

Role of Iron Concentration on Hydrogen Production from Rice Mill Effluent

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ABSTRACT: Hydrogen is the most abundant chemical element in the universe and has the highest energy content of any fuel source on the market today. In the present study, batch experiments are performed using wastewater and sludge to examine the influence of iron concentration on hydrogen production. The batch experiments are conducted in varying iron concentrations and sludge to wastewater ratios by checking the physicochemical characteristics of the wastewater. The experiment is mainly conducted by using rice mill effluent. It was inferred that maximum hydrogen production was obtained in 10% wastewater and 90% sludge also the maximum hydrogen production was happened in .15g of iron concentration. The study shows that the iron concentration plays an important role in the production of hydrogen by anaerobic bacteria as it facilitates activation of hydrogenase bacterial action cofactors and hydrogen evolution.

KEYWORDS: Hydrogen, Waste water, Sludge, Hydrogenase, Iron concentration, pH, Water displacement

I. INTRODUCTION

The worldwide energy need has been increasing exponentially, the reserves of fossil fuels have been decreasing, and the combustion of fossil fuels has serious negative effects on environment because of CO₂ emission. Owing to widespread exploitation of fossil fuels severe environmental problems like global warming and ozone depletion have already been initiated, in turn adding to worldwide economic loss by environmental damage. At this juncture, the world is seeking cleaner energy resources to mitigate imminent fuel shortages to provide the energy necessary for future. Hydrogen is considered as the future energy carrier, due to its high energy content and non-polluting nature and also it can be considered as an environmental friendly alternative to fossil fuels and other fuels in automobiles and that which can be produced with less impact on environment. Hydrogen is considered as a viable alternative fuel and “energy carrier” of future. Hydrogen gas is clean fuel with no CO₂ emissions and can easily be used in fuel cells for generation of electricity. Besides, hydrogen has a high energy yield of 122 kJ/g, which is 2.75 times greater than hydrocarbon fuels. The major problem in utilization of hydrogen gas as a fuel is its unavailability in nature and the need for inexpensive production methods. Demand on hydrogen is not limited to utilization as a source of energy. Hydrogen gas is a widely used feedstock for the production of chemicals, hydrogenation of fats and oils in food industry, production of electronic devices, processing steel and also for desulfurization and reformulation of gasoline in refineries. Hydrogen production from the recycling of organic waste is considered as a greener technology compared to conventional hydrogen production methods. Also compared to other metal ions, iron has the benefits of high protection during handling as it scarcely reacts with water at low temperature, is easily recoverable, and is efficiently excavated. Thus, in the present study, batch experiments are designed to investigate the role of iron concentration on hydrogen production from wastewater containing large amount of carbohydrate content.

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II. METHODOLOGY

A. Experimental Setup

The experimental set up consists of a batch reactor. Erlenmeyer flask of 250ml capacity is taken as the batch reactor. Working volume was considered as 100ml. The flask was tightly closed using a rubber cork with two outlets, one for sample collection and the other for hydrogen gas. The sample collection outlet was tightly closed using a clamp in order to prevent the entry of air from outside. The test was conducted in tightly controlled conditions of pH, temperature etc. Water displacement method is used to collect gas obtained.

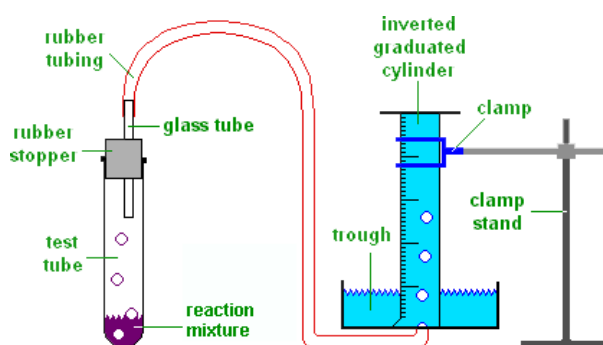


Fig. 1 Experimental set up for water displacement method

The water displacement method is the process of measuring the volume of an irregularly shaped object by immersing it in water. This method served as the basis for the principle developed by the Greek philosopher Archimedes. The principle states that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid. The principle applies to both floating and submerged bodies and to all fluids, i.e., liquids and gases. The obtained gas is collected in an inverted jar either graduated or not. If it is graduated the amount of gas can be easily calculated and if it is not suitable methods are adopted to calculate the amount of obtained gas.

B. Sample Collected

Rice mill generates wastes mainly in the solid, liquid and gaseous forms. Husk and ash constitute the main bulk of solid wastes. However husk is reused in the mill for boiling water. So residues left after combustion is ash. Gaseous emission is mainly CO, SO₂ and NO_x. Besides these, rice mill generate liquid wastes from the following operations: parboiling wastewater, paddy soaked wastewater and boiler blow down. The liquid waste from these operations ultimately passes through a common drain to the outside of the mill boundaries and this is commonly called as combined effluent or combined wastewater or loosely as effluent or waste water.

