Removal of Fermentation Gases Accelerates Anaerobic Digestion to Methane

Richard A. Kohn

University of Maryland, MD, U.S.A.
rkohn@umd.edu

Abstract

Solar energy and waste products can be converted to fuels through microbial digestion and fermentation of biomass. Methane (CH_4) gas is one of the most efficiently produced biofuels. Current processes using microorganisms to digest biomass and produce CH_4 are slow and require large reactors. We are developing faster methods that use microorganisms from the first stomach chamber (rumen) of cows. These microorganisms readily digest plant fiber, and diluting and removing fermentation gases accelerates the digestion process further.

1. Introduction

Anaerobic microbial digestion of biomass to methane and hydrogen is an effective way to convert plant organic matter to biofuel. However, this process is slow and requires retention times of weeks or months. The microorganisms that live in the first stomach chamber of cattle, called the rumen, orchestrate the fastest microbial degradation of biomass on earth. These microorganisms can produce methane (CH_4), hydrogen (H_2) and ethanol. Mixed cultures of living microorganisms degrade biomass considerably faster than pure cultures or enzymes, and many forms of feedstock can be digested with minimal pretreatment or drying. For example, grass, paper, algae, animal manure, and sewage can be digested without pretreatment.

Anaerobic digestion initially releases carbon dioxide (CO_2), H_2 and organic acids. Methane is produced from CO_2 and H_2 ($CO_2 + 4H_2 \leftrightarrow CH_4$). The organic acids (e.g., acetic acid) are subsequently broken down to H_2 and CO_2 or CH_4 in a rate-limiting step ($CH_3COOH \leftrightarrow CO_2 + H_2$). Typically, gas pressure is relieved as it builds up, so the total gas pressure is maintained at 1 atm. We calculated the ΔG for methanogenesis and acetic acid degradation under typical fermentation conditions. The ΔG was near 0 for both reactions, indicating each reaction is near equilibrium. Therefore, we hypothesized that removing end product gases would favor growth of microbes capable of degrading acetic acid, and accelerate production of additional gases.

2. Methods

Timothy hay (0.5 g) was incubated at 38°C for 24 h with media containing inocula from the rumen of a cow and starting with N_2 or CO_2 in the headspace. Produced gases were allowed to accumulate in mylar balloons or were diluted by intermittently perfusing additional gas. Gases were analyzed for CO_2, CH_4, H_2 and N_2 using gas chromatography.

3. Results

The results are shown in Table 1. Hydrogen concentration did not change despite a 5-fold dilution of initial gas headspace with N_2, but H_2 concentration increased with perfusion of CO_2. As a result, H_2 production was four times greater with N_2 perfusion compared to allowing gases to accumulate, and 11 times greater with CO_2 perfusion compared to allowing gases to accumulate. CH_4 production was greater with perfusion of N_2 and numerically greater for perfusion with CO_2. CO_2 production was 68% higher for perfusion with N_2 compared to allowing gases to accumulate.

Table 1. Measured CO_2, CH_4, H_2 and N_2 content of produced gases.

	Perfused		**Accumulated**	
	N_2	CO_2	N_2	CO_2
H_2 (%)	0.05^a	0.13^b	0.06^a	0.05^a
H_2 prod (μmol)	12.50^b	32.30^c	3.0^a	3.00^a
CH_4 (%)	1.30^a	1.50^a	5.5^b	4.80^b
CH_4 prod (μmol)	322.00^b	383.00^b	254.0^a	339.00^a
CO_2 prod (μmol)	1507.00^b	---	897.0^a	---

[ab]Means within row with different superscripts differ ($P < 0.05$), n = 3.

4. Conclusions

Microorganisms from the rumen of a cow readily degraded grass hay to CH_4 and CO_2. Dilution of fermentation gases in anaerobic digesters decreases the partial pressure of end product gases in the fermentation resulting in faster feedstock degradation. We propose design of biomass digesters using microorganisms from the cow's rumen and to facilitate dilution of fermentation gases (patent pending [1]) to decrease digestion time from weeks or months to a few days.

5. References

1. Process for rapid anaerobic digestion of biomass using microbes and the production of biofuels therefrom. R.A. Kohn, University of Maryland, U.S. Patent 2008 0187975A. International: PCT/US2007/025788.

Author Biography

Dr. Richard Kohn is a Professor of Animal Science at the University of Maryland, U.S.A. His research interests include mathematical modeling of fermentation and metabolism. He has developed methods using microorganisms to produce biofuels including methane, hydrogen and ethanol from various organic feedstock.