ECONOMIC ASSESSMENT OF BIODIESEL PRODUCTION: COMPARISON OF ALKALI AND BIOCATALYST PROCESSES

ABSTRACT:

The research paper titled "Economic assessment of biodiesel production: Comparison of alkali and biocatalyst processes" by Kenthorai Raman Jegannathan, Chan Eng-Seng, and Pogaku Ravindra examines the economic aspects of biodiesel production using different catalytic processes, specifically comparing alkali and biocatalyst methods. The study was conducted by researchers from the Department of Biotechnology at Karunya University in India and the Centre of Materials and Minerals at the University Malaysia Sabah. The research focuses on assessing the economic aspects of biodiesel production with an emphasis on three catalytic processes: alkali, soluble enzyme, and immobilized enzyme. These processes were considered in a batch mode of operation with a production capacity of 1000 tonnes. The paper highlights the growing importance of biodiesel as an alternative to fossil fuels due to its environmental benefits and increasing global production. It also discusses the transition from chemical catalysts to enzymatic processes for biodiesel production, aiming to reduce pollution and simplify production processes. The paper highlights the growing importance of biodiesel as an alternative to fossil fuels due to its environmental benefits and increasing global production. It also discusses the transition from chemical catalysts to enzymatic processes for biodiesel production, aiming to reduce pollution and simplify production processes. The study found that the production cost for biodiesel using the alkali catalyst process was the lowest at $1,166.67 per tonne, compared to the soluble lipase catalyst process at $7,821.37 per tonne and the immobilized lipase catalyst process at $2,414.63 per tonne. The higher production cost for the biocatalyst processes was attributed to the higher cost of enzymes and the longer reaction time. The use of immobilized catalysts in the biocatalyst process significantly reduced the production cost compared to soluble enzyme catalysts, as immobilized catalysts can be reused. On the other hand, soluble enzymes are not reusable, leading to higher costs. This study provides valuable insights into the cost differences between alkali and biocatalyst processes in biodiesel production. It is important to note that the research uses various economic parameters, process flow charts, and equipment lists to evaluate

the economic feasibility of the different biodiesel production methods. The study aims to support the development of more cost-effective biodiesel production processes.

INTRODUCTION:

In the face of increasing energy demand and growing environmental concerns associated with conventional fossil fuels, the quest for sustainable and environmentally friendly energy sources has gained prominence. Biodiesel, which is derived from renewable resources, has emerged as a viable alternative to conventional petrochemical fuels. Biodiesel not only addresses energy security but also offers a more environmentally benign fuel option. The production of biodiesel has witnessed significant growth on a global scale due to its environmental benefits. Regulatory policies and mandates have also led to an increase in biodiesel production, further driving its adoption. The European Union's 20:20:20 biofuel policy, for instance, is expected to spur biodiesel production globally. Biodiesel is typically produced through a process known as trans esterification, where triglycerides from sources like vegetable oils or animal fats are converted into alkyl esters, commercially recognized as biodiesel. While conventional methods employ chemical catalysts in this process, enzymatic trans esterification using lipase enzymes has gained attention as a more sustainable and eco-friendly alternative. Enzymatic processes offer advantages such as reduced wastewater treatment requirements, ease of glycerol recovery, and fewer side reactions. Economic assessment is a pivotal factor in the development of new process technologies. It aids in predicting plant costs, manufacturing costs, and facilitates comparisons between different production processes and conditions. While economic studies on biodiesel production using chemical catalysts have been conducted, limited research has explored the economic aspects of biodiesel production using biological catalysts. This research paper aims to bridge this gap by presenting an economic assessment of biodiesel production using three catalytic processes: alkali, soluble enzyme, and immobilized enzyme. The study evaluates these processes in terms of production cost, with a particular focus on the economic feasibility of using biological catalysts in comparison to alkali catalysts .The subsequent sections of the paper delve into the methods, cost estimations, and a comparative analysis between the different biodiesel production processes. This research provides valuable insights into the economic aspects of biodiesel production, which can inform decision-making and drive the development of cost-effective and sustainable biofuel production methods.

