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Simultaneous waste activated sludge disintegration and biological hydrogen production using an ozone/ultrasound pretreatment

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HIGHLIGHTS

- ▶ We examine the optimal level of ozone and ultrasound (US) individual pretreatments.
- ▶ We model the reciprocal relationships of the ozone and US pretreatments using RSM.
- ▶ The combined ozone/US pretreatment was the first time applied to produce hydrogen.
- ▶ Three different pretreated sludge samples for producing hydrogen were compared.
- ▶ The combined pretreatment achieves a maximal hydrogen yield of 9.28 mL H_2/g DS.

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ABSTRACT

This paper offers an effective pretreatment method that can simultaneously achieve excess sludge reduction and bio-hydrogen production from sludge self-fermentation. Batch tests demonstrated that the combinative use of ozone/ultrasound pretreatment had an advantage over the individual ozone and ultrasound pretreatments. The optimal condition (ozone dose of 0.158 g O_3/g DS and ultrasound energy density of 1.423 W/mL) was recommended by response surface methodology. The maximum hydrogen yield was achieved at 9.28 mL H_2/g DS under the optimal condition. According to the kinetic analysis, the highest hydrogen production rate (1.84 mL/h) was also obtained using combined pretreatment, which well fitted the predicted equation (the squared regression statistic was 0.9969). The disintegration degrees (DD) were limited to 19.57% and 46.10% in individual ozone and ultrasound pretreatments, while it reached up to 60.88% in combined pretreatment. The combined ozone/ultrasound pretreatment provides an ideal and environmental friendly solution to the problem of sludge disposal.

1. Introduction

Hydrogen is regarded as a viable alternative energy carrier that provides environmentally friendly, clean, recyclable and renewable energy, and may be able to replace fossil fuels in the near future (Ren et al., 2009, 2011). The two types of microbial cultures that are commonly used in hydrogen production are pure and mixed cultures. Mixed cultures have attracted special attention (Guo et al., 2008b, 2010a) because they are more practical than pure cultures (Ren et al., 2007), being simpler to operate and easier to control.

Investigation of inexpensive substrates is essential to lower the hydrogen production costs in potential commercial applications. Therefore, considerable attention has been paid to the use of waste activated sludge (WAS) (Mu et al., 2007; Zhang et al., 2008). Weemaes and Verstraete (1998) reported that WAS taken from a sewage treatment plant is rich in carbohydrates, proteins and other nutrients, which could be utilized for anaerobic hydrogen production. Large volumes of WAS are generated in sewage treatment plants, and the management and disposal costs of this can comprise 50–60% of the total operation expenses (Campos et al., 2009). Furthermore, traditional disposal methods are severely restricted by environmental, economic, legal and even social constraints (Yang et al., 2011). Thus, ideal methods that could both solve the WAS problem and turn the “waste” into an energy source are worthy of consideration. Hydrogen production using WAS as a culture offers a promising approach. However, hydrogen production from raw sludge has its limitations. Hydrolysis has been identified as the rate-limiting step, which may result in a relatively low hydrogen yield and long retention time (Ren et al., 2008; Van Ginkel and Logan, 2005). Therefore, various physical and chemical pretreatment methods to accelerate the hydrolysis rate have been attempted, including alkaline (Cai et al., 2004), ozonation (Braguglia et al., 2012), ultrasound

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