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Agricultural Wastes-To-Green Energy in Egypt

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Agriculture Wastes as Biomass Feedstock

In Egypt, dependence on fossil-based fuels (e.g., coal, oil, and natural gas) as a primary source of energy can cause environmental damage and health problems. Moreover, the recent rise in fossil fuels prices has driven the national economy towards a critical issue. Hence, it is worthwhile finding alternative sources of energy that can cope with the extensive utilization of fossil fuels. In parallel, agricultural wastes cause several problems to rural villages/areas in Egypt, *viz*., they can be incinerated in the field creating air and soil pollution problems. The five crops producing the highest quantities of wastes are rice, sugarcane, corn, cotton, and wheat. These wastes include cobs (corn cobs), bagasse (sugar cane bagasse), straw (rice straw), and peeling (banana and orange peels).The estimated amount of agricultural wastes in Egypt ranges from 22 to 26 million dry tonnes per year. This huge amount should be beneficially utilized rather than being incinerated or disposed in a land fill.

Agricultural wastes are mainly composed of lignocellulosic materials remained after collecting the valuable parts of crops. Lignocellulosic constituents can retain carbohydrates in the form of cellulose (35- 45%) and hemicellulose (25-40%) [1]. Hence, agricultural wastes should be subjected to a hydrolysis/delignification process to break the interpolymer/intermolecular linkages of lignocellulose complex and hydrolyze the cellulose and hemicellulose fractions [2]. The hydrolysis phase should be able to disrupt the lignin component of the plant material and release a sufficient amount of valuable sugars [3]. The extracted sugars can be managed to produce green energy either alone or in co-digestion with other organic materials.

Hydrogen Gas

Hydrogen gas, as a clean and renewable source of energy, has been found to be a potential solution for carbon-free environments. H_2 gas has the highest gravimetric energy density of 122 – 142kJ/g, which is 2.75-folds that of hydrocarbon fuels [4]. The combustion of H_2 gas produces only water with no hydrocarbons, carbon monoxide, or carbon dioxide in the end product. Hydrogen can be obtained using various forms of energy, i.e., biological (dark fermentation, or photo-fermentation), electrical (electrolysis, or plasma arc decomposition), thermal (thermolysis, thermo-catalysis, or thermochemical processes), and photonic (PV electrolysis, photo-catalysis, photo-electrochemical, or bio-photolysis) [5]. Amongst them, biological routes providea cost-effective and environmentally friendly solution for hydrogen production [6].

Biological H_2 fermentation

In the biological fermentation process, various bacterial species are capable of converting sugars (carbohydrates) into H_2 gas and other value-added products. Biological H_2 fermentation is dependent on the hydrogenases enzymes, which can be divided into iron-iron [Fe-Fe] hydrogenases, and nickel–iron [Ni-Fe] hydrogenases [7]. Recently, several types of researches have been conducted to improve the bioactivity of hydrogen-producing microorganisms and increase the conversion efficiency of the substrate into H_2. The production rate and yield of bio-H_2 are influenced by various environmental conditions such as medium pH, culture temperature, concentration and composition of substrate, inoculum dosage, and fermentation time [8]. The application of nanoparticles for encouraging the bioactivity of microorganisms to produce high hydrogen yields has been reported [4]. Nanoparticles can stimulate hydrogen productivity 0 the surface effect and the quantum size effect.

Dark Fermentation

During dark fermentation, acidogenic bacteria such as *Clostridium sp.* can convert various organic substrates (as a source of electrons and energy) into H_2 gas in addition to volatile fatty acids (VFAs) and CO_2 [9]. Most studies have reported that culture medium pH of 5.5-6.5 provides the optimum condition for hydrogen fermentation [10]. Dark fermentation can be performed under mesophilic (25- 40°C),thermophilic (40-65 °C) or hyper-thermophilic (>80 °C) conditions. The favorable ratios of nutrients supply have been reported as 11.4:1-200:1 for COD: N and 73:1-970:1 for COD:P [11]. Species of *Bacillus, Clostridium*, and *Enterobacter* have been reported to dominate the dark fermentation studies as pure cultures in the inoculum. The mixed culture of sludge should be subjected to a treatment process to eliminate the H_2 consuming bacteria such as methanogenic and homoacetogenic microorganisms [10]. The sludge treatment techniques include heat shock, acid or alkaline treatment, sonication, freezing and thawing, and bromoethane sulfonate or iodopropane methods.

Theoretically, a maximum of 4 mol hydrogen per mole glucose can be obtained when acetic acid is the major VFA component (Eq. 1). However, lower yields are obtained in real applications because a portion of the glucose is stored in cells for microbial growth and maintenance. The butyric acid formation is accompanied by the formation of 2 mol-H_2 per mole glucose (Eq. 2) while propionic acid accumulation consumes 2 mol-H_2 per mole glucose (Eq. 3). When both acetic and butyric acids are produced during dark fermentation, 2.5 mol-H_2per mole glucose can be attained. Lactic acid fermentation does not affect either the formation or the consumption of bio-H_2 generation (Eq. 4).

