MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Novel Supercritical Biodiesel Plant Design and Process Scale-up

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Objective

To design a transportable, modular biodiesel refinery in which a novel, scaled-up process will reduce the cost and environmental impact of production of high-quality biodiesel from waste cooking oil.

Background

By reducing the net anthropogenic carbon emissions from burning fossil fuels, biodiesel remains an attractive alternative to petroleum-derived diesel fuels. The traditional transesterification-based process combines an animal or plant-based feedstock and methanol to produce fatty acid methyl ester (biodiesel) and glycerol. The current production process relies on continuously stirred reactors and corrosive acid (or base) catalysts to produce biodiesel using energy-intensive separations and requires high transportation costs to supply feedstock and ship the biodiesel product to market distribution centers. These issues combine to limit biodiesel production and its use in society.

Approach

The novel system differentiates itself from current biodiesel production facilities by four distinct characteristics:

1. Modular Design
2. Transportable Configuration
3. Novel Reactor Technology
4. Improved Separation and Purification Technology

These characteristics are derived from the principles of Process Intensification, especially the second, in which the optimal design gives "each molecule the same processing experience" [2]. From this process intensified concept, a comprehensive design package has been developed.

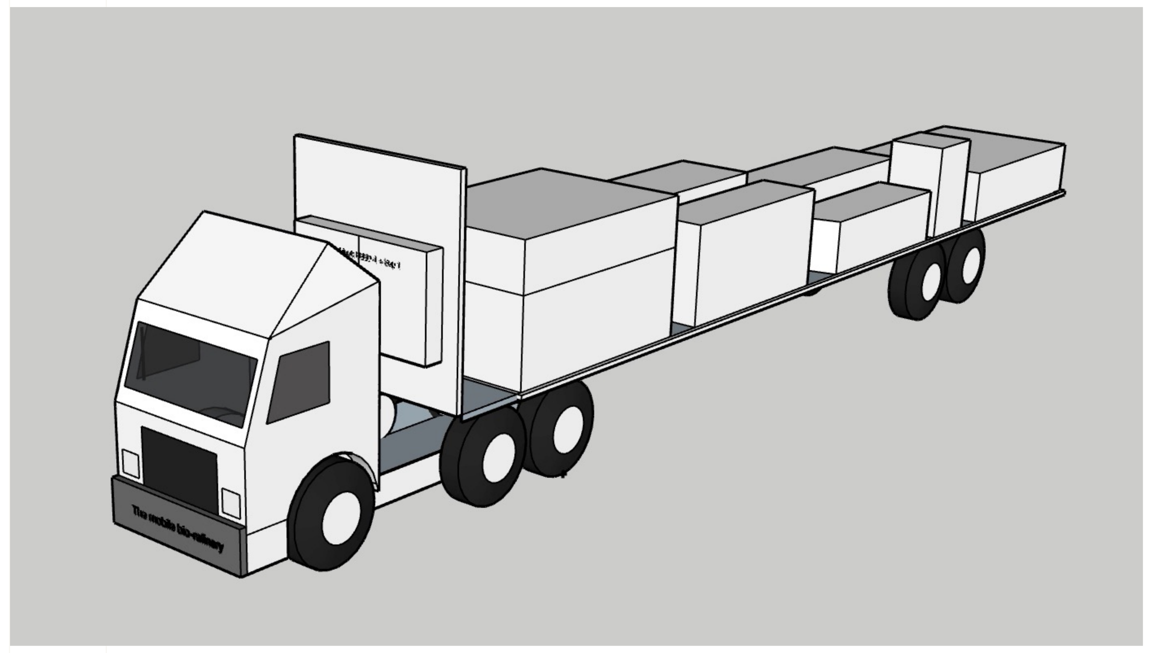

Figure 2: Conceptual 3D Sketch of Modular Design

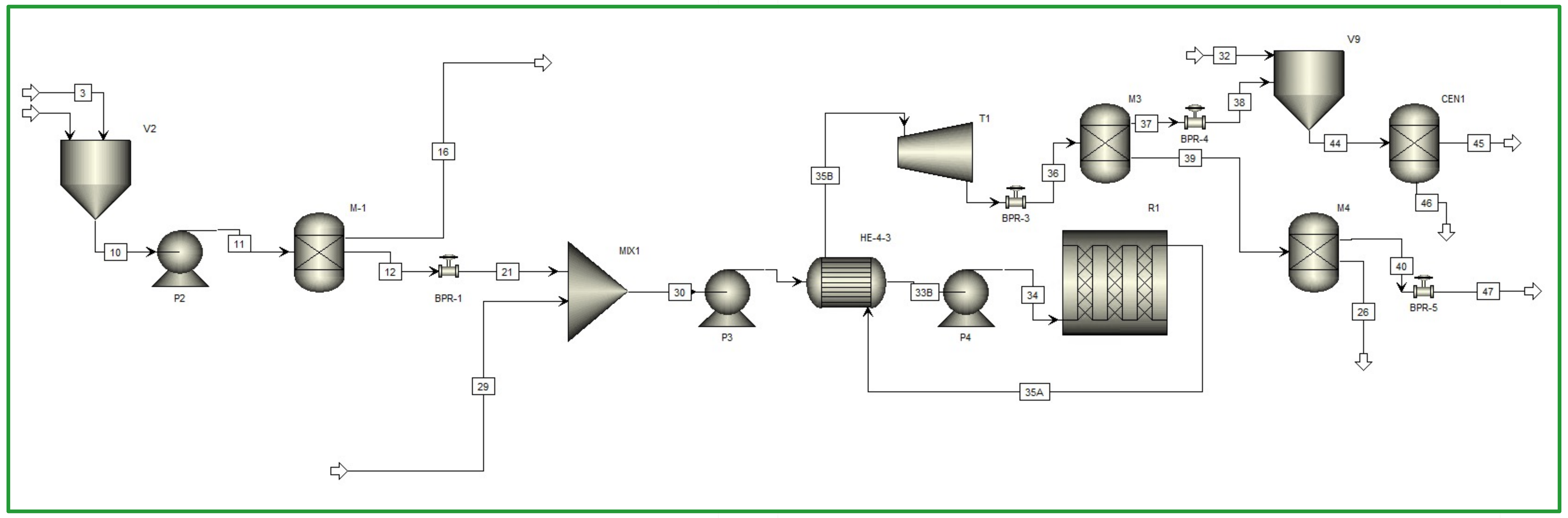

Figure 1: Aspen Plus™ Flowsheet

Component Name	Approx. Molecular Weight (Da)
Vegetable Oil	885
Free Fatty Acids	282
Acetone	58
Fatty Acid Methyl Esters	297
Glycerol	92
Methanol	32

Figure 3: Approximate Molecular Weights of Components

Results

