Development of an Enhanced Process for Resource and Energy Recovery from Rice Husk

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1. Introduction

Recently, resource and energy recovery from biomass has attracted attention as replacement for fossil fuels. Sugar is a raw material for chemical products as bio-ethanol and is recovered by enzymatic saccharification of starch (corn, sugar cane, etc.) but competes with food production. For this reason, agricultural wastes (cellulosic biomass) have been attracting as resources that are non-competitive with food. Cellulosic biomass is mainly composed of cellulose, hemi-cellulose, lignin and ash (main component is silica) that form a complex and intricate structure [(1)]. Although cellulolytic or hemicellulolytic enzymes produced by microorganism are utilized for conversion of cellulosic biomass into soluble sugar, it is resistant to enzyme due to its rigid structure. Therefore, pretreatment is necessary in order to recover resources from cellulosic biomass. In this research, a multi-stage process for resource and energy recovery has been studied (**Fig.1**). In this process, sugar, lignin and silica that eluted by pretreatment are recovered as resources, sugar is recovered by enzymatic saccharification, and then saccharification residue is utilized in methane fermentation process in order to recover energy as methane. In this research, rice husks (Yield : about 153,000 ton/year in Niigata) was used as cellulosic biomass.

2. Materials and Methods

Finely-milled rice husk by outsourcing was used. Each 1.0 g-DM (Dry Material) contained 0.36 g-cellulose, 0.19 g-hemicellulose, 0.20 g-lignin, and 0.25 g-ash. These compositions were analyzed by the Japan Food Research Laboratories.

2-1. NaOH Pretreatment

NaOH was used for pretreatment of finely-milled rice husk. 5% rice husk (w/v, VS, Volatile Solids) as the substrate was mixed with 0.5, 1.0, and 2.0% (w/v) -NaOH solutions under temperature of 90°C for 90 minutes by using hot stirrer. The solid residue and supernatant liquid were separated by centrifugation. The solid residue was washed and dried at 105°C. The filtered supernatant liquid was used for further analysis of lignin, silica, and soluble sugar. The elution ratio was calculated from the amount of each resource contained in rice husk and the amount of each resource eluted into supernatant liquid.

2-2. Enzymatic saccharification

Enzymatic saccharification was carried out by using Meiselase (Meiji Co., Ltd., Japan). Saccharification of the pretreated substrate (5%, w/v, VS, rice husk based) was performed in 100 mM acetate buffer (pH 5.0) with enzyme loading of 15 g/L. The reaction condition was at 50°C with shaking at 150 rpm for 48 hours. Reaction mixture was boiled for 5 min to inactivate enzymes and the sugar liberated was measured.

2-3. Methane fermentation

Comparative methane fermentation was performed using the saccharification residue and pretreatment residue as

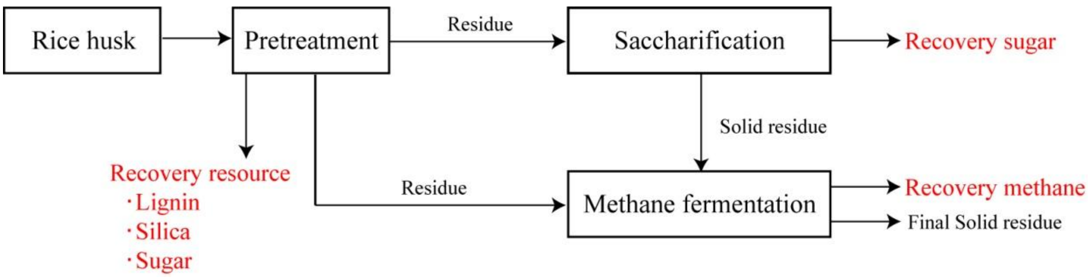

Fig.1. Proposed multi-stage process flowchart for resource and energy recovery from rice husk.

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organic sources. Mesophilic digested sludge was taken from sewage treatment center (Nagaoka, Japan) and used as seeding sludge for methane fermentation. The substrate concentrations were set to 1:1 (w/w, VS) with the sludge. After adjusting the initial pH to 7.0 ± 0.1, test vials were shaken at the rate of 100 strokes/min at 35°C during treatment time of 30 days.