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 4H_2 + 2CO_2 \quad (1)$$

$$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2H_2 + 2CO_2 \quad (2)$$

$$C_6H_{12}O_6 + 2H_2 \rightarrow 2CH_3CH_2COOH + 2H_2O \quad (3)$$

$$C_6H_{12}O_6 \rightarrow 2CH_3CHOHCOOH \quad (4)$$

Photo-Fermentation

The soluble microbial products obtained from dark-fermentation can be subsequently utilized as a substrate to generate more H_2*via*photo-fermentation [4]. In photo-fermentation, photosynthetic bacteria utilize light as an energy sourceto assimilate small organic molecules into H_2 and new bacterial cells. However, the improvement of H_2 production via photo-fermentation requires strict control on environmental conditions. For example, the optimum ranges of pH and temperature have been reported to be 6.8 – 7.5 and 31 – 36 °C, respectively [12]. Other operating parameters can include wavelength 400 1000nm and lightintensity 6-10klux.

Purple non-sulfur bacteria (PNS) are favorable photosynthetic microorganisms responsible for H_2 production during the photo-fermentation process. These gram-negative bacteria are able to absorb and utilize a wide region of the solar spectrum and perform high substrate conversion efficiencies [13]. Several strains such as *Rhodo spirillumrubrum, Rhodopseudo monaspalustris, Rhodobacter sphaeroides*, and *Rhodobactercapsulatus* have been widely employed for genetic and physiological studies in H_2fermentation production. Increasing the light illumination efficiency, and avoiding inhibitory factors (e.g., ammonia nitrogen, and oxygen) are the main factors used for enhancing the performance of photo fermentation [14].

Theoretically, the integration of dark and photo fermentation processes can achieve hydrogen yield up to 12 mol-H_2/mol-glucose. More studies have been conducted to improve the rate of photo-fermentation, thereby promoting the efficiency of the overall bio-hydrogen production process [4].

Recommendations

Future studies should be conducted to improve the bioconversion efficiencies of agricultural wastes into H_2 gas. The integration of dark and photo fermentation mechanisms should also be examined in details. In addition, the application of more complex carbon sources for bioH_2 fermentation should be studied. The ideal microbial consortium responsible for bio-hydrogen production from waste materials should be determined. Further works should be performed to assess the economic analysis and feasibility study for bioH2 generation from waste materials.

References

1. QiuC, Yuan P, Sun L, Wang S, Lo S, Zhang D (2017) Effect of fermentation temperature on hydrogen production from xylose and the succession of hydrogen-producing microflora. J ChemTechnol Biotechnol 92(8):1990-1997.
2. Kumar G, Bakonyi P, Periyasamy S, Kim S, Nemestóthy N, et al. (2015) Lignocellulose biohydrogen: Practical challenges and recent progress. Renew Sust Energ Rev 44: 728-737.
3. Reddy K, Nasr M, Kumari S, Kumar S, Gupta S, et al. (2017) Biohydrogen production from sugarcane bagasse hydrolysate: effects of pH, S/X, Fe^{2+}, and magnetite nanoparticles. Environ Sci Pollut Res 24(9): 8790-8804.
4. Nasr M, Tawfik A, Ookawara S, Suzuki M, Kumari S, et al. (2015) Continuous biohydrogen production from starch wastewater via sequential dark-photo fermentation with emphasize on maghemite nanoparticles. J Ind Eng Chem 21: 500-506.
5. Mishra P, Thakur S, Singh L, Krishnan S, SakinahM, et al. (2017) Fermentative hydrogen production from indigenous mesophilic strain Bacillus anthracis PUNAJAN 1 newly isolated from palm oil mill effluent. Int J Hydrog Energy. 42(25): 16054-16063.
6. Bravo I, Lovato G, Rodrigues J, Ratusznei S, Zaiat M (2015) Biohydrogen production in an AnSBBR treating glycerin-based wastewater: effects of organic loading, influent concentration, and cycle time. Appl Biochem Biotechnol 175(4): 1892-1914.
7. Amin M, Bina B, Taheri E, Fatehizadeh A, Ghasemian M (2016) Stoichiometry evaluation of biohydrogen production from various carbohydrates. Environ Sci Pollut Res 23(20):20915-20921.
8. Qiu C, Shi P, Xiao S, Sun L (2017) Effects of pH and substrate concentrations on dark fermentative biohydrogen production from xylose by extreme thermophilic mixed culture. World J Microbiol Biotechnol 33(1): 7.

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9. Nasr M, Tawfik A, Ookawara S, Suzuki M (2013) Environmental and economic aspects of hydrogen and methane production from starch wastewater industry. J Water Environ Technol 11: 463-475.
10. Nasr M, Tawfik A, Suzuki M, Ookawara S (2015) Mathematical modeling of bio-hydrogen production from starch wastewater via up-flow anaerobic staged reactor. Desalination Water Treat 54(1): 50-58.
11. De Gioannis G, Friargiu M, Massi E, Muntoni A, Polettini A, et al. (2014) Biohydrogen production from dark fermentation of cheese whey: Influence of pH. IntJ Hydrog Energy 39(36): 20930-20941.
12. Laurinavichene T, FedorovA, Ghirardi M, Seibert M, Tsygankov A (2006) Demonstration of sustained hydrogen photoproduction by immobilized, sulfur-deprived Chlamydomonas reinhardtii cells. Int J Hydrog Energy 31(5): 659-667.
13. Akbari L,VaziriB (2017) Comprehensive modeling of photo-fermentation process for prediction of hydrogen production. Int J Hydrog Energy 42(21): 14449-14457.
14. Wu Y-N, Wen H-Q, Zhu J-N, Ding J, Ren N-Q, et al. (2016) Best mode for photo-fermentation hydrogen production: The semi-continuous operation. Int J Hydrog Energy 41(36): 16048-16054.

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