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Start up study of UASB reactor treating press mud for biohydrogen production

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ABSTRACT

Anaerobic digestion of press mud mixed with water for biohydrogen production was performed in continuous fed UASB bioreactor for 120 days. Experiment was conducted by maintaining constant HRT of 30 h and the volume of biohydrogen evolved daily was monitored. Various parameters like COD, VFA, Alkalinity, EC, Volatile solids, pH with respect to biohydrogen production were monitored at regular interval of time. SBPR was 10.98 ml g^{-1} COD reduced d^{-1} and 12.77 ml g^{-1} VS reduced d^{-1} on peak yield of biohydrogen. COD reduction was above 70 ± 7%. Maximum gas yield was on the 78th day to 2240 ml d^{-1}. The aim of the experiment is to study the startup process of UASB reactor for biohydrogen production by anaerobic fermentation of press mud. The inoculum for the process is cow dung and water digested in anaerobic condition for 30 days with municipal sewage sludge. The study explores the viability of biohydrogen production from press mud which is a renewable form of energy to supplement the global energy crisis.

1. Introduction

The rising concern about depleting oil reserves, harmful effects of green house gas emissions and the necessity to reduce emissions from power plants and vehicles are some of the key factors that increase the urgency for development of alternative energy options. Energy security is a major challenge, which needs imaginative and innovative solutions. Fossil fuels are the major global energy resource but they cause environmental problems during combustion. Hydrogen is a promising energy alternative because it is clean, renewable and has a high energy yield of 122 kJ g^{-1}. This yield is 2.75-fold greater than that from hydrocarbon fuels. At present, hydrogen is produced mainly from fossil fuels, biomass and water using chemical or biological processes. Hydrogen can be used for power generation and transportation at near zero pollution.

Biotechnology of hydrogen production has provoked a broad attention around the world as an environmental friendly process [1–4]. Hydrogen production by microorganisms is divided into two main modes: production by algae or phototropic bacteria and production by anaerobic fermentation bacteria. Currently, more research focuses on the use of algae and phototropic bacteria [5–10]. However, the efficiency of hydrogen production by phototropic microorganism is low and it cannot be continuously operated in the absence of light. In contrast, anaerobic hydrogen fermenting bacteria can produce hydrogen continuously without the need for photo energy [11,12].

Biological hydrogen production processes have the advantages of being less energy consuming. Fermentative biohydrogen production gives high hydrogen production rates and is capable of converting organic wastes into more precious energy resources [4]. In all the studies concerning biohydrogen production, a continuous stirred tank reactor (CSTR) is used for

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continuous generation of hydrogen from organic wastes [4]. Because of its intrinsic structure, the CSTR is incapable to maintain high levels of fermentative biomass for hydrogen production, and its specific hydrogen-producing rate is scarcely kept high [13]. To overcome this problem, an upflow anaerobic reactor, with a similar structure to the upflow anaerobic sludge blanket (UASB) reactor, was tested in this study.

An upflow anaerobic sludge blanket (UASB) process is a widely applied anaerobic treatment system with high treatment efficiency and a short hydraulic retention time (HRT). Recently, UASB hydrogen production systems have been used in granulation enrichment and granule microstructure [14,15]. However, the performance of hydrogen-producing UASB systems has not been discussed in detail. A systematic investigation of reactor characteristics, such as operation stability, HRT dependence, sludge granulation and sludge discharge is still lacking. Therefore the aim of this work was to investigate the feasibility of biohydrogen production from press mud using up flow anaerobic sludge blanket bioreactor and to study the startup process of UASB reactor using press mud for biohydrogen production.

During the acidogenesis of organic wastes, hydrogen, carbon dioxide, volatile fatty acids (VFA), and sometimes alcohols, are simultaneously produced [16]. The feasibility of applying acidogenesis of organic wastes to produce hydrogen has been widely confirmed at various laboratories [4,13,17]. Compared with photosynthetic bacteria, fermentative bacteria produce hydrogen with a lower cost because they do not need light provision and have simple requirements for microbial growth [4]. Another attraction of anaerobic hydrogen bioproduction is that highly concentrated organic wastewater and biomass, such as municipal solid wastes, sewage sludge, can be used as raw material, which can solve pollution as well as generate hydrogen [4].

