Biodiesel production process using solid acid catalyst: influence of market variables on the process’s economic feasibility

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Abstract: There are a number of efficient alternative technologies for the production of fuel-quality biodiesel from various feedstock types. The solid acid catalyzed transesterification process is one such approach. In this study, the whole process of biodiesel fuel production using solid acid catalysts has been simulated using commercially known software – SuperPro Designer – and the effects of some selected market variables on the economic feasibility of the whole process have been investigated. The market variables considered are oil cost, biodiesel price, alcohol cost, catalyst cost, labor cost, tax variation, maintenance cost, and glycerol selling price. Net present value and project payback time have been used as the parameters for evaluating the effect of changes in these market variables on the economic feasibility of the process. Possible market variations in oil cost and biodiesel price strongly affect the viability of the production process, whereas changes in labor cost and equipment maintenance cost could show less effect. © 2021 The Authors. Biofuels, Bioproducts, and Biorefining published by Society of Chemical Industry and John Wiley & Sons, Ltd

Key words: biodiesel; solid acid catalyst; process simulation; economic feasibility; sensitivity

Introduction

The expanding human population, together with a significant improvement in living standards, especially in the developing world, have accelerated and diversified economic activity, which, in turn, is increasing world energy demand. Most such economic activity is, in one way or another, dependent on the use of conventional fossil fuels, such as petroleum oils, coal, and natural gas. However, the extensive use of these conventional energy resources is considered as the leading cause of global warming, because 65% of carbon dioxide, which is the main component of greenhouse gases (GHG), is emitted from fossil fuel when used.¹ Conventional fossil fuels also have limited reserves, which might create the issue of energy insecurity and challenge the sustainability of economic activity.
Many argue that the possible solution to such multifaceted problems could be extensive production and utilization of renewable energy resources. The most promising renewable energy resources include solar, wind, hydropower, geothermal, and biomass. Among them biomass is the most versatile, abundant, cheap, and the one that is augmentable to the required quantity and quality. Biomass can be converted into solid, liquid, and gas fuel resources following a number of available conversion routes. The liquid forms of biomass fuel, called biofuels, are receiving due emphasis as they can effectively substitute their fossil fuel counterparts or can be used in blends with fossil fuels, whereby a considerable amount of fossil fuel consumption can be cut for economic and environmental benefits.

Biodiesel is one of the biofuels that can be used directly in diesel engine without modification. Fuel-quality biodiesel produced through the conventional transesterification reaction using high-quality oil resembles the fossil diesel in most of its fuel properties. In addition, biodiesel has better environmental and some fuel advantages compared with conventional fossil diesel. As a fuel, biodiesel has better lubricating character than fossil diesel, which might help to protect moving parts in the engine from deterioration due to inevitable friction. The higher content of oxygen in biodiesel than fossil diesel could also favor the complete combustion of the biodiesel, significantly reducing the amount of pollutants emitted from the process. The environmental advantages of biodiesel can be associated with its biodegradability, non-toxicity, and overall carbon neutrality.

Biodiesel fuel can be produced from various feedstock types such as cooking oil, non-edible oil, animal fat, and tallow. There are also a number of possible routes for the production of fuel-quality biodiesel from these various feedstock types. These include, homogeneous and heterogeneous base catalyzed transesterification, homogeneous and heterogeneous acid catalyzed transesterification and esterification, supercritical transesterification, and enzyme catalyzed transesterification and esterification reactions, among others. The latest but least studied process technologies for fuel-quality biodiesel production include nanocatalysts, ionic liquid catalysts, and membrane technologies. The conventional method for the production of biodiesel at industrial scale involves homogeneous base catalysts such as sodium hydroxide and potassium hydroxide. However, the process involving these catalysts demands high-quality oil with free fatty acid (FFA) content of less than 0.5%,2 which otherwise could end up in producing more soap than the required biodiesel product, if oil feedstock with high FFA content is used. This is because the saponification reaction between the FFA and the homogeneous base catalyst could dominate over the transesterification reaction that is supposed to occur between the triglyceride and the alcohol.