METHODOLOGY:

The methods section of the research paper outlines the procedures and steps taken in the study to assess the economic aspects of biodiesel production using different catalytic processes. The research was conducted by comparing three methods: alkali catalyst, soluble enzyme catalyst, and immobilized enzyme catalyst. The study focused on biodiesel production with a batch mode operation and a production capacity of 1000 metric tonnes. This section delves into the methodologies employed in the study, including the process flow sheets, process time charts, and equipment lists techniques. It provides a clear picture of the processes, timelines, and equipment involved in biodiesel production, which, in turn, forms the basis for estimating production costs and conducting comparisons between different production methods.

Process Flow Sheets:

Process flow sheets are visual representations of a production process that detail the various steps involved in transforming raw materials into a final product.The process flow sheets describe the process flow for each of the three biodiesel production methods under consideration: alkali catalyst, soluble enzyme catalyst, and immobilized enzyme catalyst. Process flow sheets are essentially flowcharts or diagrams that illustrate the steps involved in producing biodiesel, including raw material input, chemical reactions, and product output. These flow sheets provide a visual representation of the processes being analyzed. The process starts with the preparation of the feedstock, which is typically vegetable oil, in this case, palm oil. It may involve heating or filtering to remove impurities or adjust its physical properties. Transesterification: In this step, the prepared feedstock (palm oil) is mixed with alcohol (typically methanol) in the presence of a catalyst. In the alkali catalyst process, chemical catalyst (typically sodium hydroxide) is used. This chemical catalyst helps convert triglycerides in the oil into biodiesel through transesterification. In the soluble enzyme catalyst process, a soluble lipase enzyme is used as the catalyst. The lipase catalyzes the same transesterification reaction but is in soluble form. In the immobilized enzyme catalyst process, an immobilized lipase enzyme is used as the catalyst. The immobilization process allows the reuse of the enzyme, reducing the cost. Separation: After transesterification, the reaction mixture separates into two layers: biodiesel and glycerin.

Glycerin is a byproduct of the reaction. In the alkali catalyst process, the glycerin contains soap formed during the reaction. It is sent to a neutralization tank and then separated from water through distillation. In the enzyme catalyst processes (soluble and immobilized), there is no soap formation, so there's no need for the neutralization and distillation steps. Washing and Purification: The biodiesel is then typically washed with hot water to remove impurities. Distillation may be used to further purify the biodiesel in some cases. The process flow sheets show these main steps in each of the three processes, highlighting the key differences, especially in the separation and purification stages due to the choice of catalyst (alkali, soluble enzyme, or immobilized enzyme). These flow sheets are essential in process engineering and plant design, helping engineers and researchers understand the sequence of operations and the equipment required to produce biodiesel efficiently. They also serve as a basis for estimating the costs and analyzing the economic feasibility of each process, which is the main focus of the research paper.

Process Time Charts:

Process time charts are used to visually represent the various steps and the time required for each step in the biodiesel production process. These charts provide a detailed breakdown of the production process and help in understanding the time dynamics of different stages. Process time charts are essential for understanding the time dynamics of each process, especially in a batch mode of operation. They help to visualize how long each step takes and provide insights into the production schedule. These charts show that the batch cycle time for the alkali catalyst process is significantly shorter than that of the biocatalyst processes, which operate for longer durations to achieve the same production capacity. Process Steps: Each process time chart represents a specific biodiesel production method. In this case, there are three methods: alkali catalyst, soluble enzyme catalyst, and immobilized enzyme catalyst. The charts show a sequence of steps required for each method. Time Duration: For each method, the time (usually in hours) required for each step is indicated on the y-axis of the chart. This helps in understanding how long each part of the process takes. Batch vs. Continuous Operation: These charts primarily deal with batch mode operations. In a batch process, a set quantity of materials is processed at a time, and the entire batch goes through each step together. The time charts illustrate when each batch is processed and how long it takes. In contrast, continuous processes involve a constant flow of materials and are not represented in these charts. Sequential Flow: The process steps are laid out sequentially along the x-axis of the chart, indicating the order in which they occur. For example, in the alkali catalyst process, you may have steps like "Preparation of feedstock," "Transesterification," "Settling," and "Washing." The chart shows when each of these steps begins and ends. Comparison of Different Processes: These charts allow for a direct comparison of the time required for each step in the different biodiesel production methods. This is essential for understanding why one method might be more time-consuming than another. For instance, the charts may reveal that the immobilized enzyme process takes significantly longer than the alkali catalyst process. Synchronization: In this specific study, to ensure a fair comparison of the three methods, some processes may be synchronized. For example, to match the production capacity for all three methods, the biocatalyst processes were assumed to operate multiple units simultaneously, as indicated by the batch cycle time. Overall, these process time charts are valuable tools for assessing the efficiency and feasibility of different biodiesel production methods. They provide insights into where time is spent during the production process, helping researchers and engineers make informed decisions about process optimization and cost-effectiveness.