Although some studies have been conducted on mixed cultures of anaerobic bacteria [11,18–25], the optimal condition for hydrogen production has not been fully understood. The accumulation of intermediate products in systems can inhibit fermentation. In practical operation, high hydrogen yields are associated with a mixture of acetate and butyrate as fermentation products. However, little information is available for anaerobic hydrogen production at pilot scale with mixed microbial cultures, although pilot-scale study is critical to testify the productivity before a new biotechnology is put into full scale operation, and using mixed microbial cultures is a more cost-effective and promising approach to achieve hydrogen bioproduction in large scale. In addition, as a byproduct through fermentation pathways, hydrogen production is affected by fermentation end-products, including, acetic acid, propionic acid, butyric acid, and lactic acid. But there is very limited information of the correlation between fermentation pathways and hydrogen production ability.

Ren [11] had confirmed that the acclimatized anaerobic activated sludge had a high hydrogen producing ability (as high as 10.4 m^3 H_2 m^{-3} reactor d^{-1}) in a continuous reactor with an available volume of 9.6 L. It has been found that a high cell density (higher than 5 g L^{-1}) in bioreactor is required to keep high hydrogen yield, since low cell intensity cannot efficiently convert organic substrates to hydrogen, especially at short hydraulic retention time (HRT < 4 h). Several studies have found that great amount of VFA and CO2 produced from highly concentrated influent inhibited metabolic activities of anaerobic bacteria [12,26–28]. The hydrogen production rate obtained in molasses (29) HBR system was 5.57 m^3 H_2 m^{-3} reactor d^{-1} and yield was 26.13 mol kg^{-1} COD removed with OLR of 35–55 kg COD m^{-3}. Ueno et al. [18] investigated the hydrogen production rate by anaerobic micro flora in chemostat culture.

In light of the above developments, this work used sewage sludge as the seed sludge source for hydrogen production in a UASB system. Sucrose is readily found in this industrial waste and was therefore used as the carbonaceous substrate for hydrogen fermentation. The substrate has 3% sugar which is an excellent natural nutrient for microorganism.

2. Materials & methods

2.1. Bioreactor system

A 20 L UASB biohydrogen-producing reactor was used in this study. The plexi glass made lab scale UASB reactor has a column of internal diameter 10 cm, height 190 cm ($H/D > 10$) with a gas liquid separator at the top having internal diameter of 20 cm and height 20 cm, having an effluent port at 15 cm. HRT is based on the volume of the fluid between feed and effluent port which is 20 L. Seven sampling ports were evenly fixed over the entire height of the column. Total biomass level in the reactor was kept at around 1/3rd the height of the column i.e. about 70 cm. The reactor was operated in continuous flow mode. The temperature is kept in ambient condition. The influent pH was kept in the range of 5.5–6 by addition of 0.1 N HCL or NaOH. The influent flow rate is controlled by a peristaltic pump to maintain constant HRT of 30 h.

2.2. Seed microorganism

Sewage sludge contains a variety of microflora favoring biohydrogen production in suspended growth systems [30,31] and might be a good source for cultivating granular sludge for hydrogen production. The seed sludge was collected from a municipal waste water treatment plant maintained by Public Works Department, Govt. of Pondicherry. It was sieved through a wire mesh of diameter 0.5 mm to remove the solid materials that may block the flow in the pump. Cow dung was mixed with water in the ratio 1:2 and digested under anaerobic condition for 30 days by adjusting pH in the range of 5–6, in batch mode with the addition of nutrients. Later this cow dung seed was filtered in wire mesh (0.5 mm) to remove the fibrous materials. This cow dung filtrate and sewage was mixed (4:1) heated at 70 °C for 1 h to inhibit the methanogens and fed into the reactor. The characteristics of seed sludge viz. total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), total volatile solids (TVS), total volatile dissolved solids (TVDS), total volatile suspended solids (TVSS) etc. are given in Table 1.

2.3. Feed substrate

So far, majority of research work has been directed at expensive pure substrates to a much lesser quantity of solid waste [32]. In most studies on microbial production of