The main reason for limited utilization of biodiesel fuel is its higher cost of production compared to the fossil diesel. And the cost of feedstock takes more than 75% of the total cost of production.2 This implies that using cheaper feedstock alternatives could significantly reduce the unit cost of biodiesel production and make the fuel economically more competitive than its counterpart – fossil diesel. However, such feedstock types do usually have higher FFA content, which make them unsuitable for the conventional catalyst technologies. Even though the other alternative technologies such as acid catalysts, enzyme catalysts, supercritical alcohol, could not be well applied at industrial scale, they are proved to be effective in producing fuel quality biodiesel from low-cost feedstock with considerable FFA content.4–6 Acid catalysts could help to catalyze esterification and transesterification reactions simultaneously; in this way there would be more biodiesel produced than using most other catalyst technologies. The heterogeneous acid catalysts do have additional advantages of easy recovery from the process for possible reuse a number of times.

Among the solid acid catalysts, sulfonated carbon catalysts proved to be effective in catalyzing the process of biodiesel production from low-quality feedstock with high FFA and moisture content.7–10 Rashid et al.11 studies possible synthesis of biodiesel from palm fatty acid distillate (PFAD) using efficient sulfonated-derived tea waste-heterogeneous catalyst. Accordingly, 97% conversion of the PFAD to biodiesel could be achieved at optimum reaction conditions of 4 wt% of catalyst loading with 9:1 of methanol to PFAD for 90 min of reaction time at 65 °C of reaction temperature. This study indicated that sulfonated tea waste (STW) catalyst displays significant catalytic activity for the esterification of the PFAD; and the catalyst could be easily recovered and reused for five cycles without reactivation.11 In another study Konwar et al.12 used oil-cake waste (OCW) derived catalysts and sulfonated catalysts for the conversion of acidic oil (oils containing 8.17–43.73 wt% of FFA) to biodiesel. The catalyst could achieve 97% conversion at optimum reaction conditions at a temperature of 80°C, methanol to acid oil molar ratio of 43:1, catalyst loading rate of 5 wt%, and reaction time of 8 h.12 Similarly, the catalyst could easily be recovered from the process and reused five consecutive times without significant loss in its catalytic activity. This study also indicated that the catalytic activity of the solid sulfonated acid catalyst could be better than that of the homogeneous one when the equivalent amount of H2SO4 was applied under similar conditions.12 This implies possible use of the catalyst, which is also less-corrosive, in place of sulfuric acid for FFA reduction from
acrylic oil to make the oil feedstock suitable for conventional catalyst technologies. Da Conceição et al. investigated the possible production of biodiesel from macaw palm oil using sulfated niobium oxide catalyst through simultaneous esterification and transesterification of the oil. Accordingly, 99.2% conversion of the oil to biodiesel could be achieved under optimum reaction conditions of 120:1 mol L\(^{-1}\) ratio of ethanol to macaw palm oil at 250°C reaction temperature, 30 wt% catalyst loading rate and within a reaction time of 4 h. Behera et al. evaluate the use of sulfonated biochar as solid acid catalyst for transesterification of algal oil to produce biodiesel. The study also evaluated the catalytic activity of biochar produced from sugarcane bagasse, coconut shell, corn cob, and peanut shell following surface modification. Finally, peanut shell pyrolyzed at 400°C with the sulfonic acid density of 0.837 mmol g\(^{-1}\) having 6.616 m\(^2\) g\(^{-1}\) surface area was selected for efficient catalysis. Using this solid acid catalyst, a biodiesel yield of 94.91% could be achieved under optimum reaction conditions of 5 wt% catalyst loading, methanol to oil molar ratio of 20:1 at reaction temperature of 65°C and after 4 h reaction time.

