Hydrogen Production by Combined Fermentation of Wild Taro and Surplus Sludge

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Abstract. In order to alleviate the energy problem in the world, wild taro and residual sludge were used as the substrate for joint fermentation, and the effects of different pretreatment methods of wild taro on the joint fermentation system were studied to find the best reaction conditions, and the fermentation products were analyzed by using meteorological chromatograph. The experimental results show that the residual sludge after heat treatment can inhibit the activity of methanogens, so as to increase the yield of hydrogen. At the same time, it was found that the complex macromolecules such as cellulose rich in the wild taro could be effectively decomposed after the pre-treatment, releasing a large number of carbon sources, regulating the C/N of the anaerobic fermentation system, improving the activity of the anaerobic microorganisms in the system, so as to obtain the highest hydrogen production. When the pretreatment pH was 11 and the treatment time was 24h, the maximum gas production reached 203.5 mL, including 49.25 mL hydrogen and 24.2% hydrogen concentration.

1. Introduction

With the rapid development of industry and the increasing energy crisis, the world has accelerated the development of biomass energy [1-2], including bio-hydrogen [3], biogas, ethanol and other fuels. Conventional hydrogen production methods mainly include fossil fuel method and water electrolysis method. The fossil fuel law consumes a lot of fossil fuels and causes pollution. Although the water electrolysis method can regenerate raw materials, it consumes a lot of energy. In contrast, production of hydrogen by microorganisms has its unique advantages.

Currently there are two hydrogen microorganism research: Light legitimate and fermentation [1], wherein the fermentation in Hydrogen has a high hydrogen yield, without light, wide fermentation substrate material sources, etc. [2-3]. In addition to glucose, biomass rich in complex macromolecules such as cellulose and hemicellulose can also be used as a substrate for microbial fermentation after pretreatment [4-5]. Since solar energy directly from the biomass, with renewable and does not produce secondary pollution, and therefore the hydrogen fermentation of biomass of great legal importance. The efficient and economical treatment and disposal of sludge as well as harmlessness, reduction and resource utilization is a major issue that needs to be solved urgently, which has an important impact on urban environmental protection and sustainable economic and social development. Therefore, the use of surplus sludge as a fermentation base material to produce hydrogen can achieve the purpose of waste energy utilization, which not only controls environmental pollution, but also alleviates the energy crisis by turning waste into treasure [6]. The surplus sludge is rich in organic matter such as protein and
polysaccharides. It is a good substrate for hydrogen production by fermentation, and the surplus sludge contains a large number of microorganisms. Through proper pretreatment, the purpose of screening hydrogen-producing bacteria and inhibiting hydrogen-consuming bacteria can be achieved [7-10]. However, the carbon and nitrogen of sludge is relatively low, which is not conducive to the metabolism of anaerobic microorganisms. Therefore, in this experiment, wild taro was used as an external carbon source and co-fermented with sludge. The growth and reproduction speed of wild taro is so large that the villages in southern China are full of wild taro plants, causing certain pollution to the environment[11]. At the same time, similar to straw[12], wild taro is rich in a large amount of cellulose and lignin and other substances, and wild taro, algae[13] and kitchen waste[14] are all a kind of high-quality fermentation substrate.

2. Materials and Methods

2.1. Materials

The wild taro was collected from a village in Xiamen, dried and ground into powder for preservation. The residual sludge was taken from a sewage treatment plant in Xiamen and stored at 4 °C, and the solid content (TS) of the sludge was about 3%. Fresh surplus sludge is placed in a beaker, the beaker was sealed, placed in a water bath at 100 °C constant temperature water bath 30min, then cooled to room temperature under natural conditions.

(1) Thermal Pretreatment: 5 parts by weight of other wild Taro after drying was ground to powder was dissolved in 30mL of distilled water were placed in 50 °C, 60 °C, 70 °C, constant temperature water bath 80 °C, 90 °C the water bath 30min.

(2) Acid (alkali) pretreatment: 5 parts of dried wild taro were ground into powder and dissolved in 30mL distilled water. The pH values were adjusted to 2, 2.5, 3, 3.5, 4 (8, 9, 10, 11, 12) with HCl (NaOH), respectively, and soaked for 24h.

