Anaerobic digestion of crude glycerol from biodiesel production for biogas generation: Process optimization and pilot-scale biodigester operation

Bruna Sampaio de Mello[1,2], Arthur Pozzi[3], Brenda Clara Gomes Rodrigues[1,2], Maria Angélica Martins Costa[1], Arnaldo Sarti[1,2,4]

[1] São Paulo State University (UNESP), Institute of Chemistry, Campus Araraquara, Department of Engineering, Physics and Mathematics, 14800-900, Araraquara, SP, Brazil.
[2] Bioenergy Research Institute - IPBEN, UNESP, Institute of Chemistry - Araraquara, SP, Brazil
[3] University of Araraquara, 14801-320, Araraquara, SP, Brazil
[4] Center for Monitoring and Research of the Quality of Fuels, Biofuels, Crude Oil, and Derivatives- Institute of Chemistry - CEMPEQC, UNESP. Araraquara, SP, Brazil
Keywords: *bioenergy, CCD, methane, waste cooking oil.*
Presenting author email: brunamello30@gmail.com

Biodiesel is a biodegradable fuel derived from renewable sources (waste cooking oil, fats, soybean oil), which can be obtained by different processes such as transesterification. However, like any industrial process, residues and wastes are generated and for each kilogram of biodiesel produced, approximately 100 g of glycerol (GLY) are generated by the transesterification process (Chilakamarry et al., 2021). In this context, a very promising technology is using crude GLY as a substrate for anaerobic digestion and/or co-digestion and methane production (Viana et al., 2012).

In this study, glycerol (GLY) generated in biodiesel production from waste cooking oil was used as the sole organic source for biogas production. The experiment was divided into two parts: the first phase consisted of an experimental design based on central composite design (CCD) focusing on optimizing the biogas production from crude GLY in lab-scale reactors (500 mL). The second phase was conducted on a pilot-scale (1 m^3) biodigester based on the results of CCD. Optimization of the factors that influence the anaerobic digestion of crude glycerol was performed by CCD with two variables, food to microorganism (F/M) ratio and batch time (t_b), at five levels and the specific methane production (SMP) was the response variable. The results showed that F/M ratio of 2.04 gCOD/gVS and a batch time of 5 days reached the highest specific methane production of 46 NmLCH4/gVS (Figure 1). The desirability function revealed that the optimal conditions related to the maximum methane production were a batch time of 6 days while the ideal F/M ratio was not achieved in the interval evaluated.

