H_2/CO_2 Fermentation for Carbon Dioxide Removal from Biogas

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Abstract

The biogas produced from the anaerobic degradation of waste has a calorific value of 21.48 MJ/m^3 (with about 60% methane content). Unfortunately, this promising energy source contains 30% of non-calorific carbon dioxide, which is released in the atmosphere as greenhouse gas when the biogas is used as energy provider.

Convert the carbon dioxide contained in the biogas to methane represents an advantage with double impacts. 1) Solve the problem of the greenhouse gas emission from anaerobic digestion and 2) increase the biogas energy value. The shift of carbon dioxide to methane necessitates finding out a reactor operational characteristics (material balance, dilution rate and temperature) that allow an efficient conversion performance and an economically less cost application process with gas as substrate. The present study proposes to achieve the sub-cited objectives by using H_2/CO_2 fermentation chemostat reactors with acclimated hydrogenotrophic methanogens culture.

Experimental chemostat reactors are regularly fed with minerals salt and limiting trace metals at different dilution rates; in addition, 12 L mix gases H_2/CO_2 (80:20, v/v) is supplied as limiting single substrate. The material balance is determined by the application of the Monod model to the steady state chemostat cultivation. The results show that 0.1/d is the dilution rate at which the cells concentration is maximal and the methanogenic activity, 0.41 LCH_4 /gVSS.d, the highest. The growth yield Y_{CH4} is 11.66 g cells formed /mmol H_2/CO_2 consumed. The maximal specific growth rate μmax and the Monod half saturation coefficient K_S are 0.15/d and 0.82 g/L respectively. The determined material balance data are computed from the Monod chemostat model and the result predicts the

dependence of the H_2/CO_2 concentration, S and the cell concentration, X on the dilution rate and the cells washout is realized when the dilution rate is 0.14/d.

In the H_2/CO_2 fermentation, like all bioprocess researches, the economic considerations play an important role in the plant design. I have investigated an experiment, the impacts of vary the mixing durations, the heat balance and the vitamin B_{12} production on the carbon dioxide conversion to methane process economy. Using four mixing durations (60 min/h, 45 min/h, 30 min/h and 15 min/h) to four reactors set up at 0.1/d dilution rate with two fermentation temperatures (37^{o}C and 20^{o}C). The results show that 60 min/h mixing duration has the maximum H_2/CO_2 gas dissolution rate in the liquid but the best conversion rate of H_2/CO_2 gas to methane is at 45 min/h mixing duration with 37^{o}C (80.8%) and 20^{o}C (39.8%). The continuous mixing rate may induce cells damage in the culture growth. I have measured the vitamin B_{12} presence in the effluent and the maximal production is at 45 min/h mixing, 3 mg/L-effluent for 37^{o}C and 0.61 mg/L-effluent for 20^{o}C cultivations. The application of the obtained experimental results to estimate the carbon dioxide reduction from the biogas produced in an anaerobic wastewater treatment plant (Chikusei City) gives the following results. The release of carbon dioxide in the atmosphere if the biogas produced from Chikusei City plant is use as energy source is reduced from 153.6 Nm3/d emission to 29.5 Nm3/d at 37^{o}C and for 20^{o}C cultivation, the reduction is from 173.9 Nm3/d to 111.6 Nm3/d. The methane content in biogas increases from 268.7 Nm3/d to 392.8 Nm3/d at 37^{o}C and from 279 Nm3/d to 341 Nm3/d at 20^{o}C.The vitamin B_{12} production is 32.7g/m^3 effluent at 37^{o}C and 8 g/m^3 effluent at 20^{o}C.