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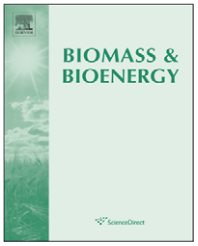

Ethanol production from kitchen waste using the flocculating yeast *Saccharomyces cerevisiae* strain KF-7

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ABSTRACT

A process for producing ethanol from kitchen waste was developed in this study. The process consists of freshness preservation of the waste, saccharification of the sugars in the waste, continuous ethanol fermentation of the saccharified liquid, and anaerobic treatment of the saccharification residue and the stillage. Spraying lactic acid bacteria (LCB) on the kitchen waste kept the waste fresh for over 1 week. High glucose recovery (85.5%) from LCB-sprayed waste was achieved after saccharification using Nagase N-40 glucoamylase. The resulting saccharified liquid was used directly for ethanol fermentation, without the addition of any nutrients. High ethanol productivity ($24.0\,g\,l^{-1}\,h^{-1}$) was obtained when the flocculating yeast strain KF-7 was used in a continuous ethanol fermentation process at a dilution rate of $0.8\,h^{-1}$. The saccharification residue was mixed with stillage and treated in a thermophilic anaerobic continuous stirred tank reactor (CSTR); a VTS loading rate of $6\,g\,l^{-1}\,d^{-1}$ with 72% VTS digestion efficiency was achieved. Using this process, 30.9 g ethanol, and 65.2 l biogas with 50% methane, was produced from 1 kg of kitchen waste containing 118.0 g total sugar. Thus, energy in kitchen waste can be converted to ethanol and methane, which can then be used as fuels, while simultaneously treating kitchen waste.

1. Introduction

In Japan, the annual generation of organic waste from the food industry and kitchen garbage is about 20 million tons per year. Most of this waste is directly incinerated with other combustible waste, and the residual ash is disposed of in landfills. However, incineration is costly and energy consuming, and since these wastes have a high moisture content, they must be burnt with other drier wastes, resulting in the production of dioxins. Recently, more economically attractive treatment methods such as composting and anaerobic digestion have been used to treat some of this waste and produce compost or biogas, but imbalances in supply and demand for recycled products hinder the wider application of these alternative approaches. Since these wastes are rich in sugars that could be converted to more valuable products, attention is being directed to biorefinery processing of these wastes to produce biomass materials such as lactic acid [1–3]. In addition, ethanol can also be produced from these sugars. Ethanol, a major fuel additive and a promising future energy alternative, is now produced mainly from corn in America and China and from sugarcane in Brazil. However, since corn is a major food source, its use as a fuel source has been criticized. Moreover, using corn as a feedstock is a major

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contributor to the significant cost of ethanol production, so biomass wastes such as corn fiber, waste wood and food wastes are far more attractive as cheap feedstocks for ethanol production.

In this study, we focus on ethanol production from kitchen waste collected from dining halls. As kitchen waste is highly perishable, and most of the sugars in the waste are starch-based sugars (Table 1), a process for producing ethanol from kitchen waste was developed, as shown in Fig. 1. The process consists of freshness preservation of the waste with the aid of lactic acid bacteria (LAB), saccharification of sugars in the waste using glucoamylase, continuous ethanol fermentation of the saccharified liquid using flocculating yeast, and anaerobic treatment of the saccharification residue and stillage. This process converts energy in the waste first to ethanol, and then to methane, which can then be used as a fuel; in addition, the waste is simultaneously treated. Although there have been several reports regarding the production of lactic acid from food waste [1–3], there have been only very limited studies regarding the production of ethanol from food waste [4,5]. The present paper is the first report regarding ethanol fermentation from kitchen waste.