In this specific study, the possible production of biodiesel fuel using sulfonated solid acid catalyst has been simulated using commercially well known software called SuperPro Designer, for analysis of the effect of eight market variables on the economic feasibility of the process. The market variables considered include oil cost, biodiesel price, catalyst cost, alcohol cost, tax variation, maintenance cost, labor cost, and glycerol price. Net present value and project payback time were the main parameters applied for evaluating the sensitivity of the process towards global fluctuations in the market variables.

### Materials and methods

#### Description of materials

The raw materials used in the designed production process include acidic oil feedstock, ethanol, and sulfated carbon catalyst. The oil feedstock is assumed to have 10% FFA content, and it is supposed to represent most non-edible acidic oil to make the oil feedstock suitable for conventional catalyst technologies. The alcohol involved in the process is ethanol because it is cheaper to produce in the Ethiopian context, as there are already established plants; it is also renewable and safe to handle. The catalyst used is sulfated carbon catalyst. This type of solid acid catalyst is becoming more interesting as it has been proved to be efficient for the production of fuel-quality biodiesel from cheap oil feedstock.

Incomplete carbonization (thermal pyrolysis) of cheap carbon containing wastes such as peanut shell, sugarcane bagasse, coconut shell, corn cob, oil cake, and other carbon-based wastes from agro-industries and then the biochar produced could be subjected to sulfonation by treatment with sulfuric acid. When such sulfated carbon catalysts are used to catalyze biodiesel production processes, they exhibit the advantages of both heterogeneous base catalysts and mineral acid catalysts. The operational stability of such type of catalyst could be in such a way that the catalyst can be reused four consecutive times, under optimized reaction conditions, without considerable change in its catalytic activity.

#### Design assumptions

The overall unit procedures involved in this biodiesel fuel production process have been designed based on the following assumptions, also elsewhere:

- 5177.23 kg h\(^{-1}\) is taken as the oil feeding rate, which could represent the medium-scale production process;
- the oil feedstock is assumed to be free from any solid matter and it is supposed to be continuously supplied throughout the year;
- the oil feedstock is assumed to have 10% FFA content and its triglyceride is represented by triolein with density of 907.8 kg m\(^{-3}\) and its FFA is represented by oleic acid with density of 895 kg m\(^{-3}\);
- the biodiesel product is represented by ethyl oleate with density of 873.9 kg m\(^{-3}\);
- total working hour per year is taken to be 7920, or the total working days per year is 330;
- because of the presence of polar compounds such as ethanol and glycerol, a non-random two liquid (NRTL) thermodynamic model is taken as the activity property package for the calculation of activity coefficient of the liquid phase in the simulations;
- the total lifetime of the production project is assumed to be 15 years and no loan is involved in the investment;
- pressure drop is neglected in all of the designed equipment;
- the catalyst is assumed to be reused multiple times and this is considered for the calculation of the total cost of the catalyst.

#### Description of the simulated production process

The process considered in this study is sulfated carbon catalyzed biodiesel production from low-cost oil feedstock. The overall process involves two dominant reactions, a transesterification reaction between the triglyceride and ethanol as well as an esterification reaction between the FFA
and ethanol. However, the possible occurrence of a hydrolysis reaction between water and triglyceride of the oil is neglected because the amount of water produced from the esterification process and the moisture content of the oil feedstock are very small compared with the total supply of the feedstock.

The optimum conditions for the transesterification reaction are taken to be an ethanol-to-oil molar ratio of 30:1, catalyst loading rate of 7.5 wt% (with respect to oil mass), and reaction temperature of 180 °C to achieve 99% conversion within 4 h reaction time. The oil feedstock feeding capacity or feeding rate for the process is considered to be 5177.23 kg h⁻¹, which is assumed to represent a medium-sized production capacity. Accordingly, the optimum amounts of the catalyst and ethanol have been determined based on the considered optimum reaction conditions together with the assumed oil feeding rate.

