Methane Production from Biomass Wastes by Anaerobic Fermentation (Vol. 4): Rationalization of Multi-Stage Fermentation and High Temperature Fermentation & Examination of Hydrogen Fermentation

Methane fermentation technologies for biomass waste have been used around the world for many years. However, there has been a lack of quantitative studies into fermentation mechanisms. The International Water Association's model for methane fermentation "Anaerobic Design Model No.1" (ADM1) [1] was applied to two-stage continuous and high temperature processes of methane fermentation and to hydrogen fermentation process, which has potential to increase energy production. The improvements in yield of methane fermentation and the mechanisms of hydrogen fermentation were investigated.

- To improve methane fermentation process, a combination of a higher fermentation temperature of 55°C and a two-stage continuous fermenter was investigated. In the case of sewage sludge, the COD decomposition rate increased by 33% at high temperatures, with biogas production costs reduced from 3.3 JPY/MJ to 2.3 JPY/MJ. In the two-stage fermentation, the COD decomposition rate increases by 6–8%.
- Hydrogen is produced when the pH of the fermenter is between 4 and 5. The examination involved a combination of two tanks. The first tank, used for hydrogen production, is kept at at 55°C with a pH of about 5, and the second tank, for methane fermentation, is kept at 35°C with a pH of about 8. After a total residence time of 20 days, the amount of energy generated by both sewage sludge and garbage was 11% more than that of methane fermentation only (Table 1).

Proposals for Policy Development

ADM1 can be used to predict hydrogen and methane fermentation. As a next step, it will be necessary to optimize the model and fermentation conditions by confirming consistency with experiments.

1) Quantitative analysis and optimization of the fermentation mechanisms and systems are required, So that the COD decomposition rate would be increased to more than 80%.
2) For hydrogen fermentation, conditions need to be considered for optimal fermentation that inhibits methane-producing fermentation bacteria and activates hydrogen-producing fermentation bacteria.

Table 1: Hydrogen fermentation and energy production

Raw materials: supply of 5m^3/d, concentration of 58.6 kg-COD/m^3

Raw material	Sewage sludge	Sewage sludge	Raw garbage	Raw garbage
Hydrogen fermentation tank	**Yes**	**No**	**Yes**	**No**
Temperature (°C)	55		55	
pH	4.83		4.79	
Residence time (d)	**1**	**-**	**1**	**-**
Amount of CO_2 produced (m^3/d)	11.9		9.13	
Amount of H_2 produced (m^3/d)	4.31		4.21	
Amount of CH_4 produced (m^3/d)	1.85		1.36	
Amount of energy produced (MJ/d)	113		94	
Methane fermenter				
Temperature (°C)	35	35	35	35
pH	8.19	7.87	8.14	7.81
Residence time (d)	**19**	**20**	**19**	**20**
Amount of CO_2 produced (m^3/d)	55.3	55.5	82.8	81
Amount of H_2 produced (m^3/d)	0.0251	0.0016	0.004	0.0026
Amount of CH_4 produced (m^3/d)	69.1	65	94.5	87.5
Amount of energy produced (MJ/d)	2474	2327	3383	3133
Total amount of energy produced (MJ/d)	**2587**	**2327**	**3477**	**3133**
Comparison with methane fermentation only	**1.11**	**1**	**1.11**	**1**
Total COD decomposition rate (digestion rate)	**0.520**	**0.479**	**0.719**	**0.657**

[1] D.J. Batstone et al., "Anaerobic Digestion Model No.1", Scientific and Technical Report No.13, International Water Association, 2002.