Sample was collected from a nearby rice mill. The taken sample includes both waste water and sludge. Waste water is collected from the sedimentation tank which comes just after the skimming tank. The sample without oil and grease are collected since their presence may affect the bacterial action which helps in efficient hydrogen production. Sludge was collected from the bottom of settling tank and it was used in the experiment as it contain large amount of biomass including bacteria which facilitates biological reactions.

C. Reactions taking place

During the aerobic growth of microorganisms, oxygen serves as the acceptor of electrons coming from organic substrates while in the fermentation process the electron may be taken over by various substances, including protons, which results in the production of molecular hydrogen by these microorganisms. In the fermentation process glucose, which is the primary source of carbon, is transformed into pyruvate during the glycolytic pathway. Next, pyruvate is oxidized to acetyl coenzyme A in the presence of coenzyme A and an oxidized form of ferredoxin. Ferredoxin in

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oxidized form is created during the reduction of protons to molecular hydrogen with the participation of hydrogenase. The final products of glucose oxidation include organic acids (acetic, propionic), carbon dioxide and hydrogen. Obtaining hydrogen during fermentation is possible with the use of many microorganisms such as from the genus *Clostridium* (*C. butyricum*, *C. pasteurianum*), genus *Enterobacteriaceae* (*E. coli*, *E. cloacae*) as well as from thermophilic microorganisms from the genus *Thermoanaerobacterium* (*T. thermosaccharolyticum*). Bacterial cultures used during the fermentation process of obtaining hydrogen are most often obtained from samples which constitute their natural habitat such as sewage sludge, post-fermentation deposits, and industrial equipment elements. The most desired source of organic matter, necessary for the growth of cells and production of hydrogen, is glucose. This substance may be obtained during the processing of materials commonly recognized as waste. In this project sludge obtained from treatment plant acts as the source of microorganisms and bacteria.

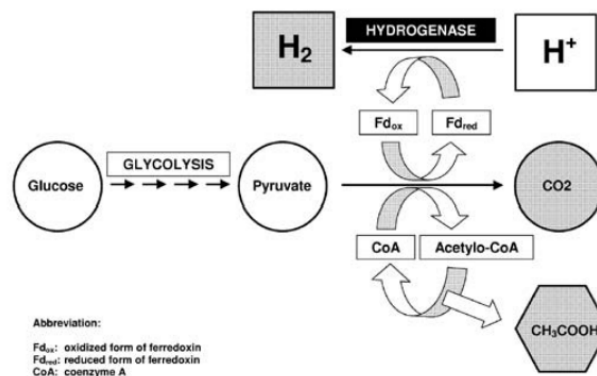


Fig. 2 Reactions taking place for hydrogen production

D. Experiment conducted

- Before and after conducting the experiment, test for p^H and solids were done.
- The p^H of the sample should be within the range of 6-7 and test temperature should be $25^{\circ}C$ - $35^{\circ}C$.
- Heated the sample for 2 hours at $110^{\circ}C$ for inactivate the methanogens and enhancing hydrogen producing bacteria.
- Mix waste water and sludge in different proportions with different iron concentrations.
- Observe the evolution of hydrogen for 3 days

III. EXPERIMENTAL RESULTS

The experiment is conducted in various iron concentrations of sludge and waste water like 50:50, 60:40, 70:30, 80:20, and 90:10. The following are the values obtained for solids and p^H before and after conducting the experiment and the corresponding evolution of hydrogen for 50:50 and 90:10 mix proportions of sludge and waste water.

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A. 50% Wastewater and 50% sludge

Table 1. Before Hydrogen production

Sl.no	Parameter	Obtained value
1	pH	4.5
2	Total solids	1500 mg/l
3	Total fixed solids	1100 mg/l
4	Filterable solids	250 mg/l
5	Non filterable solids	1250mg/l
6	Volatile solids	400 mg/l

The pH obtained was 4.5 which were not within the range adopted for the test. So suitable alkali (NaOH) was added to bring the pH within the range. The sum of filterable and non filterable solids gave the total solid content in the sample.

