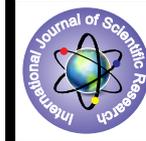


Investigation of Bio-Wastes and Methods for the Production of Bio-Hydrogen – A Review



Engineering

KEYWORDS : Bio-hydrogen, Biomass Palm, Oil mill effluent, Ligno-cellulosic materials, Food and starch-based materials

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ABSTRACT

Hydrogen is a clean energy carrier which has a great potential to be an alternative fuel. Abundant biomass from various industries is a source for bio-hydrogen production where combination of waste treatment and energy production would be an advantage. This paper deals with the production of biogas from availability of waste materials. The study analysis the various types of potential biomass which are the source for biogas generation such as food and starch based wastes, cellulosic materials, dairy wastes along with the production methods.

1. Introduction

Hydrogen has good prospects as an energy alternative which addresses remedy concerns about environmental pollution. Hydrogen, when burned in air, produces clean energy without Pollution and produces no greenhouse gases. Hydrogen gas can be produced by water electrolysis, coal gasification, or biological conversion of organic matter. Among these means, biological conversion from organic matter has been studied as a candidate for energy-saving processes by many investigators. A large number of bacterial species have been shown to be hydrogen producers. Biological hydrogen production from a renewable biomass such as the organic fraction of waste or wastewater has a considerable potential with respect to solving global environmental issues. Renewable biomass is the most versatile non-petroleum based resource that is generated from various industries as waste materials. Lignocellulosic materials such as wood and wood products, food and starch-based materials, organic industry wastewater, household wastewater and biodiesel industry waste could be potential resources for bio-hydrogen production and as a cost effective energy production process. The objective of this study is to present an overview about the wastes available for the production of biogas.

2. Types of bio-hydrogen production methods for various waste materials

The following chapters deal with the bio-mass generation from various wastes and their production methods, also their generation capacity rate for different compositions.

2.1. Carbohydrate Rich materials

Food wastes from the industry and household contain high levels of carbohydrate and protein. Currently, food wastes from the industry are mostly treated anaerobically. However, lactic acid, bio compost and energy from food wastes would be a value added strategy for treatment of food wastes. The organic constituent especially carbohydrate in food wastes could be a potential substrate for anaerobic hydrogen production. The specific hydrogen production potential of food wastes was found to be higher than sewage sludge. However, hydrogen production potential increased as sewage sludge composition was increased up to 13–19% of volatile solids. The maximum specific hydrogen production potential of 122.9ml H₂/g carbohydrate-COD was found at 87:13 (food waste: sewage sludge). A comparative study was carried out by Pan, J., Zhang, R., El-Mashad, H., Sun, H., & Ying, Y. (2008). on hydrogen production at mesophilic and thermophilic conditions.

The hydrogen yield from the thermophilic acidogenic culture was higher than the mesophilic culture in all tested food to microorganism ratio. Continuous hydrogen fermentation in

a leaching bed reactor was carried out by Han, S., & Shin, H. (2004). At an optimized dilution factor (D), from the reduced COD of the food wastes was converted to hydrogen, volatile fatty acids, ethanol and carbon dioxide. It was suggested that control of D gave environmental conditions favorable for hydrogen production. Further, the efficiency was improved by enhanced degradation of slowly degradable matters. It delayed the shift of the predominant metabolic flow from hydrogen and acid forming pathway to solvent forming pathway. Potential of hydrogen production from highly concentrated, carbohydrate-rich wastewaters was reviewed by Van Ginkel, S., & Logan, B. (2005). The biogas produced using wastewater from apple processing and potato processing industries contained 60% hydrogen with no methane generation. When additional nutrients were added to the wastewaters, it showed an increase of hydrogen production. The overall hydrogen production was 0.9 L-H₂/L medium for apple processing waster and 2.1 L-H₂/L medium for potato processing wastewater. Rice slurry is another potential starch-based waste from industry as rice is the most common dietary food. Rice contains carbohydrate, protein, lipid and water.

2.2. Wood based materials

Wood materials- Lignocellulosic materials, containing cellulose, hemicelluloses and lignin, are products of photosynthesis, which form the structural component of plant cell wall. Lignocellulose is available in bulk as Lignocellulosic wastes of agricultural and wood industries. Lignocellulolytic materials are the largest renewable sources of hexose and pentose sugars with potential use for industrial fermentation especially for ethanol production (Soloman, B., Barnes, J., Halvorsen, K. (2007), Chen, M., Xia, L., & Xue, P. (2007) and Balusu, R., Paduru, R., Kuravi, S., & Reddy, S. (2005)). However, the limitation was the pretreatment process involved to degrade cellulose to simple sugars (Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y., Holtzapple, M., & Michael Ladisch. (2005)). Hydrogen production from lignocellulosic materials would be a potential process with the help of pretreatment on materials and cellulolytic microorganisms. During the hydrogen production phase, Clostridium cellulolyticum was found to be in close contact with cellulose and bacterial cell was released at the end of growth indicating the exhaustion of accessible cellulose Gelhaye, E., Petittdemange, H., & Gay, R., (1993). E. harbinense can produce hydrogen efficiently from mono saccharides but not cellulose. The bioaugmentation of both strains improved hydrogen production from microcrystalline cellulose from 755ml H₂/L-medium to 1810ml H₂/L-medium Lay, J. (2001). The relationship of reducing sugar in cellulose hydrolysate was reported by Lo, Y., Bai, M., Chen, W., Chang, J. (2008). Lignocellulosic materials were initially degraded by Cellulomonas sp. rich sludge, and the reducing sugar-rich hydrolysate was readily used by pure Clostridium sp. for hydro-

