Bioresource Technology 128 (2013) 87–93

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Reduction in environmental impact of sulfuric acid hydrolysis of bamboo for production of fuel ethanol

Zhao-Yong Sun [a], Yue-Qin Tang [b], Shigeru Morimura [a], Kenji Kida [a,b,*]

[a] Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto City, Kumamoto 860-8555, Japan
[b] College of Architecture and Environment, Sichuan University, No. 24 South Section 1, First Ring Road, Chengdu, Sichuan 610065, China

HIGHLIGHTS

- Effluent from biological treatment of stillage could be reused to recover sugar from residue.
- Rinse water and recovered sulfuric acid could be reused in the saccharification process.
- Condensate without acetate could be reused as elution water in acid–sugar separation.
- 86.3% of the process water and 77.6% of the sulfuric acid could be recycled.
- Environment impact was reduced by reuse of stillage and sulfuric acid.

ARTICLE INFO

Article history:
Received 24 May 2012
Received in revised form 17 September 2012
Accepted 16 October 2012
Available online 26 October 2012

Keywords:
Bamboo
Ethanol
Concentrated sulfuric acid hydrolysis
Methane fermentation
Reuse of stillage

ABSTRACT

Fuel ethanol can be produced from bamboo by concentrated sulfuric acid hydrolysis followed by continuous ethanol fermentation. To reduce the environmental impact of this process, treatment of the stillage, reuse of the sulfuric acid and reduction of the process water used were studied. The total organic carbon (TOC) concentration of stillage decreased from 29,688 to 269 mg/l by thermophilic methane fermentation followed by aerobic treatment. Washing the solid residue from acid hydrolysis with effluent from the biological treatment increased the sugar recovery from 69.3% to 79.3%. Sulfuric acid recovered during the acid–sugar separation process was condensed and reused for hydrolysis, resulting in a sugar recovery efficiency of 76.8%, compared to 80.1% when fresh sulfuric acid was used. After acetate removal, the condensate could be reused as elution water in the acid–sugar separation process. As much as 86.3% of the process water and 77.6% of the sulfuric acid could be recycled.

1. Introduction

Bamboo is a promising renewable feedstock for production of fuel ethanol because of its high growth rate and high content of holocellulose (up to 70% of the dry base) (Shimokawa et al., 2009; Yamashita et al., 2010; Sathitsuksanoh et al., 2010). Saka (2001) has reported that 3.3 million tons of bamboo could potentially be converted to ethanol every year in Japan; however, presently, most of the bamboo available is not being effectively utilized.

A process designed to utilize bamboo as a raw material for fuel ethanol production has been proposed previously (Sun et al., 2011). The process consists of hydrolysis with concentrated sulfuric acid, removal of color compounds, separation of acid and sugar, hydrolysis of oligosaccharides, and subsequent continuous ethanol fermentation. The sugar concentration (148.1 g/l) and the sugar recovery efficiency (81.6%) were higher than those reported previously (Clausen and Gaddy, 1993; Iranmahboob et al., 2002). A high fermentation yield of 92% based on glucose and a high ethanol productivity of 8.2 g/l/h were achieved in the continuous fermentation.

A major environmental concern with this process is the usage of large quantities of sulfuric acid. Although the sulfuric acid used during hydrolysis was recovered with anion exchange resins, its reusability was unknown. In addition, the stillage from the distillation process would require treatment to avoid negative environmental effects. At an industrial scale, recycling of recovered sulfuric acid as well as the treatment of stillage would have numerous benefits not only for the environment but also for the reduction of process water. There are two reports having previously been addressed on process water for production of ethanol from

* Corresponding author at: College of Architecture and Environment, Sichuan University, No. 24 South Section 1, First Ring Road, Chengdu, Sichuan 610065, China. Tel./fax: +86 28 8599 0936.
E-mail address: kida@gpo.kumamoto-u.ac.jp (K. Kida).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.10.082