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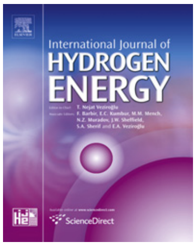

Technical Communication

Experience of a pilot-scale hydrogen-producing anaerobic sequencing batch reactor (ASBR) treating food waste

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ABSTRACT

A pilot-scale H_2-producing anaerobic sequencing batch reactor (ASBR) treating food waste was operated. During the operation, the carbon/nitrogen (C/N) ratio was adjusted from 10 to 30 by changing the composition of the food waste. When the C/N ratio was lower than 20, the H_2 yield was maintained at around 0.5 mol H_2/mol $\text{hexose}_{\text{added}}$, accounting for 2.3% of energy conversion efficiency contained in food waste to H_2, but it gradually dropped at higher C/N ratios. The low performance was accompanied by increased production of lactate, propionate, and valerate. In order to recover the performance, alkaline shock (pH 12.5 for 1 day) was imposed on the entire mixed liquor in the fermenter. This alkaline shock method was so effective that the H_2 yield significantly increased to over 0.9 mol H_2/mol $\text{hexose}_{\text{added}}$, and was then stabilized at 0.69 mol H_2/mol $\text{hexose}_{\text{added}}$. In addition, the settling characteristics of H_2-producing ASBR, which was separated into three layers, were investigated. Ribonucleic acid (RNA) as well as volatile suspended solid concentrations of each layer were measured to suggest how to enhance the H_2 production in ASBR operation.

1. Introduction

Owing to its environmentally friendly aspects in producing hydrogen, biological H_2 production via dark fermentation has gained significant attention these days. Dark fermentation proved to be more practicable and commercially applicable than light-dependent biological processes because of its fast production rate, technical simplicity, and no requirement of additional light energy [1]. In addition, dark fermentation allows one to utilize waste and wastewater as substrates, which greatly enhances the economic benefit. For example, food waste causing problematic odor and leachate could be a suitable feedstock for biological H_2 production [2].

Carbon/nitrogen (C/N) ratio of waste feedstock, which depends on the source, is a crucial parameter in biological processes. Since nitrogen is the most essential nutrient for the bacterial growth, its proper supply could maximize the microbial growth, enhancing the reactor performance. However, its excessive addition could cause ammonia inhibition [3]. Besides, it is reported that C/N ratio has a crucial

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function on extracellular polymeric substance (EPS) production and biological nutrient removal systems [4,5]. The importance of C/N ratio in H_2 production has also been mentioned before, however it was only investigated in batch operation [6] and moreover, there has been no report on treating non-sterilized actual waste.

In the present work, food waste was selected as a feedstock, and a pilot-scale H_2-producing anaerobic sequencing batch reactor (ASBR) was operated, which could provide essential information for the practical application. Intentionally, the C/N ratio was controlled by adding steamed rice or peptone to the raw food waste. In addition, alkaline shock (pH 12.5 for 1 day) was tried in the whole mixed liquor in the fermenter in an attempt to recover the performance.

2. Materials and methods

2.1. *Seed sludge and feedstock*

The seed sludge was taken from an anaerobic digester in a local wastewater treatment plant. The pH, alkalinity, and volatile suspended solids (VSS) concentration of the sludge were 7.6, 2.83 g $CaCO_3$/L, and 5.5 g/L, respectively. It was heat-treated at 90 °C for 15 min to inactivate hydrogen consumers and to harvest spore-forming anaerobic bacteria such as *Clostridium* sp. [7].

The food waste collected from a school cafeteria where more than 1000 people eat at every meal was used as the main feedstock, and steamed rice and peptone were intentionally added to control the C/N ratio. The characteristics of the food waste, including the C/N ratio, volatile solid and carbohydrate content were almost constant, with a margin of error of less than 10%. Here, the terminology 'C/N ratio' was defined as '(chemical oxygen demand (COD) of carbohydrate)/(total nitrogen (TN)) ratio'. It is more reasonable to fix total the carbohydrate concentration than to fix total organics because the H_2 production potential of carbohydrates is much higher than that of lipids or proteins [8]. The average C/N ratio of food waste, steamed rice, and peptone were 19.10, 76.12, and 0.23, respectively, and about 55% of food waste and 96% of steamed rice was composed of carbohydrate on a COD basis. The carbohydrate content in the peptone was negligible. The average C/N ratio of food waste in Korea was 18.02 [9], which was similar with the value obtained in this study.

