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Enhancing strategy on renewable hydrogen production in a continuous bioreactor with packed biofilter from sugary wastewater

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ABSTRACT

A flex-matala packed biofilter with specific surface area 365 m^2/m^3 and free volume 94% was used as a bacteria carrier in a Continuous Stirred Tank Reactor (CSTR) in this study. The continuous stirred tank reactor with packed biofilter (CSTR-PBF) was designed and operated under sugary wastewater substrate at concentration of 20 g total sugar/L and HRT 8–0.5 h to assess the biohydrogen producing ability. Biofilter was installed at 60 mm height from the bottom of bioreactor (middle of the bioreactor). It was found that the optimum condition was at HRT 1 h with HPR of 88.73 L H_2/L/d, substrate utilization of 92.95% and yield of 1.37 mol H_2/mol hexose. A flex packed biofilter used in CSTR system is a better approach to accumulate biomass concentration in bioreactor for enhancing biohydrogen production rate comparison with other kinds of continuous bioreactor. The sugary wastewater used as substrate for biohydrogen production not only produce the renewable energy but also mitigate the organic wastewater pollution.

Introduction

Hydrogen is considered to be an ideal energy sources with no CO_2 emission [1], producing water as its only by-product when it burns [2,3]. Therefore, hydrogen is now universally accepted as an environmentally safe [4]. Besides, hydrogen has a theoretically high energy yield of 122 kJ/g, which is 2.75 times greater than hydrocarbon [5] and wider range of industrial applications as compared to methane [6].

Hydrogen can be produced by many methods among that biological method by dark fermentation, batch and

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continuous mode using pure culture or mixed cultures. Biological hydrogen production from the fermentation of renewable substrates is one promising alternative of commercially produced foods products [7–9]. Microorganisms commonly used in the dark fermentation process are mixed cultures [5,10–12]. Using mixed cultures are more interested in using pure cultures because more practical, simpler to operate and easier to control [6]. Dark fermentation has various advantages, for example, high rate of bacterial growth, requires low energy input, no oxygen limitation problems, low costs [13–17], can produce biohydrogen all day long without light, has a variety of carbon sources can be used as substrates. Various types of waste materials can be used as substrate for biohydrogen production such as sugary wastewater. Sugary wastewater is more efficient than other materials as raw material for biohydrogen production. Simple sugars, such as sucrose and glucose, are converted at elevated temperatures to hydrogen at high conversion efficiencies [7,18–20], easily biodegradable carbon source, present in most of the industrial effluents. These indicate that sugary wastewater will be the most useful for industrial biohydrogen production.

Continuous stirred tank reactors (CSTR) are commonly used for continuous biohydrogen production [14,21–24]. In a CSTR, hydrogen-producing microbes are completely-mixed and suspended in the reactor liquor from the mixing pattern. Biomass is well suspended in the mixed liquor, which has the same composition as the effluent. Under such hydrodynamics, a good substrate-microbes contact and mass transfer can be accomplished. On the other hand, the CSTR is unable to maintain high level of fermentative biomass because of the rapidly mixed operating pattern. Biomass wash-out of the biomass may occur at short hydraulic retention times (HRTs) [25], thus the hydrogen production rates are considerably restricted [14]. The hydraulic mixing regime in a fixed-bed bioreactor is less turbulent comparing with the CSTR, this results in higher mass transfer resistance along with lowered rates of substrate conversion and hydrogen production [14]. To retain high biomass concentrations in reactors, various techniques have been developed for hydrogen fermentation, including sludge immobilization [23,24,26–28], utilization of up flow reactor [29–31] and immobilized on porous support such as loofah sponge, expanded clay and activated carbon [32], membrane reactor [33–35].

Anaerobic granular sludge bed bioreactors were supplemented with activated carbon carriers and combined with distributors installed at different locations to investigate the effect of distributor/carrier on biohydrogen production efficiency. Plastic net stimulated the substrate/microorganisms contact and sludge granulation, thereby leading to much better hydrogen production performance when compared with those obtained from traditional CSTR [36]. An attempt to upgrade the performance of traditional CSTR for biohydrogen production, a flex-matala biofilter was packed in bioreactor avoid wash out and promote the formation and retention of granular sludge. To reach the goals of promoting sustainable environment and green growth by converting high-organic wastewater to clean energy technologies, the hydraulic retention time (HRT) with a constant of substrate concentration of 20 g total sugar/L was investigated on correlation of biohydrogen production rate and biomass concentration in the bioreactor.

Materials and methods

Bioreactor system

Fig. 1 shows the schematic diagram of the continuous stirred tank reactor with packed biofilter (CSTR-PBF) system. The system is consisted of four unit, including a feeding tank, main body of bioreactor (CSTR-PBF), gas/liquid separator and automatic control system. The experiment was carried out in 2.5 L working volume bioreactor. The bioreactor had a

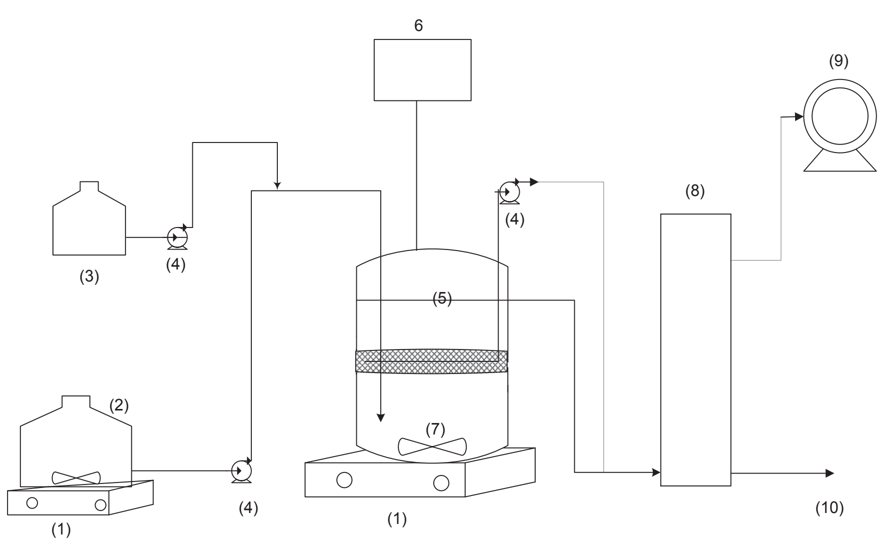

Fig. 1 – Schematic diagram of the continuous stirred tank reactor with packed biofilter (CSTR-PBF) system (1. Hot plate, 2. Substrate tank, 3. NaOH tank, 4. Pump, 5. Bioreactor, 6. pH controller, 7. Magnetic stirrer, 8. Gas liquid separator, 9. Wet gas meter, 10. Effluent.).