Table 1 – Representative composition of kitchen waste used for ethanol fermentation

Test parameters	Results (ww^{-1}%)
Total solid (TS)	19.7
Volatile total solid (VTS)	18.8
Ash	1.9
Moisture	80.3
Total sugars[a] (based on wet weight)	11.8
Total sugars[a] (based on dry weight)	59.8
Holocellulose (based on dry weight)	1.6
Lignin (based on dry weight)	0.8
Protein (based on dry weight)	21.8
Lipid (based on dry weight)	15.7

[a] Total sugars referred to starch sugars. Protein contents were calculated with total nitrogen contents by multiplication as coefficient 6.25. Results were mean values of 3 analyses.

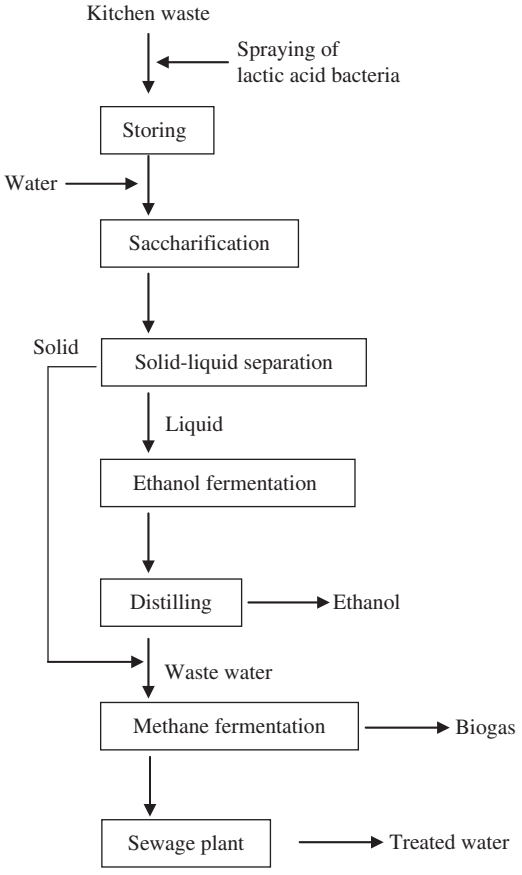

Fig. 1 – Flow chart of the ethanol production process from kitchen waste.

2. Methods

2.1. Microorganism strains

The flocculating yeast *Saccharomyces cerevisiae* KF-7 was used for batch and continuous ethanol fermentation tests. This yeast strain was constructed by protoplast fusion of the flocculating yeast strain IR-2 and the thermotolerant yeast strain EP-1 [6].

LAB strain 4, closely related to *Lactobacillus paracasei* (98% rRNA gene sequence similarity), was isolated from a vegetable beverage and used for the preservation of kitchen waste.

2.2. Cultivation of LCB

LCB cells grown on a 1% YPD (1% glucose, 1% yeast extract, 2% peptone, 2% agar) slant were transferred to 1% YPD liquid medium and cultured at 37 °C for 24 h with mixing at 100 rpm using a rotary shaker. The resultant pre-cultivation broth was used for jar fermentor cultivation using *tofu* compression liquid (pH 5.85; glucose 190 mg l^{-1}; suspended solid (SS) 3.38 g l^{-1}; volatile suspended solid (VSS) 2.79 g l^{-1}) as the medium. Cultivation was carried out at 37 °C and 100 rpm for 24 h. The culture broth, with approximately 10^{10} cell ml^{-1}, was stored in a spray bottle and used in kitchen waste storage experiments. The LCB broth could be stored for 1 month without obvious change in the number of viable cells.

2.3. Storage of kitchen waste

Kitchen waste used in this study was collected from the students' dining hall of Kumamoto University, Japan. Large pericarps were removed, the remaining waste was stored in a plastic basket at room temperature, and LCB broth was evenly sprayed on the surface of the waste once a day when necessary. A water weight was placed over the waste in order to produce anaerobic conditions. Representative characteristics of the collected kitchen waste are shown in Table 1. Kitchen waste stored at room temperature for 3 days with and without LCB treatment was used for lab-scale experiments, and LCB-sprayed waste stored for 1 week was used for bench-scale experiments.