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Bio-hydrogen Production from sago effluent

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Abstract

The present study focuses on the exploitation of Sago effluent as a source for hydrogen production. Hydrogen production was investigated at different parameters namely pH, Temperature and substrate. The pH was varied from 4.0 - 6.5, temperature ranges from 30°C - 70°C and substrate concentration (Glucose and Nitrogen) varied from 0.25 g/l - 1.25 g/l and their interaction on hydrogen gas production were studied. The raw cow dung was used as inoculums for hydrogen gas production. In this study revealed that the maximum hydrogen production was occurred in acidic condition (pH 5.5). The highest rate of hydrogen production was observed at 1.25 g/l of substrate concentration (both Glucose and Nitrogen) under 55 °C.

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Introduction

50 million tonnes of hydrogen was traded annually worldwide with a growth rate of nearly 10% per year for the time being (Winter, 2005). Based on the National Hydrogen Programme of the United States, the contribution of hydrogen to total energy market will be 8–10% by 2025 (Armor, 1999). In alternate energy, development researchers seeking cost-effective and efficient hydrogen production technologies has been gained significant attention. India's energy security would remain at risk until alternative fuels to substitute/supplement petro-based fuels are developed based on indigenously produced renewable feedstock. In biofuels, the country has a spark of hope in providing energy security (Neha *et al.,* 2011).

Hydrogen gas is termed as a clean fuel because water instead of greenhouse gases is produced when combusted. Hydrogen is considered to be an alternative fuel of great potential use (Lattin and utgikar, 2007). It has a high energy yield of 122 kJ/g, which is 2.75 times greater than gasoline (Antonopoulou *et al.,* 2006). Hydrogen has the potential to lessen the world's dependency on fossil fuels. But further research and technology is needed before a sustainable hydrogen economy can be established.

Anaerobic production of hydrogen using fermentative bacteria is an exciting new area of technology development that offers the potential to produce usable hydrogen with simple process from a variety of renewable resources such as organic wastes (ex. food processing waste and animal waste) even without light source (Dark fermentation) (Nath and Das, 2004). Under normal anaerobic conditions the majority of hydrogen produced is consumed by methanogenesis by symbiotic process such bacteria (Parawira, 2004). These bacteria must be inhibited; resulted hydrogen producing bacteria alone flourish and produce pure hydrogen. The major criteria for substrate selection are the availability, cost, carbohydrate content, and biodegradability (Kargi and Kapdan, 2006). Researchers have studied different types of substrates for biological production of hydrogen.

Alternatively, wastewaters with organic waste such as food processing and animal waste also have great potential as substrate for hydrogen production sources (Benemann, 1996). Sago is one of the organic rich wastes which are prepared from the milk of *Manihot esculenta* (Tapioca Root). In Tamil Nadu, tapioca is mostly cultivated in the districts of Erode, Namakkal and Salem. These tapioca processing units are known as sago factories. A large number of tapioca sago industries are found in Attur taluk of Salem District. The effluent from these sago industries is having higher chemical oxygen demand and total solids. These two parameters can be potentially exploited for the production of hydrogen. Along with pH control proper knowledge on substrate selection composition and concentrations are essential for better yield of hydrogen production. The present study focuses on the exploitation of Sago effluent as a source for hydrogen production and effect of parameters such as pH, Temperature and substrate.

Materials and methods

Collection of the effluent

The Sago effluent sample was collected in sterile 25 liters containers from Sago industry in Salem District, Tamil Nadu. The collected samples were brought to the laboratory and stored at 4°C for further analysis.

Table 1. Parameters consider for optimization of hydrogen gas production.

One factor at a time	Two factors at a time
pH	pH and Temperature
Temperature	pH and Substrate (Glucose)
Substrate (Glucose)	pH and Substrate (Nitrate)
Substrate (Nitrate)	

Effluent characterization

The Sago effluent was analyzed for the following parameters namely pH, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) as per standards (APHA 1998)

Table 2. Physicochemical characteristic of Sago waste effluent.