gen production. With an initial reducing sugar (RS) concentration of 0.8 g/L, the hydrogen production and yield were approximately 23.8ml H₂/L and 1.21mmolH₂/g RS (1.09mmolH₂/g cellulose), respectively. Acidification of lignocellulosic waste materials using diluted HCl successfully increased hydrogen production from 10 to 136- fold compared to hydrogen production from raw waste (Fan, Y., Zhang, G., Guo, X., Xing, Y., & Fan, M. (2006), Fan, Y., Zhang, Y., Zhang, S., Hou, H., & Ren, B. (2006) and Zhang, M., Fan, Y., Xing, Y., Pan, C., Zhang, G., & Lay, J. (2007)).

2.3. Dairy wastes

Lactose-rich wastewater can be found in the cheese and dairy industry wastewater. Cheese whey contains about 5% lactose, which can be a substrate for fermentation purposes. Even though several technologies have been applied to convert lactose-rich wastewater to other products, utilization and disposal of wastewater are still one of the problems in dairy industry (Ferchichi, M., Crabbe, E., Gil, G., Hintz, W., Almadidy, A. (2005), Nath, A., Dixit, M., Bandiya, A., Chavda, S., & Desai, A. (2008) and Fenggl, Letey, J., Changac, Campbellmathewsm. (2005)). had conducted experiments to study the possibility of hydrogen production from crude cheese by Clostridium saccharoperbutylaceticum. Hydrogen production rate was affected by pH with the optimum at mild acidic range. The highest hydrogen production potential and yield of hydrogen were achieved at 1432ml and 2.7 mol H₂/mol lactose, respectively at pH 6. An increase of yield of hydrogen production was achieved at 3mol H₂/mol lactose Clostridium thermolacticum at continuous mode Collet, C., Adler, N., Schwitzgugue Bel, J.P., Ringer, P. (2004). Venkata Mohan, S., Lalit Babu, V., Sarma, P. (2007) had evaluated the potential of hydrogen production from dairy wastewater coupled with wastewater treatment. Hydrogen gas production was found highest with the organic loading rate of 3.5 kg COD/m³ day, with yield of hydrogen production at 1.105mmol H₂/m³ -min and 64.7% COD removal.

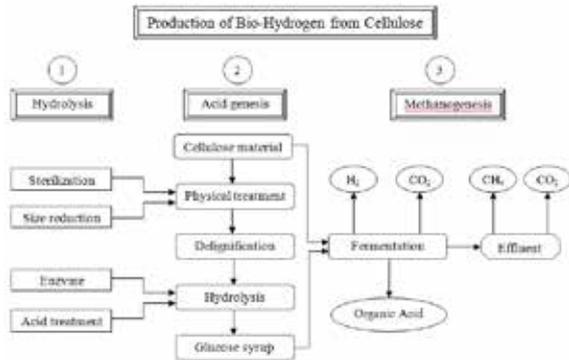


Table - 1: Characteristics of Palm Oil Mill effluent

Biochemical Oxygen Demand	22,000-5,43,000
Chemical Oxygen Demand	75,200-96,300
Total carbohydrate	16,300-20,200
Total nitrogen	830-920
Ammonium-nitrogen	25-30
Total Phosphorus	97-125
Phosphate	8,300-10,600
Oil	35,000-42,000
Total solids	8,500-12,000
Suspended solids(SS)	4,200-4,500

Source: O-Thong, Prasertsan P, Intrasungkha N (2008)