3. Results and Discussion

3-1. NaOH process

NaOH pretreatment has been proved effectiveness in removing lignin. In this research, the eluted lignin was increased depending on NaOH concentration (**Fig.2**). The maximum elution rate of the lignin was 21% (w/w) in 2.0%-NaOH condition. The eluted sugar was also increased depending on NaOH concentration. When NaOH concentration increases from 0.5% to 1.0%, the elution rate of silica also increases (0.023 g/g-DM → 0.147 g/g-DM) . It is suggested that the NaOH pretreatment was effective in elution of the silica from the rice husks.

3-2. Enzymatic Saccharification

Maximum amount of recovery sugar was 0.48 g/g-DM in 0.5%-NaOH condition (**Fig.3**). However, the recovered sugar was decreased when NaOH concentration increases. This is because the amount of pretreatment residue decrease when increasing the NaOH concentration.

3-3. Methane Fermentation

The residue of both pretreated and enzymatic saccharification and only pretreated were used on methane fermentation (**Fig.4**). Methane was recovered from residue of enzymatic saccharification by methane fermentation. The recovered methane from pretreatment residue was twice when using saccharification residue. It seems easy degradable components was decreased in enzymatic saccharification.

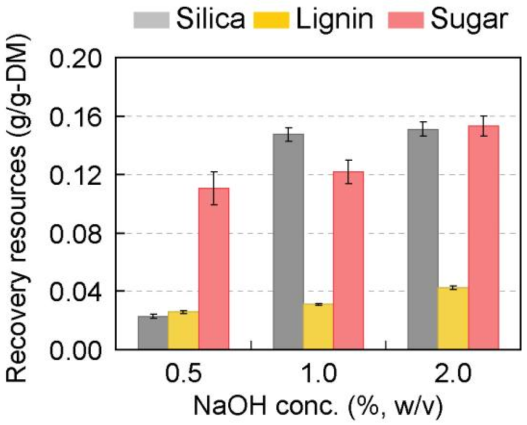

Fig.2 Resources recovery from pretreatment

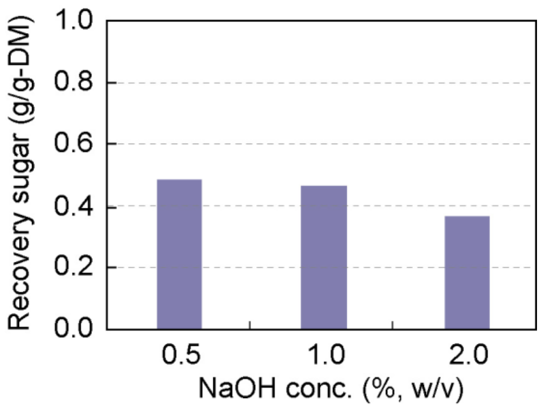

Fig.3 Sugar recovery from enzymatic saccharification

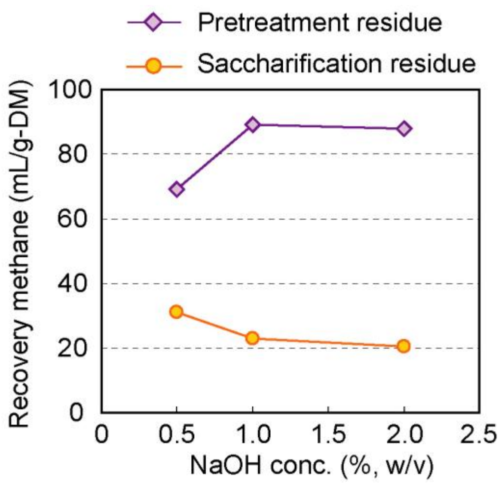

Fig.4 Methane recovery from methane fermentation

4. Conclusion

In this research, the recovery of energy and resources as silica, sugar, lignin and methane were achieved. The amounts of recovered resources on pretreatment increased depending on NaOH concentration. It was confirmed that the pretreatment with NaOH not only separate lignin and sugar but also silica at high efficiency. The enzymatic saccharification has potential for sugar recovery. Maximum amount of sugar recovery after enzymatic saccharification was 0.48 g/g-DM, and maximum recovery rate was 87.3% in 0.5%-NaOH condition. Methane was recovered from saccharification residues by the methane fermentation process.

Reference (1) Komilis D.P. *et al*., Waste Managment, Vol. 23, pp. 419-423, 2003