Parameters	Observation
Colour	Pale White
Odour	Pungent
pH	5.3
COD	4693 mg/l
TDS	5200 mg/l

Preparation of inoculums

Cow dung was collected from Vadapalanji near Madurai Kamaraj University, Madurai and it was brought to the laboratory. After cleaning, cow dung slurry was prepared with mixing of water to cow dung in the ratio of 1:1. Prepared Cow dung slurry (Inoculums) was pre heated at 100°C for 1 hr to inhibit the methane producing organisms and allowed only hydrogen producing organisms. Prepared slurry was filled in bottles with 2.5 litres capacity (bioreactor) and the lid of the bottle was closed with single holed cork and sealed. A glass tube was inserted in the hole of the cork and rubber tube was connected to it. The whole set up was maintained for about 3 months. The inoculum for hydrogen production was taken from the above bioreactor.

Production of hydrogen gas

Sterilized sago waste effluent sample (250 ml) was taken in 500 ml bottles and 10 % inoculum was mixed with the effluent. The lid of the bottle was closed by a one holed rubber cork and made air tight by sealing it. Then a glass tube was inserted in the hole of the cork and rubber tube was connected to it. This setup was used to monitor hydrogen gas production in the bottle. After overnight Incubation the amount of gas produced was measured in next day.

Measurement of hydrogen gas

The volume of hydrogen gas production was measured using water displacement method. The gas produced was tested for the presence of hydrogen using a lighted wooden splint which was placed in a small tube consisting of the gas. A small pop sound was indicative of the hydrogen gas (Whitten *et al.*, 2009).

Optimization of conditions

For higher production of hydrogen gas, pH, temperature and substrate concentrations were optimized. Parameters consider for higher production of hydrogen was shown in table 1.

Results

Characterization of the effluent

The physico-chemical properties of Sago effluent were analyzed as per APHA standards and results were shown in Table 2. Starch containing materials were abundant in nature and have great potential towards hydrogen production. According to the reaction stoichiometry, a maximum of 553mL hydrogen gas was produced from one gram of starch with acetate as a byproduct (Zhang *et al.*, 2003).

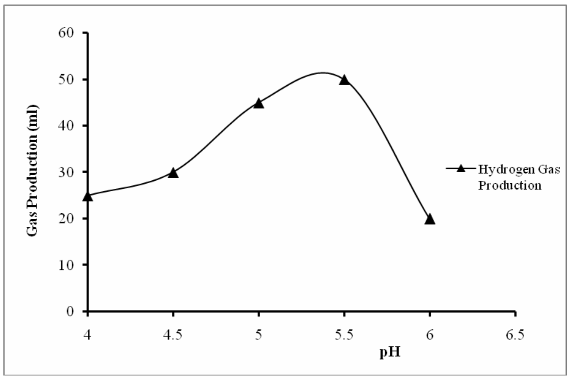

Fig. 1. Effect of pH on hydrogen gas production.

Optimization of Hydrogen gas production (One factor at a time) Effect of pH on hydrogen gas production

Fig.1 showed that the pH has remarkable influence on hydrogen gas production. At acidic pH of 5.5 resulted the higher gas production about 50 ml. The pH was increased towards the neutral gas production was gradually decreased. Each microbial group involved in anaerobic degradation has a specific pH range for optimal growth. The optimum pH range for specific hydrogen production rate is 5.5 – 5.7 (Van Ginkel and Sung, 2001; Khanal *et al.,* 2004). Experiments on pH levels from 6.0 – 8.0 reported that the dominant microbial population was affected at different values within that range (Demirel and Yenigun 2002). Constant pH provides stability to this process (Parawira 2004).

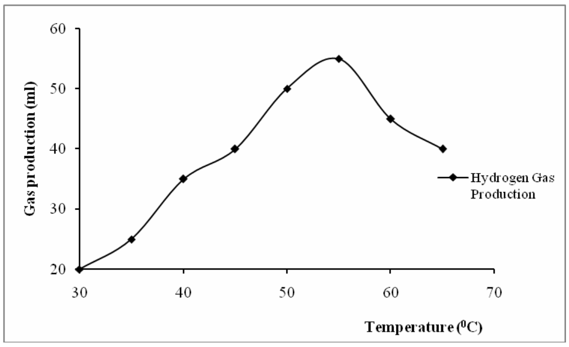

Fig. 2. Effect of temperature on hydrogen gas production.