2.4. Oil Mill Waste

Oil mill-Palm oil is a major cash crop in many tropical developing countries including Malaysia, where palm oil is a major revenue earner. During the extraction of crude palm oil (CPO), the mills generate liquid waste, namely palm oil mill effluent (POME). On average, for a tonne of fresh fruit bunch (FFB) processed,

it generates about a tonne of POME with COD in the range of 70-100 kg COD/L (O-Thong, S., Prasertsan, P, Intrasungkha, N., Dhamwichukorn, S., Birkeland, N. (2007)). As the BOD and COD of POME are too high to be discharged to domestic waterways, pre-treatment processes need to be done. The common practices of POME treatment are by using ponding system or open digestion tank with long hydraulic retention time (HRT), bad smell and difficulty in biogas collection (Chin, K., Lee, S., Mohammad, H. (1996) and Yacob, S., Hassan, M., Shirai, Y., Wakisaka, M., Subash, S. (2005)). Researches have been carried out to seal open digestion tank to collect biogas which pollutes the environment (Yacob, S., Shirai, Y., Hassan, M., Wakisaka, M., Subash, S. (2006)). Previously, some researches have been carried out on the utilization of POME as substrate for the production of commercial products such as citric acid and compost (Alammz Jamal, P, Nadzirmn. (2008)). Atif Aay, Fakhru'l-Razi, A., Ngan, M., Morimoto, M., Iyuke, S., Veziroglu N. (2005) has studied the possibility of hydrogen production from raw POME. It was found out that the production of hydrogen was comparable with the published data of hydrogen production from carbohydrate-rich wastewater. An optimized thermophilic condition was developed with the prediction of hydrogen gas at 6.5 L H₂/L POME O-Thong S, Prasertsan P, Intrasungkha N, Dhamwichukorn S, Birkeland N. (2007). O-Thong S, Prasertsan P, Karakashev D, Angelidaki I. (2008) observed the diversity of microbe in anaerobic sludge for hydrogen production at thermophilic condition. Thermophilic hydrogen producing bacteria was identified as Thermoanaerobacterium, thermosaccharolyticum.

2.5. Glycerol waste

Glycerol is generated in large amount during the production of biodiesel. With every 100 lbs of biodiesel produced by transesterification of vegetable oils or animal fats, 10 lbs of crude glycerol is generated Yazdani Ss, Gonzalez R. (2007). The glycerol generated is presently applied as an ingredient of cosmetics, but a further increase in the production of biodiesel fuels would raise the problem of efficiently treating waste containing glycerol from this industry. The production of 1, 3- propanediol from glycerol waste has caught the attention of researchers as it can be applied as a basic ingredient of polyesters Petitdemange G, Durr C, Abbad Andaloussi S, Raval G. (1995). Anaerobic treatment of glycerol at thermophilic and mesophilic temperature was studied using an immobilized bioreactor packed with polyurethane (Yang Y, Tsukahara K, Sawayama, S. (2008)). The average removal of dissolved organic carbon was 86.7% at thermophilic condition. 16srRNA study indicated that hydrogenotrophic and Methanobacterium sp. were present syntrophically. Therefore, presumably hydrogen could be possibly to be produced from glycerol waste with indigenous hydrogenotrophic bacteria. Ito T, Nakashimada Y, Senba K, Matsui T, Nishio N. (2005) conducted a study on hydrogen and ethanol production from waste discharged after biodiesel manufacturing process using Enterobacter aerogenes HU-101. Experimental results showed that the addition of yeast extract and tryptone are needed to accelerate the production of hydrogen and biodiesel waste should be diluted due to the high salt content. Hydrogen production rate reaches maximum at 63 mmol/ L/h by using porous ceramics as support materials to immobilize cell. Yeast extract, NH₄Cl, KCl and CaCl₂ were found to be the most important components that influence hydrogen production from glycerol (Liu, F, Fang, B. (2007)). Sakai, S., Yagishita, T. (2007) demonstrated hydrogen production in bio electrochemical cells using thionine as an exogenous electron transfer mediator to be reduced by E. aerogenes and reoxidized by electrode supplied with electric current. By using this system, E. aerogenes was found effectively consumed glycerol. The rates of both glycerol consumption and hydrogen and ethanol production increased with increasing thionine concentration and increasing surface areas of the working electrode. Glycerol consumption in the electrode system reactor was 2.6-fold higher than the normal fermentation system.

Conclusion

The analysis of biological waste materials gives us a clear view about the production of biogas. The characteristics of the wastes have been efficiently reviewed and the following conclusions have been drawn.

- The demand for conventional fuels are being increased day-by-day at an alarming rate, therefore, bio-hydrogen will be the potential alternate fuel produced from the Biogas.
- Hydrogen is currently an expensive energy compared to other conventional energy sources. The microbial production of hydrogen will be an alternative way to produce hydrogen economically. Utilization of wastes to generate hydrogen energy could reduce the production cost, making the hydrogen gas more available and cheaper.
- The production efficiency must be improved and an infrastructure for transporting and distributing hydrogen efficiently is to be developed.
- The combination of waste treatment and energy production is an added advantage. If the biomass that is obtained is used effectively, then the energy needs of humans could be met easily.
- Along with the above advantages hydrogen fuel cell vehicles can be run with zero emission which is eco-friendly, also hydrogen either blended with petrol or can be used in substitute for petrol in spark ignition engines.

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