A Piping and Instrumentation Design (P&ID) of the refinery has been prepared in AutoCAD Plant 3D™. After extensive review and discussion, it was revised and completed as an integral part of the design. This P&ID was used to complete a comprehensive Hazard and Operability (HAZOP) Study, and possible deviations in process conditions were formally addressed by adding engineering and administrative controls to ensure safe operation. Based on this, a detailed Control Narrative for all seven nodes in the process was developed and reviewed.

Additionally, all equipment and instrumentation has been named and listed in a bill of materials from which the capital expense of the refinery was estimated. Lastly, a detailed Aspen Plus™ simulation has been developed to properly model the scalability of the process, considering specific equipment size. This model is being used to assess the thermodynamic efficiency of the process.

Discussion

This innovative process will be faster and more efficient than the current FAME biodiesel production process. A novel spiral wound plug flow reactor allows the uncatalyzed transesterification reaction to efficiently and safely produce high-quality biodiesel locally reducing the feedstock transportation costs. Nanofiltration membrane technology allows separation at lower operating costs and reduced carbon emissions.

Figure 4: Novel Reactor Technology at the Lab-scale [1]

Concluding Remarks

With a P&ID, a HAZOP Study, a bill of materials, a Control Narrative and an Aspen model, this novel refinery is closer to commercial operation in a full-scale plant. Future work includes continuing to improve the Aspen model and developing fabrication drawings while developing a full system controls model using a Mimic™ controls model. The team plans to construct and test a prototype plant to establish this intensified process for the biodiesel industry aimed at supporting a better, more sustainable future.

References

1. Hassan, A.A., Smith J.D. (2021) "Laboratory-scale Research of Non-catalyzed Supercritical Alcohol Process for Continuous Biodiesel Production," Catalysts, 11 (4) 435.
2. Stankiewicz, A. I. and Moulijn, J. A. "Process Intensification: Transforming Chemical Engineering," Chemical Engineering Process, 22-34 (Jan. 2000).

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