Effect of temperature on hydrogen gas production

Temperature was considered as one of the most important parameter which affects both biohydrogen production and microbial metabolisms in mixed cultures (Li and Fang, 2007). Fig. 2 showed that the higher gas production was observed in 55°C. When temperature was higher than 55° C then the gas production also slowly decreased. For instance, the highest amounts of hydrogen from grass were obtained at 70 °C using a heat-treated inoculum from a dairy farm digester, (Pakarinen *et al.*, 2008).

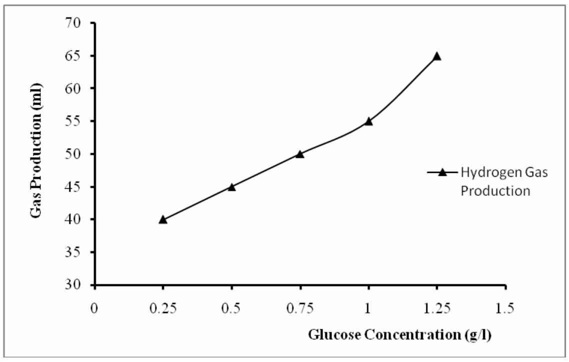

Fig. 3. Effect of glucose concentration on hydrogen gas production.

Regarding food waste, thermophilic temperatures seem more suitable to hydrogen production despite significantly different observations reported in the literature. These differences might be due to the origin of the inoculum, the quantity of readily-biodegradable compounds as well as the operating conditions. Yokoyama *et al.*, (2007) examined the effect of the fermentation temperature (37°C to 85°C) on biohydrogen production using dairy cow waste slurry. He found maximum production observed at 60 °C and 75 °C, with yields of 29:25 and 18:5 mLH_2 g^{-1} VS overall observation revealed that the increase in hydrogen production was globally correlated with higher operating temperatures.

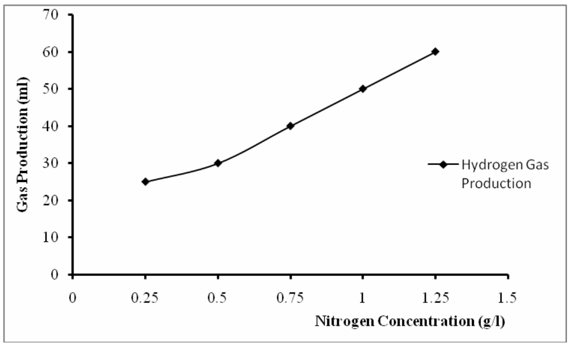

Fig. 4. Effect of nitrogen concentration on hydrogen gas production.

Effect of substrate concentration (Glucose) on hydrogen gas production

The highest gas production 65 ml was observed at 1.25g/l concentration of the glucose. When concentration of the substrate was increased gradually then the gas production also slowly increased (Fig 3.) Thong *et al.,* (2008) observed that the hydrogen production rate using *Thermoanaerobacterium thermosaccharolyticum* PSU-2 was increased positively with increase sucrose concentration up to 20 g l^{-1} further it was decreased. Theoretically, bioconversions of 1 mol of glucose yield 12 mol of hydrogen gas (H_2).

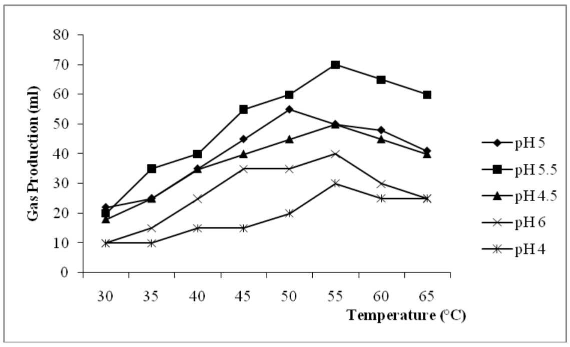

Fig. 5. Effect of pH and temperature on hydrogen gas production.