The process layout is simulated using a commercially known software called SuperPro Designer; and it has been carried out based on some important design assumptions, reaction conditions, and predetermined production capacity. Figure 1 indicates the whole simulated process involving all the necessary equipment required for the possible production of fuel-quality biodiesel.

The preheated oil feedstock (at 180 °C) is pumped into the reactor (R-101) at the rate of 5177.23 kg h⁻¹. At the same time, the ethanol is also supplied to the reactor at a rate of 8093.73 kg h⁻¹. This reactor is designed to have a constant temperature of 180 °C and packed with sulfated carbon material as catalyst. The rate at which the output is released from the reactor is in such a way that the reactants could stay in the reactor for about 4 h reaction time, within which 99% conversion could be achieved. The output from the reactor is directly let into centrifugal decanter (CD-101) for separation of the glycerol from the rest of the product. The upper outlet from the centrifugal decanter is then directed into the first distillation column (C-101) for recovery of the excess ethanol for possible reuse. Finally, the bottom outlet from this first distillation column is let into the second distillation column for further purification of the biodiesel product, which is then be cooled for direct use, transport, or storage.

In this process design, the storages for raw materials, products, and byproducts are not included in the simulation. It is assumed that the raw materials can be consumed directly, and the biodiesel and glycerol can be put into use immediately after they are produced.

**Economic assessment**

The biodiesel production process has been designed by including all unit procedures required to produce fuel-quality biodiesel. Accordingly, the technical performance of this process option was found to be very good, which could be expressed in terms of the quality and quantity of biodiesel produced. However, the viability of the process option is verified more if techno-economic performance analysis could be done. Therefore, for economic performance assessment, the capital and operation costs have been determined using the best current values of equipment, utilities, labor, and raw materials according to the requirements for the designed process model.

**Capital cost estimation**

Capital cost considers both direct and indirect plant costs, working capital cost, and startup and validation costs. Direct plant cost includes equipment purchasing and installation cost, as well as cost of instrumentation, insulation, etc.; whereas the indirect plant cost includes engineering and construction cost. The delivered cost of equipment has been estimated using the Peters and Timmerhaus method, and the latest Chemical Engineering Plant Cost Index used for the estimation was 665 for February 2020. Table 1 provides a
The utilities included in the process design are chilled water, steam, and electricity, and their respective cost values have been determined using information from relevant literature and market prices in Ethiopia. Table 2 summarizes the estimation of the operation cost categories.

### Economic sensitivity analysis

The economic feasibility of the process is mostly dependent on the operation of the production process, which can be affected directly by the variation in the value of the market variables. Thus, this particular study focuses on eight market variables that might have a significant effect on the economic feasibility of biodiesel production using solid acid catalyst. In doing so, the study also considers the current market values of the variables as well as the possible fluctuation of the same to investigate the economic sensitivity response of the process towards the possible fluctuations. The optimum market values of the variables have been determined based on the current market scenarios in Ethiopia. Accordingly, the minimum and maximum cost values were entered into the simulation and the response of the production process towards the possible change of each market variable were assessed. Table 3 indicates the cost ranges for each market variable.

### Result and discussion

For the considered market scenario, the production process has been proved economically feasible. The biodiesel could be produced with a unit production cost of 0.67 US$ kg$^{-1}$. The overall production business enables a positive net present value (NPV), internal rate of return (IRR) of 8.52% (at 7% interest rate), a gross margin of 36%, and payback time of 1.5 years to be achieved.

The assessment of the sensitivity of the production process towards the changes in market values of the selected variables revealed that there is a possibility of making the production business economically more reliable. In this regard, cheaper feedstock alternatives and reduced cost of ethanol alcohol could improve the economic competitiveness of the business in general. The effect of change of the selected market variables on the economic feasibility of the production business is indicated as follows.