The pretreatment of surplus sludge and fermentation of wild taro for hydrogen production were carried out in a 250mL conical flask, and the experimental device is shown in Figure 1. Before fermentation, the pH value of the substrate was adjusted to 7.0 with 6mol/L HCl or 6mol/L NaOH, and 250mL of surplus sludge and an appropriate amount of wild taro were taken into the conical flask. The conical flask was purge with nitrogen for 5min to remove the excess oxygen, and then the conical flask was sealed quickly. The sealed-conical flask was placed in a constant temperature water bath and subjected to anaerobic fermentation at 35 °C. The fermentation gas was collected and analyzed by drainage method. The fermentation gas was extracted regularly with a needle and sent to the gas chromatograph for component analysis.

![Figure 1. Schematic diagram of experimental device.](image)
The gas components produced by the fermentation in this experiment are mainly H2 and CO2. The Agilent Technologies 7890B GC System gas chromatograph is used to analyze the components of the fermentation gas. The column model is 5A, the specification is 3mm × 2mm, and the parameter setting is: column temperature 50 °C, injector temperature 50 °C, thermal conductivity detector temperature 120 °C, carrier gas helium, flow rate 30mL/min.

3. Results and Analysis

3.1 Effect of different N ratio on wild taro and combined sludge fermentation hydrogen

In this experiment, a total of 8 nodes with different mixed carbon-nitrogen ratios are set up, and wild taro is added according to different mixed carbon-nitrogen ratios. From Table 1 and Figure 2, it can be seen that when the carbon-nitrogen ratio is 11:1, the hydrogen production is the largest, and the hydrogen production is 149.5mL, a hydrogen concentration of 15.403%, the amount of hydrogen production was 23.03mL. It means that when the C/N ratio of wild taro is 11, it is the most suitable growth environment for hydrogen-producing bacteria, which can promote the metabolism of hydrogen-producing bacteria, accelerate their decomposition of organic matter, and produce more hydrogen.

Table 1. Effects of different C/N ratios on hydrogen production by joint fermentation of wild taro and residual.

| N ratio | Gas production (mL) | H2 concentration (%) | H2 production (mL) |
|---------|---------------------|----------------------|-------------------|
| 10.25: 1 | 77.5                | 8.791                | 6.81              |
| 10.50: 1 | 92                  | 11.172               | 10.28             |
| 10.75: 1 | 106                 | 7.654                | 8.11              |
| 11.00: 1 | 149.5               | 15.403               | 23.03             |
| 11.25: 1 | 113                 | 14.645               | 16.55             |
| 11.50: 1 | 127.5               | 12.227               | 15.59             |
| 12.00: 1 | 84.5                | 13.92                | 11.76             |
| 12.25: 1 | 85.5                | 9.976                | 8.53              |

Figure 2. Effects of different C/N ratios on hydrogen production by combined fermentation.
3.2 Heat treatment of sludge and wild taro combined production rate of hydrogen

According to Table 2 and Figure 3, hydrogen production is the best when the temperature is 70℃, gas production is 216mL, hydrogen concentration is 20.730%, and hydrogen production is 43.01mL. The main reason is that the hydrogen producing bacteria in the hydrogen production link activated the fermentation hydrogen producing bacteria rapidly when the temperature was 70℃, while the ethanol producing bacteria had no obvious inhibitory effect, so that the hydrogen production reached the maximum. When the temperature is 80℃ and 90℃, the gas production is 175.5mL and 171mL respectively, the hydrogen concentration is 15.441% and 13.992%, and the hydrogen production is 27.10mL and 23.93mL respectively. Indicates that when the temperature is <; At 70℃, the activity of hydrogen producing acetic acid producing bacteria was affected by hydrogen partial pressure, which reduced its metabolic activity, and thus reduced the gas production to a certain extent. When the temperature is greater than 70℃, the protein activity of the fungus is destroyed and the gas production is reduced.

Table 2. Effects of different temperatures on hydrogen production by joint fermentation of wild taro and residual sludge.

| Temperature | H₂ production (mL) | H₂ concentration (%) | H₂ production (mL) |
|-------------|--------------------|----------------------|-------------------|
| 50          | 156.5              | 13.867               | 21.7              |
| 60          | 175.5              | 16.857               | 29.58             |
| 70          | 216                | 20.73                | 43.01             |
| 80          | 175.5              | 15.441               | 27.1              |
| 90          | 171                | 13.992               | 23.93             |

Figure 3. Effects of different temperatures on hydrogen production by joint fermentation of wild taro and residual sludge.

3.3 Effect of acid treatment method on hydrogen production of wild taro

As apparent from Table 3, when the pH was 2, the gas production of 125 mL of, at pH 2.5, gas production of 139 mL; pH is 3, the gas production of 163 mL; pH is 3.5, gas production of 150 mL; pH 4, The gas production volume is 142mL. The gas production rate rises with the increase of temperature. When the pH is 3, the gas production rate reaches the highest, and as the pH continues to rise, the gas production rate begins to decrease.

