CONCEPTUAL DESIGN OF A METHANOL SYNTHESIS PROCESS FROM MICROALGAE BIOGAS

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ABSTRACT – Nowadays, chemical industries seeks to develop clean technology for energy production, so that environmental impacts can be minimized. Methanol is an important chemical and a green alternative to supplant fossil fuel as energy storage. In this context, a conceptual methanol synthesis plant utilizing biogas produced from microalgae as feedstock was designed and analyzed utilizing computational simulation. The results obtained shows that the proposed process is capable of producing high purity methanol with a high global conversion, which confirms its potential to be a viable and green alternative source.

1. INTRODUCTION

The development of clean technology for energy production has become priority for the industry in recent years. In this context, the search for a biomass that can be utilized as renewable sources and can be both environmentally and economically friendly is of great interest. The use of microalgae for biogas production emerges as a potential substrate source (Dębowski et al., 2013).

Methanol is a primary chemical product with a wide range of application, as it can be used as solvent, fuel and as feedstock for the synthesis of other chemicals such as formaldehydes and acetic acid. Moreover, the use of methanol as energy storage replacing fossil fuels can reduce greenhouse gases emissions (Olah et al., 2009).

The use of biogas as feedstock for the methanol synthesis has been investigated by Vita et al. (2018) and Santos et al. (2018). The authors studied biogas from sources such as landfill and corn cobs, which have different compositions compared to the biogas from microalgae. As far as we know, there is no work in the literature considering the use of biogas from microalgae for methanol production.

A conceptual design of the methanol synthesis plant from biogas was developed based on the works of Vita et al. (2018) and Santos et al. (2018). The plant was then simulated to obtain the methanol yield and global conversion of the process, with the objective of studying this rote as a new and more environmentally friendly route.
2. METHODOLOGY

The process can be divided in three different steps: biogas reform, syngas conversion to methanol and the posterior purification and separation. The composition of biogas from microalgae, 68% of CH₄ and 32% of CO₂, was adapted from the work of Giwa (2017). The conceptual plant flowsheet is illustrated in Figure 1.

![Conceptual plant of methanol production from biogas](image-url)

Figure 1 – Conceptual plant of methanol production from biogas.

The feed streams of biogas and steam are sent to the reformer, in which syngas is formed by the combined Steam and CO₂ reform reactions. The syngas is then compressed and sent to the synthesis reactor, in which the methanol is produced. The reactor output is sent to the flash vessel and the distillation columns, where the unreacted gases are recycled and methanol is separated and purified so that it can achieve the commercial purity of 99.85% (Grade AA).

The methodology for the simulation of the proposed plant was based on the specifications for the equipment and process streams referent to the processes developed by Vita et al. (2018) and Santos et al. (2018). Since the purification step was not present in the works of the previous authors, the distillation columns were designed based on the data of Hawkins (2013). In this work, the software UniSim Design Suite R390.1 from Honeywell was utilized. The plant was simulated in steady-state, with the thermodynamic packages of Peng-Robinson and UNIQUAC.
3. RESULTS

Figure 2 shows the simulation flowsheet of the UniSim interface and Table 1 shows the results obtained for the main streams of the methanol synthesis plant.

![Methanol plant simulation](image)

Figure 2 – Methanol plant simulation.

| Stream        | Biogas | Steam | Syngas | Prod1 | Methanol | Water | Vent |
|---------------|--------|-------|--------|-------|----------|-------|------|
| Temperature (°C) | 25     | 25    | 35     | 82    | 81       | 131   | 38   |
| Pressure (bar)   | 1      | 1     | 1      | 1,6   | 1,8      | 2,8   | 95   |
| Flowrate (kmol/h)| 1000   | 1000  | 3065   | 1065  | 855      | 210   | 291  |

|                     |        |       |        |       |          |       |      |
|---------------------|--------|-------|--------|-------|----------|-------|------|
| Molar Fractions     |        |       |        |       |          |       |      |
| CO₂                 | 0,380  | -     | 0,059  | -     | -        | -     | 0,489|
| CH₄                 | 0,620  | -     | 0,001  | -     | -        | -     | 0,009|
| CO                  | -      | -     | 0,266  | -     | -        | -     | -    |
| H₂                  | -      | -     | 0,618  | -     | -        | -     | 0,496|
| MeOH                | -      | -     | -      | 0,802 | 0,9985   | 0,0001| 0,005|
| H₂O                 | -      | 1,000 | 0,056  | 0,198 | 0,0015   | 0,9999| 0,001|
The results obtained demonstrate that the simulation of the conceptual plant in UniSim shows satisfactory results, with a global conversion of biogas to methanol of around 85% and methanol production values in the rounds of 26700 kg/h, which is similar to the results found by Santos et al. (2018) for other biogas sources such as palm oil effluent and landfill gases, and Luyben (2013) for the conventional fossil fuel syngas plant.

The results from the simulation of the methanol synthesis plant, considering the conceptual design phase, shows that biogas from microalgae is able to produce a methanol yield with comparable capacity compared to the conventional and other biogas processes. Furthermore, the conceptual plant illustrates the potential of this alternative rote, demonstrated by the high global conversion of the process and the capability of generating a methanol of the highest commercial grade.

4. CONCLUSION

The simulation of the conceptual methanol synthesis plant form microalgae biogas achieved satisfactory results when compared to other biogas and conventional plant from the literature. The methanol production process from biogas algae showed to be a possible alternative for a green methanol synthesis rote, complying with the highest commercial grade for the product. Therefore, this work shows that there is potential to be explored in the utilization of biogas from microalgae for this purpose. For future works, a techno-economic analysis can aid in the development of this technology.

5. REFERENCES

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