### Table 1. Capital costs for the construction of a biodiesel production plant with production capacity of 41004 tons per year.

| Cost categories                           | Percentage allocation | Amount (thousand US$) |
|-------------------------------------------|-----------------------|-----------------------|
| Direct plant cost (DC)                    |                       |                       |
| Equipment purchasing cost (PC)            | 26 × PC               | 1897                  |
| Installation                              | 20 × PC               | 936                   |
| Process piping                            | 10 × PC               | 379                   |
| Instrumentation                           | 3 × PC                | 57                    |
| Electrical                                | 15 × PC               | 285                   |
| Building                                  | 10 × PC               | 285                   |
| Yard improvement                          | 15 × PC               | 190                   |
| Auxiliary facilities                      | 25 × PC               | 474                   |
| **Total direct plant cost (DC)**          |                       | **4249**              |
| Indirect plant cost (IC)                  |                       |                       |
| Engineering                               | 5 × (DC + IC)         | 340                   |
| Contingency                               | 10 × (DC + IC)        | 680                   |
| **Total indirect plant cost (IC)**        |                       | **2549**              |
| **TOTAL PLANT COST (DC + IC)**            |                       | **6798**              |
| Contractors’ fee                          | 5 × (DC + IC)         | 340                   |
| Contingency                               | 10 × (DC + IC)        | 680                   |
| **Sum of contractor’s fee and contingency (CFC)** |                       | **1020**              |
| **Total direct fixed capital cost (DC + IC + CFC)** |                       | **7818**              |
| Working capital (WC)                      | 3625                  |                       |
| Startup and validation cost (SVC)         | 391                   |                       |
| **Total capital investment cost (DC + IC + CFC + WC + SVC)** |                     | **11834**             |

The assessment of the sensitivity of the production process towards the possible change of each market variable were assessed. Table 3 indicates the cost ranges for each market variable.
Table 2. Summary of operating cost calculations for biodiesel production capacity of 41 004 ton per year.

| Cost category | Calculation | Amount (US$000) | %   |
|---------------|-------------|----------------|-----|
| 1. Raw materials | From material balance | 34 451.00 | 81.41 |
| 2. Utilities cost | From material balance | 5247.00 | 12.40 |
| Variable costs (VC) | (1) + (2) | 39 698.00 | |
| 3. Maintenance | 10% × PC | 190.00 | 0.45 |
| 4. Operating labor | Manning estimates | 176.00 | 0.42 |
| 5. Laboratory cost | 30% × (4) | 53.00 | 0.12 |
| 6. Depreciation | 10% × DC | 449.00 | 1.06 |
| 7. Insurance | 2% × DFC | 156.00 | 0.37 |
| 8. Local tax | 15% × DFC | 1173.00 | 2.77 |
| 9. Factory expense | 5% × DFC | 391.00 | 0.92 |
| 10. Miscellaneous | Fixed | 70.00 | 0.17 |
| Fixed costs (FC) | (3) + (4) + … + (10) | 2658.00 | |
| Annual operating cost | (VC) + (FC) | 42 318.00 | |
| Net unit production cost | 0.67 US$ kg⁻¹ OR 0.58 US$/liter of biodiesel product | |

Table 3. Ranges of market variables for study.

| Market variables | Minimum value | Standard value | Maximum value |
|------------------|--------------|---------------|--------------|
| Biodiesel selling price (US$ kg⁻¹) | 0.77 | 0.98 | 1.20 |
| Glycerol selling price (US$ kg⁻¹) | 0.30 | 0.60 | 0.85 |
| Oil purchasing cost (US$ kg⁻¹) | 0.35 | 0.45 | 0.56 |
| Ethanol purchasing cost (US$ kg⁻¹) | 0.10 | 0.24 | 0.40 |
| Catalyst purchasing cost (US$ kg⁻¹) | 0.05 | 0.20 | 0.30 |
| Equipment maintenance (% of PC) | 2 | 10 | 30 |
| Local tax (% of DFC) | 5 | 15 | 30 |
| Labor cost (basic rate in US$ h⁻¹) | | | |
| Operator | 2 | 5 | 10 |
| Reactor operator | 3 | 7 | 15 |
| Total basic rate (US$ h⁻¹) | 5 | 12 | 25 |