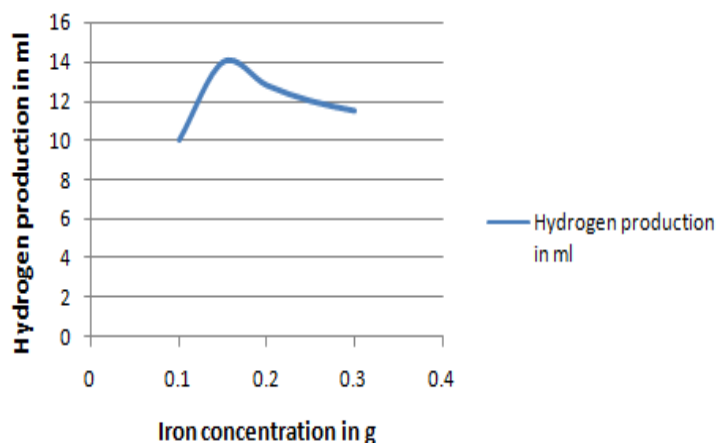


Fig. 3 Hydrogen production

Table 2. Amount of Hydrogen produced in various iron concentration

Iron Concentration in g	0.1	0.15	0.2	0.25	0.3
Hydrogen production in ml	10	14	12.8	12	11.5

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The maximum hydrogen production occurs at 0.15g and minimum at 0.1g of iron concentration. The hydrogen production was in a range of 10 ml to 14 ml. The maximum amount of hydrogen produced was 14 ml.

Table 3.After Hydrogen production

Sl.no	Parameter	Obtained value
1	pH	6.7
2	Total solids	1150 mg/l
3	Total fixed solids	1100 mg/l
4	Filterable solids	150 mg/l
5	Non filterable solids	1000 mg/l
6	Volatile solids	50 mg/l

It is evident that the solid content gets reduced after the production of hydrogen. In normal treatment process also the aim is solid removal. The amount of solids gets reduced as a result of the various biological reactions taking place. By the biological reactions the larger compounds may break down into smaller ones thereby the amount of solids reduces.

B. 10% Wastewater and 90% sludge

Table 4.Before Hydrogen production

Sl.no	Parameter	Obtained value
1	pH	4.92
2	Total solids	1200 mg/l
3	Total fixed solids	650 mg/l
4	Filterable solids	450 mg/l
5	Non filterable solids	750 mg/l
6	Volatile solids	550 mg/l

Sludge is a semi-solid material that is produced as a by-product of treatment process. It contain large amount of bacteria and other microorganisms which helps in various biological and enzymatic reactions. The solid content in the sample were represented in the above table. The solid content was analysed after hydrogen production also.

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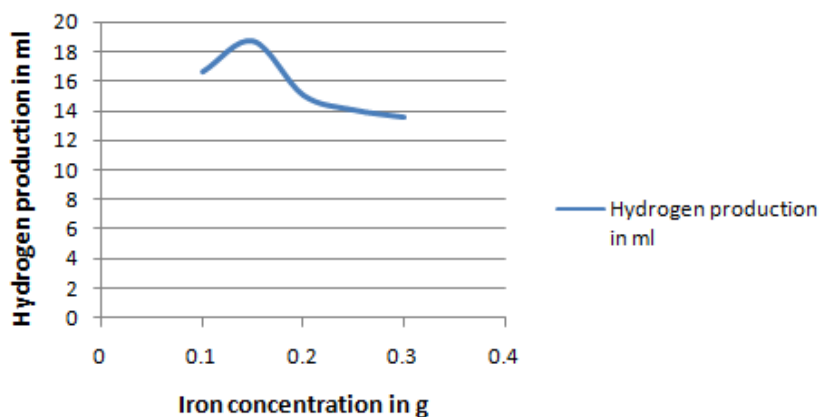


Fig. 4 Hydrogen production

Table 5. Amount of hydrogen produced in various iron concentration

Iron Concentration in g/l	0.1	0.15	0.2	0.25	0.3
Hydrogen production in ml	16.6	18.7	15	14	13.5

The maximum hydrogen production occurs at 0.15g and minimum at 0.3g of iron concentration. The hydrogen production was in a range of 13.5 ml to 18.7 ml. The maximum amount of hydrogen produced was 18.7 ml.

Table 6. After Hydrogen production

Sl.no	Parameter	Obtained value
1	pH	7.88
2	Total solids	1000 mg/l
3	Total fixed solids	650 mg/l
4	Filterable solids	300 mg/l
5	Non filterable solids	700 mg/l
6	Volatile solids	350 mg/l

The amount of total fixed solids remains the same before and after hydrogen production indicating that the residue remained after igniting the sample at high temperature remains the same before and after hydrogen production. The solid content gets reduced after the production of hydrogen. So breakdown of organic matter takes place.

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IV. CONCLUSIONS

- Maximum hydrogen production is obtained at
 - .15 g of iron concentration
 - 90% sludge and 10% waste water
- There is no change in total fixed solids before and after experiment
- There is a reduction in the value of solids after the experiment.

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