Equipment List: The Equipment List section provides a comprehensive list of all the equipment and machinery used in the biodiesel production process. Each piece of equipment is described in terms of its specifications, capacity, and cost. This part provides specifications for the equipment used in the production of biodiesel for a capacity of 1000 tons per year. It outlines the machinery and their costs for each of the three processes. This information is crucial for estimating the costs of equipment procurement and installation. For instance, the authors would have listed equipment such as tanks for palm oil, methanol, hot water, FAME (Fatty Acid Methyl Ester), glycerol, waste water, and pumps for various functions. They also mention the specifications of key equipment like transesterification vessels, methanol vessels, and heaters. The list might also include equipment used for waste treatment, such as the separation of soap in the alkali catalyst process.

COST ESTIMATION:

Cost estimation is a vital aspect of this study. The section discusses the procurement costs of equipment and provides a detailed breakdown of costs related to plant investment and manufacturing. This cost estimation section is essential for understanding the economic feasibility of different biodiesel production methods and plays a crucial role in determining the most cost-effective approach.

Plant Cost: These include the expenses related to setting up the production facility, including equipment procurement, installation, piping, insulation, civil and structural work, electrical and instrumentation, computer systems, engineering, supervision, and general expenses. Equipment : The paper lists various equipment items required for biodiesel production, including tanks, pumps, vessels, heaters, condensers, filters, and more. The prices and capacities of these equipment pieces are specified. Installation : This part of the cost accounts for the installation of the equipment. Piping : Piping costs are estimated, taking into account the complexity and length of the piping required in the plant. Insulation and Painting : This cost accounts for insulating equipment and the painting of equipment where necessary. Civil and Structure : This significant cost represents the construction and preparation of the physical infrastructure for the production plant, including buildings, foundations, and structural elements. Electric and Instrumentation : This expense includes the installation of electrical systems and instrumentation for monitoring and controlling the plant. Computer System : The cost of computer systems, which may be used for process control, data logging, and other purposes. Engineering and Supervising : Costs related to engineering work, project management, and supervision during the construction phase.

Manufacturing Cost: This sub-section examines the manufacturing costs for biodiesel production, considering raw materials, utilities (steam, electricity), labor, and other expenses. The annual costs of depreciation, repair, interest, and tax are also factored in. These costs per ton are compared for each of the processes. Raw Material Costs: This section provides a detailed breakdown of the costs associated with raw materials. The cost of key raw materials such as palm oil, methanol, sodium hydroxide, HCl, lipase, and more is presented. Utilities: These costs include the expenses for energy (steam, electricity), water (tap water), and manpower (labor). Byproducts: For biodiesel production, glycerol is considered a byproduct. The costs associated with the disposal of glycerol are estimated. Depreciation: A percentage of the plant investment cost is allocated to depreciation expenses. Repair: Repair costs are estimated at 3% of the plant investment cost. Interest and Tax: The paper accounts for 3% of the plant cost for interest and tax expenses.

COMPARISON BETWEEN PREVIOUS STUDY AND PRESENT STUDY:

The "Comparison between previous study and present study" section of the research paper provides a comparative analysis of the findings in the current study with those of previous research in the field of biodiesel production. This section serves to highlight the key differences and similarities between the two sets of data, shedding light on how the new study's results fit into the existing body of knowledge. The information presented here helps readers understand the economic implications of the different studies and their relevance to real-world biodiesel production scenarios.

Background on Previous Studies: Sakai et al. Study (2009): The previous study conducted by Sakai and colleagues in 2009 focused on the economic assessment of batch biodiesel production processes using both homogeneous and heterogeneous alkali catalysts. The study evaluated manufacturing costs, and the relevant data for this study is used as a point of reference. Other Previous Studies: Other relevant studies in the field assessed different aspects of biodiesel production, such as technoeconomic analyses and cost assessments.