**Effect of change of oil cost**

Irrespective of the production technology involved, the oil feedstock cost usually takes the larger share of the total biodiesel production cost. It is therefore reasonable to investigate how the profitability of the production business could behave towards possible fluctuation of the market value of oil feedstock cost. Accordingly, the response of the business has been evaluated in terms of NPV and project payback time and the results are indicated in Fig. 2. The NPV shows a sharp decrease for a smaller increment in the oil purchasing cost; for example, an increase in oil cost by 100 US$ per ton results in the reduction of the NPV by 25 million US$; and the production process could be economically feasible for oil feedstock cost less than 450 US$ per ton. The effect of change of the oil cost on the payback time is not that much considerable. For the same increment in the oil cost by 100 US$ per ton, the payback time could only increase by a quarter of a year. This is a very small change compared with the 15 years lifetime of the project considered in the design.

**Effect of change of alcohol cost**

The optimum quantity of the alcohol involved in the reaction is 8094 kg h⁻¹, which is the largest among the raw materials. This implies the cost of the alcohol can have significant effect on economic feasibility of the production process. Consequently, as indicated in Fig. 3, the variation of the cost of the alcohol resulted in considerable change in the NPV and payback time of the business. A very small increment in the cost of the alcohol (150 US$ per ton) could result in huge reduction in the amount of the NPV, which is about 54 million US$; and the alcohol cost greater than 240US$ per
ton would make the business economically unproductive. Comparatively, the possible change in the market values of alcohol cost could not affect the payback time much, because 150 US$ per ton increment in the cost of the alcohol could only increase the payback time by less than quarter of a year.

Effect of change of catalyst cost

The catalyst technology in this production process is the sulfated carbon, which can be easily produced from cheap carbon containing wastes. However, since higher amount of catalyst is used to favor the conversion, the cost of the catalyst might directly affect the economic feasibility of the business. Thus, to evaluate how the cost variation affect the business, possible catalyst cost range of 50–300 US$ per ton has been used. As indicated in Fig. 4 the effect of the cost variation is more explained in terms of the change in the NPV; for which an increment in the catalyst cost by 290 US$ per ton could result in 5.5 million US$ reduction in the NPV of the business. In addition, the production business would not be economically viable for a catalyst cost greater than 270 US$ per ton.

Effect of change of biodiesel price

As biodiesel is the main product for revenue, its price has a significant effect on the economic viability of the whole process. Investigating the effect of the possible fluctuation of the market value of the biodiesel price is therefore very crucial for the determination of the threshold price for biodiesel, beyond which the business is not feasible. Accordingly, as indicated in Fig. 5, the change in biodiesel price has a strong effect on the economic feasibility of the business, and this effect is equally pronounced by both NPV and payback time of the business, as they are changed substantially. However, at a higher biodiesel product price range, the payback time of the business tends to normalize. A biodiesel price change by 210 US$ per ton could result in a decrease in payback time of a year and a quarter, as well as a 78 million US$ NPV increment into the business. Based on the current market scenario, the business could only be economically feasible for biodiesel price more than 970 US$ per ton (0.97 US$ per kg).
Effect of change of glycerol price

Glycerol is considered to be the second means of revenue for this production business; thus, the possible fluctuation in its price is assumed to have a substantial effect on the economic feasibility of the business. As indicated in Fig. 6, the effect of glycerol price variation on the project payback time and NPV is straightforward. However, the change in payback time due to change in glycerol price is not that considerable, for example a price change of 500 US$ per ton of glycerol could only result in a reduction in the payback time of about 2 months, which is insignificant compared to the 15 years project life time. Comparatively, the effect of the variation in glycerol price is more pronounced with respect to the NPV of the business, because a price change of 300 US$ per ton of glycerol could bring NPV of 7.5 million US$ into the business. For the given market scenario, the business could not be economically viable with glycerol price less than 0.5 US$ kg\(^{-1}\) (500US$ per ton).