2.2. *Reactor operation and analytical methods*

The pilot-scale H_2 fermentation system was divided into four compartments for: grinding, pretreatment, feeding, and fermentation. Food waste collected from the school cafeteria, and the steamed rice were ground to less than 5 mm in diameter, followed by alkali pretreatment at pH 12.5 for 1 day using 6 N KOH solution. Direct conversion of carbohydrate to acids by the pretreatment was negligible, less than 4%. It was reported that this pretreatment method enhanced H_2 production by suppressing unintended microbial reactions and was economical [2]. Pretreated feed was pumped to the feed tank and diluted with tap water to maintain the carbohydrate concentration at 30 g carbo. COD/L (COD of carbohydrate) [10]. Around 10 g of KOH was added to 1 L of diluted food waste, which would increase the concentration of K^+ up to 0.2 mol/L in the reactor. However, this concentration was still lower than the reported inhibiting concentration, and thus the inhibitory effect of K^+ was not considered here [4].

The working volume of the fermenter was 0.15 m^3 (liquid depth of 770 mm and inner diameter of 500 mm) with a total volume of 0.23 m^3. 0.05 m^3 of feed was pumped in every 12 h, corresponding to 36 h of hydraulic retention time (HRT). One cycle of the sequencing batch operation consisted of 0.5 h filling, 8 h reaction, 3 h settling, and 0.5 h decanting. During filling and reaction phases, the broth was agitated at 30 rpm. The operation pH was controlled at 5.3 ± 0.1 by 3 N KOH addition [2,10]. It was important not to add alkali solution during the settling and decanting phases even though the pH was lower than 5.3. Otherwise, excess amount of alkali solution could enter the fermenter as there was no mixing during the static phases. The fermenter was installed in a temperature controlled room at 35 ± 1 °C [2,7,10]. At the start-up, one-third of the fermenter was filled with heat-treated sludge and the rest with alkali-pretreated substrate (30 g carbo. COD/L). Continuous operation was started after 175 L of H_2 had evolved, which was equivalent to an H_2 production yield of 0.5 mol H_2/$hexose_{added}$.

Gas and liquid products were analyzed by the methods described in Kim et al. [7].

2.3. *Settling characteristics*

In order to investigate the settling characteristics of the ASBR, samples were taken from the four ports located at 5, 23, 41, and 69 cm above the fermenter bottom, after 3 h of settling. Not only VSS but also ribonucleic acid (RNA) concentration was measured according to Liwarska-Bizukojc and Ledakowicz [11].

3. Results and discussion

3.1. *Effect of C/N ratio*

Fig. 1 shows the daily variation of H_2 yield (mol H_2/mol $hexose_{added}$) at various C/N ratios. Over 40% of H_2 content was

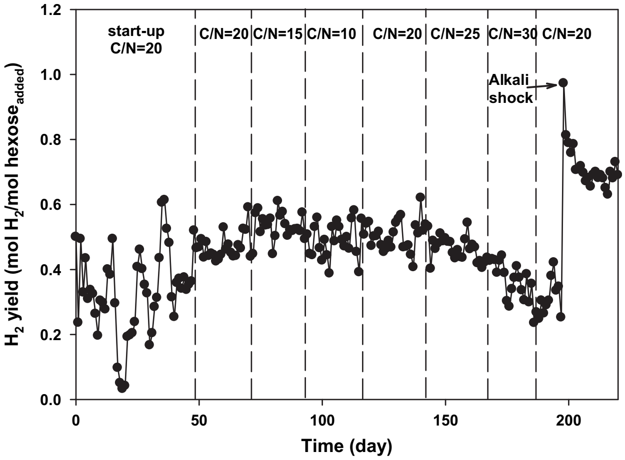

Fig. 1 – Daily variation of H_2 production yield at various C/N ratios.