as a diesel fuel. The result of the cloud point test was 2.8^0 C.