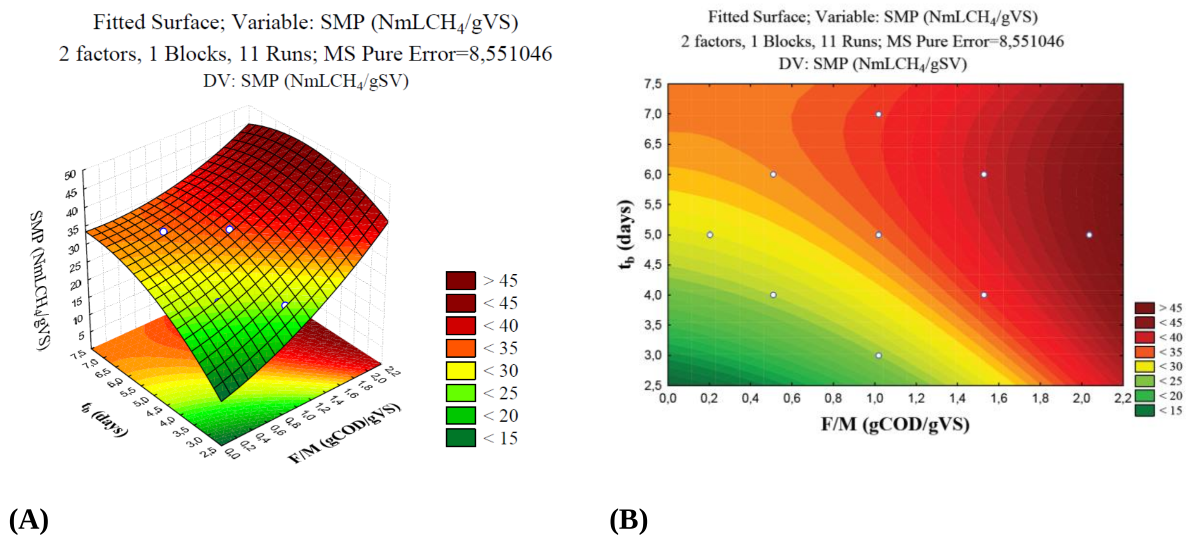

Figure 1. 3D response surface (A) and Contour plot (B) of the SMP from the anaerobic digestion of crude GLY.

Based on the results of the CCD, pilot-scale digester (1 m^3) was monitored, and biogas production from crude GLY as the sole carbon source was evaluated. The crude GLY, without pretreatment or nutrient supplementation, was pumped from a storage tank (5 L) to the bottom of the biodigester by a peristaltic pump which also provided the recirculation of the system. The added volume of crude GLY was varied according to the results of CCD (F/M ratio), ranging from 0.5 L to 2.5 L. At the beginning of the biodigester operation, the cycle time was set at 7 days (5 cycles), then reduced to 6 days (2 cycles) also according to the results of CCD. The volume of the biogas flow rate was measured daily by a commercial volumetric gas meter and samples were taken as a function of time and analyzed by gas chromatography.

Figure 2 presents the results of each cycle evaluated. The cycles that presented the highest accumulated and specific production of biogas (with, on average, 68% in methane) were cycles 3 and 4, in which the volume of glycerol added to the biodigester was 1 L. Cycles 1 and 2, which used 0.5 L of glycerol, showed lower daily biogas production, with daily averages of 74.7 and 57.7 L in cycles 1 and 2, respectively. These results contradicted the results demonstrated by the CCD lab experiments. The ideal batch time reached in the pilot-scale operation was 7 days, and the F:M of 0.2 gCOD/gVS. During the following cycles (5 – 9), biogas production had a great inconstancy, mainly due to the accumulation of glycerol and volatile fatty acids in the biodigester.

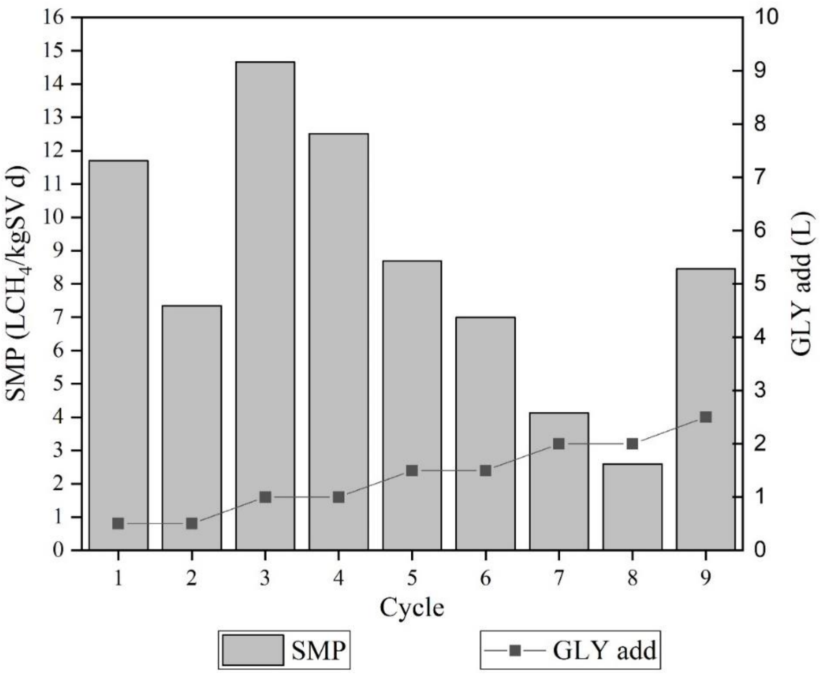

Figure 2. Specific methane production according to the volume of GLY added each cycle.

References

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