Purification of Crude Glycerol and Its Conversion to Bio-Chemicals

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Canadian canola-based biodiesel production is projected to increase over the next few years. Researchers at the University of Saskatchewan conducted a multi-year, multi-objective project with the aim to improve the glycerol purification process as well as the glycerol-based by-product process. With commercialization, value-added processing may generate additional revenue for the industry, expand the use of canola and other vegetable oils in green fuel and chemical development, and improve the environmental footprint of biodiesel production, in-turn potentially reducing petro-based fuel production.

Canadian canola-based biodiesel production is projected to increase over the next few years, also increasing the amount of crude glycerol in the production waste stream. Crude glycerol does not have direct uses, but when purified it is a promising low-cost feedstock for producing value-added chemicals such as glycerol-ether and glycerol-carbonate.

Researchers at the University of Saskatchewan conducted a multi-year, multi-objective project with the aim to improve the glycerol purification process as well as the glycerol-based by-product process, which could be added to current canola-based biodiesel production facilities in effort to improve economic benefit and reduce their environmental footprint. The project objectives were to optimize the glycerol purification process using bench testing methods in both batch and semi-continuous flow processes, to develop, characterize, test, and validate novel ceramic catalytic ultra- and nano-filtration membranes and convert purified glycerol into value-added products, such as glycerol ether and glycerol carbonate. Researchers also conducted an industrial-scale techno-economic feasibility study to determine scalability of these new process developments in currently operational biodiesel production facilities.

Crude glycerol was purified using a series of physico-chemical treatments, including saponification, acidification, phase separation, and extraction, yielding 88.6% wt. pure glycerol, which was further purified with membrane filtration processes. Two studies were conducted to evaluate the effects of temperature, pressure, flow rate, and molecular weight cutoff of ceramic membrane on glycerol purity to optimize glycerol purification processes. The first study was conducted in a batch system and the results were used to determine the best process conditions for glycerol purification. A maximum purified glycerol yield of

97.5% wt. was obtained. In the second study, best process conditions were defined for a semi-continuous flow system and a maximum glycerol yield of ~94% wt. was obtained.

In two additional studies, researchers developed, characterized, tested, and validated two different ceramic membrane catalysts to convert pure glycerol into value-added glycerol ether and glycerol carbonate. In one study, various ceramic catalyst membranes (filters) were developed and tested with differing levels of TPA (12-Tungstophosphoric acid) composition (ranging from 25% to 75%). In another study, researchers aimed to develop a green process for the production of glycerol-carbonate using a titanium-SBA-15 based solid acidic ceramic catalyst membrane, which is preferred to what is currently in use as it's non-toxic with eco-friendly silica framework, is easily recoverable, and can be restored for additional uses through calcination, further reducing process waste. This newly developed ceramic catalyst membrane had better performance compared to previous solid catalysts currently reported in the literature.

To complete the project, a techno-economic analysis was carried out and showed it is economically feasible to purify glycerol, based on a scenario where all the purified glycerol is converted to the value-added chemicals solketal (a glycerol-ether additive to improve biodiesel quality) and glycerol carbonate. In this scenario, the required capital investment was $0.72 M and the net present value of the project was $26 M over 10 years of operation after start-up with capital investment in the initial three-year period with no returns. The unit cost of purifying a kg of crude glycerol was $13.62 and the unit revenue is $116.62 (USD) per kg of crude glycerol input, making it a promising undertaking. A value-added production process would provide a great return, but alongside a multi-million dollar biodiesel plant, there is an insignificant overall return in revenues. The greatest benefit of the addition of a value-added process would be in offsetting environmental costs and improving facility bottom-line.

These studies resulted in the development and analysis of various process improvements, including glycerol purification and processing for value-added products, particularly glycerol ether and glycerol carbonate. These technologies, if implemented in an industrial-scale biodiesel production facility, may decrease the overall cost of production of biodiesel and determine new ways to use otherwise discarded crude glycerol. With commercialization, value-added processing may generate additional revenue for the industry, expand the use of canola and other vegetable oils in green fuel and chemical development, and improve the environmental footprint of biodiesel production, in-turn potentially reducing petro-based fuel production.

Scientific publications

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