From Table 3 and Figure 4, it can be concluded that when the pH is 3 under acidic conditions, the
hydrogen production is the largest, mainly because when the pH is 3 under acidic conditions, hydrogen-producing bacteria have the highest protein activity and are most suitable for hydrogen-producing bacteria. The surplus sludge and wild taro acts, so that the maximum amount of hydrogen production. Under acidic conditions, when the pH is 2 and 2.5, the gas production volume is 125mL, 139mL, the hydrogen concentration is 8.915%, 11.365%, and the hydrogen production volume is 11.14mL, 15.80mL, which are significantly lower than when the pH is 3. This shows that when the pH is less than 3.0, the pH is too low, which affects the metabolic activity of activated sludge microorganisms, resulting in a certain degree of attenuation of gas production.

Table 3. Effects of different acidic conditions on hydrogen production from wild taro and surplus sludge.

| pH | H₂ production (mL) | H₂ concentration (%) | H₂ production (mL) |
|----|--------------------|----------------------|--------------------|
| 2  | 125                | 8.915                | 11.14              |
| 2.5| 139                | 11.365               | 15.8               |
| 3  | 163                | 17.833               | 29.07              |
| 3.5| 150                | 17.091               | 25.64              |
| 4  | 142                | 16.221               | 23.03              |

Figure 4. Effects of different acidic conditions on hydrogen production from wild taro and surplus sludge.

3.4 Effect of alkali treatment method on hydrogen production of wild taro

Is apparent from Table 4, when the pH is 8, the gas production of 148.5mL, pH of 9, the gas production of 171 mL; pH of 10, to 175 mL of gas production; pH of 11, gas production is 203.5mL; pH is 12. The gas production volume is 158mL. The gas production rate rises as the temperature rises. When the pH is 11, the gas production rate reaches the highest, and as the pH continues to rise, the gas production rate begins to decrease.

From Table 4 and Figure 5, an alkaline condition with the highest hydrogen production is obtained.
When the pH is 11, the gas production is 203.5mL, the hydrogen concentration is 24.200%, and the hydrogen production is 49.25mL. Mainly because of the time at pH 11, preferably active hydrogen-generating bacteria, thereby promoting the conversion of glucose to hydrogen, so that hydrogen production reached a maximum. At pH 12, gas production is 158.0mL, a hydrogen concentration of 21.507%, the amount of hydrogen production was 33.98mL. When the pH is too high i.e. over-described alkali treatment conditions, the decomposition rate of the microorganisms is suppressed, so that the attenuation gas production.

**Table 4.** Effects of different alkaline conditions on hydrogen production from wild taro and surplus sludge.

| pH  | H₂ production (mL) | H₂ concentration (%) | H₂ production (mL) |
|-----|--------------------|-----------------------|--------------------|
| 8   | 148.5              | 15.095                | 22.42              |
| 9   | 171                | 17.637                | 30.16              |
| 10  | 175                | 22.056                | 38.6               |
| 11  | 203.5              | 24.2                  | 49.25              |
| 12  | 158                | 21.507                | 33.98              |

![Figure 5](image-url) Effects of different alkaline conditions on hydrogen production from wild taro and surplus sludge.

### 4. Conclusion

1. Through experiments, it can be seen that when the C/N ratio is 11:1, the combined fermentation of wild taro and the surplus sludge has the best effect, with a gas production of 149.5 mL and a hydrogen concentration of 15.403%; when the pretreatment temperature is 70 °C, the combined fermentation of wild taro and sludge has the best hydrogen production effect, with a gas production of 216 mL and a hydrogen concentration of 20.730%; when the pH is 3, the combined fermentation of wild taro and sludge with acid pretreatment has the best hydrogen production effect. The gas volume is 163mL, and the hydrogen concentration is 17.83%. When the pH is 11, the combined fermentation of wild taro with alkali pretreatment and surplus sludge to produce hydrogen has the best effect, with a gas production of 203.5 mL and a hydrogen concentration of 24.2%.

2. Comparing three different pretreatment methods, the alkaline pretreatment method has the best effect. Under alkaline conditions, the protein activity of hydrogen-producing bacteria is the highest, and the activity is the highest, which promotes the conversion of glucose to hydrogen, which is beneficial to
wild taro and activated pollution. The combined fermentation of mud to produce hydrogen greatly activates the activity of hydrogen-producing bacteria.

5. References

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