Effect of change of labor cost

The labor category for this production process includes reaction supervisors, reactor operators, and technicians. The respective cost for these professionals has been determined based on the current labor market in Ethiopia; and in relative terms the actual labor cost is very cheap in the country. However, by considering the possible change in the basic rate for each labor category, which is expressed in terms of US$ per hour, the effect of the change has been analyzed and is presented in Fig. 7. Compared with the other factors, the overall effect of the change of labor cost on the economic feasibility is insignificant. This could allow improving the payment to the professionals involved without affecting the return from the business, and there would be better motivation from the workers. However, for the considered range of labor cost fluctuation, the NPV responds in a straightforward manner, while there is no considerable change in terms of the payback time of the project that seems to remain constant. An increase in the labor cost, in terms of basic rate, equivalent to 20 US$ h\(^{-1}\), could bring a 2.2 million US$ reduction in the NPV of the business, and a labor cost above 23 US$ h\(^{-1}\) would make the business unprofitable.

Effect of local tax variation

The local tax taken in this process simulation for economic performance analysis is income tax, which can range from 5% to 30% of the direct fixed cost (DFC) of the project. Figure 8 shows how the tax variation could affect the NPV and payback time of the production business. For an increment in the local tax with 10% of DFC, the NPV of the business could be reduced by about 4.8 million US$. However, for the same change in the local tax amount the payback time could not indicate considerable variation. Local tax greater than 17% of DFC would make the business economically unproductive. This suggests some kind of subsidy scheme from the government to sustain the economic feasibility of the project.
Effect of change of maintenance cost

The sustainability of the production process is entirely dependent on how well the equipment maintenance and repair activities are scheduled and conducted. Such frequent maintenance and repair activities could incur significant costs, which might also put pressure on the profitability of the business. Figure 9 indicates how the variation in the amount of money for equipment maintenance, which is expressed in terms of percentage of equipment purchasing cost, could affect the NPV and payback time of the business. For the considered cost variation, the payback time could not show any change; however, the NPV has been more responsive in relative terms. A maintenance cost change of 23% purchasing cost (PC) could reduce the NPV of the business by 21 million US$. But still for 25% of PC allocated for equipment maintenance, the business is profitable with positive NPV.

Conclusions

The study investigates the effect of eight market variables on the economic feasibility of biodiesel production from low-cost feedstock using solid acid catalyst (sulfated carbon). The studied process option could produce fuel quality biodiesel with good economic performances for the given market scenario.

The economic sensitivity analysis indicated that, among the studied market variables, the biodiesel selling price and oil purchasing have the strongest effect on the economic aspects of the process. Accordingly, biodiesel has to be sold with a price of more than 0.98 US$ kg$^{-1}$ for the business to be economically viable. Comparatively, the minimum cost of oil feedstock has to be 0.45 US$ kg$^{-1}$, beyond which the process would not be profitable. The other most important market variable affecting the viability of the business is the alcohol purchasing cost, for which an increment in its cost by 0.1 US$ kg$^{-1}$ could result in a reduction of the NPV by about 39 million US$. The glycerol byproduct selling price and local tax variation do have a relatively lesser effect on the economic feasibility compared to the above-mentioned variables. Changes in labor cost and equipment maintenance cost could not have a considerable effect on the viability of the business. This implies that enough money can be allocated for regular equipment repair and maintenance activities, which could help sustain the productivity of the process. The lesser economic effect of the labor cost variation could also help to improve the payments for the workers, whereby more experienced technicians would be attracted for employment.

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Disclaimer

Any decision made using the results from this specific study is not counted as the responsibility of the authors. The process option simulated and included in this study is merely for research purposes. Anyone interested in the study in general or in the simulated process option in particular, please contact the authors for more information concerning the limitations and scope of the designs.

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