Effect of substrate concentration (Nitrogen) on hydrogen gas production

Nitrogen was a very important as well as essential for synthesis of component for proteins, nucleic acids and enzymes for growth of hydrogen-producing bacteria. Thus, an appropriate level of nitrogen addition was beneficial to the growth of hydrogen producing bacteria and to fermentative hydrogen production accordingly. (Bisaillon, 2006) maximum hydrogen gas production (65 ml) was observed at 1.25 g l^{-1} concentration of the Nitrogen substrate. (Fig. 4) When concentration of the substrate is high then the gas production also slowly increased.

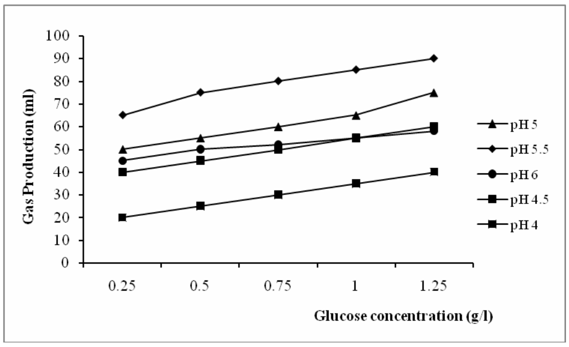

Fig. 6. Effect of pH and glucose concentration on hydrogen gas production.

Optimization of Hydrogen gas production (Two factors at a time) Effect of pH and Temperature on hydrogen gas production

The effect of pH and temperature on hydrogen gas production was shown in Fig.5. In all temperature (35°C – 50 °C), pH 5.5 alone showed higher gas production with range at 55 – 70mL. Optimal temperature reported for fermentative hydrogen production was not always the same, it may fell into either the mesophilic range (around 37 °C) or thermophilic range (around 55 °C) (Li and Fang, 2007). Increasing temperature could induce the yield ability of hydrogen-producing bacteria during fermentation period, but temperature at much higher levels could decrease the yield (Wang and Wan, 2008).

Effect of pH and Substrate (Glucose) on hydrogen gas production

At 1.25g/l concentration of the glucose substrate and pH of 5.5. Resulted 80 ml of hydrogen gas production, when concentration of the substrate was high then the gas production also slowly increased.

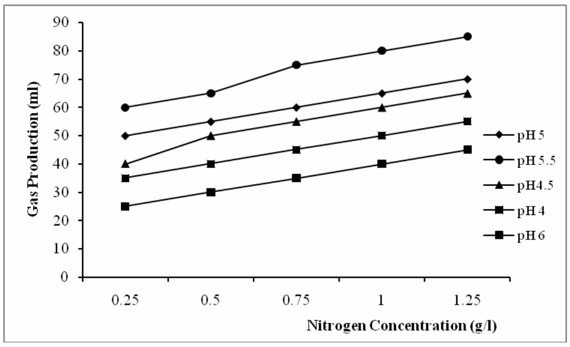

Fig. 7. Effect of pH and nitrogen concentration on hydrogen gas production.

Effect of pH and Substrate (Nitrogen) on hydrogen gas production

The maximum gas production (80 ml) was observed at 1.25g/l of the nitrogen substrate and pH 5.5. When concentration of the nitrogen substrate was high then the gas production also slowly increased. More investigations of nitrogen concentration on fermentative hydrogen production using organic wastes as substrate are recommended.

Conclusion

The major problem concern on in bio-hydrogen production from wastes was the low rate of conversion and hydrogen yield. Low yields and the rates of hydrogen formation may be overcome by selecting more effective hydrogen producing organism or mixed microbial cultures for development of more efficient processing schemes, optimizing the environmental conditions as well as developing more efficient photo-bioreactors. An attempt was made to produce hydrogen gas using sago effluent alteration of pH, temperature and substrate concentration and conditions were optimized. The highest Hydrogen yield was achieved at a temperature of 55 °C. The optimum pH for hydrogen production from sago effluent was found as 5.5. Appropriate level of nitrogen and glucose is much beneficial to the growth of hydrogen producing bacteria as well as and production of hydrogen.

There are still many variables that are important for higher hydrogen production. These can be explored further to achieve economic viability of hydrogen production.

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