Comparative Metrics: Plant Capacity and Catalyst Type: The primary point of comparison is between the capacity of the biodiesel production plant and the type of catalyst used. The present study uses an alkali catalyst and has a production capacity of 1,000 tonnes, while the Sakai et al. study used an alkali catalyst as well but had a capacity of 7,260 tonnes. Feedstock and Costs: Different feedstocks are compared. The present study uses palm oil with a feedstock cost of $557 per tonne, while Sakai et al. used waste cooking oil with a feedstock cost of $445 per tonne. The glycerol credit is $100 per tonne in the present study, whereas Sakai et al. reported no glycerol credit. Manufacturing Costs: The manufacturing costs are compared for the two studies. In the present study, the manufacturing cost for the immobilized enzyme catalyst process was found to be $2,414.63 per tonne. In contrast, Sakai et al. reported a manufacturing cost of $641 per tonne for the batch process using homogeneous alkali catalyst. Plant Costs: The plant investment costs are another key metric. In the present study, the plant cost for the alkali catalyst process with a 1,000-tonne capacity is $2.12 million. This is compared to Sakai et al.'s reported plant cost of $7.99 million for a 7,260-tonne capacity plant.

The present study's manufacturing costs for the immobilized enzyme catalyst process are significantly higher than Sakai et al.'s costs for the batch process using homogeneous alkali catalyst. This difference is primarily attributed to variations in feedstock costs and catalyst type. The present study highlights the higher cost associated with palm oil feedstock, and the manufacturing costs are increased accordingly. Plant costs for the smaller 1,000-tonne capacity plant in the present study are notably lower compared to Sakai et al.'s larger 7,260-tonne capacity plant, which accounts for the substantial cost difference. This comparison reveals that the choice of feedstock and production capacity, as well as the type of catalyst, significantly impacts the economics of biodiesel production. The higher cost of palm oil feedstock and the smaller production capacity contribute to the increased manufacturing costs and lower plant investment costs in the present study.

CONCLUSION:

The conclusion section of this research paper provides a summary of the key findings and insights gained from the economic assessment of different biodiesel production processes. It also offers a reflection on the implications of the study's results for the biodiesel industry and the potential for improving the cost-effectiveness of biocatalyst processes. It presents a profound synthesis of all the findings, providing a concise yet comprehensive understanding of the subject. The conclusion underlines the superiority of the alkali catalyst process due to its cost-effectiveness, primarily attributed to shorter reaction times. However, it also offers a glimmer of hope by suggesting that cost reductions in biocatalyst processes could be achieved with further advancements in enzyme technology and reduced enzyme costs. Comparative Production Costs: The conclusion starts by highlighting the main result of the study. It confirms that biodiesel production using the alkali catalyst process was found to be the most cost-effective among the three processes under consideration. The cost per tonne of biodiesel produced using alkali catalyst was the lowest when compared to the soluble enzyme and immobilized enzyme catalyst processes. Factors Influencing Costs: The conclusion delves into the factors contributing to these cost differences. It explains that the higher production cost in the biocatalyst processes, both soluble and immobilized, can be primarily attributed to the higher cost of enzymes. Additionally, the longer reaction time required in the enzymatic processes impacts production costs significantly. Importance of Reusability: The conclusion highlights the importance of the reusability of the immobilized enzyme catalyst, which helps reduce production costs. In contrast, the soluble enzyme catalyst does not share this advantage and, as a result, incurs higher costs. Future Implications: The conclusion reflects on the potential for biocatalyst processes to become more cost-competitive in the future. It mentions the development of white biotechnology as a promising avenue for reducing the cost of lipase enzymes, a critical factor in enzymatic biodiesel production. Summary of Cost Comparisons: To reiterate, the conclusion emphasizes that while alkali catalyst processes currently offer the lowest production costs, improvements in biocatalyst processes, such as enhancing the reusability of immobilized lipase and reducing enzyme costs, could make them more competitive. Implications for Research and Industry: The conclusion implies that further research and development efforts should focus on making biocatalyst processes economically viable for large-scale biodiesel production. As the biofuels industry continues to grow, finding ways to reduce costs will be crucial to ensuring the sustainability and competitiveness of biodiesel as an alternative to fossil fuels.

In summary, the conclusion of this research paper underscores the economic assessment of biodiesel production processes, with an emphasis on the cost-effectiveness of alkali catalyst versus biocatalyst processes. It suggests that there is potential for improvement in biocatalyst processes, making them more competitive with traditional chemical catalyst processes in the future.