Experimental Research of Batch Co-Anaerobic Fermentation under Constant Temperature of Mixed Biomass

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Abstract: To study the influence of batch anaerobic fermentation under constant temperature of mixed biomass (cow dung and wheat straw) and make sure the optimum mixing ratio, the experiment which mixed cow dung and wheat straw in batch anaerobic fermentation was under CO2. Contrastive analysis the experimental results which shows that the single material of cow dung was superior to the other three groups in the incipient stage, however, co-digestion was just a way which have a cost effective and environmental protection, and needed a reasonable co-digestion ratio of cow dung and wheat straw could increase the biogas production rate and utilization of crop straw. These experimental results were great of instruction for mixed materials anaerobic fermentation under the thermostatic condition. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Mixed biomass, Thermostatic anaerobic fermentation, Accumulative gas production, C/N ratio, Biogas composition.

1. Introduction

As the development of rural urbanization in China and the improvement of farmers, a large number of manure, straw, fruit and vegetable waste, sewage are abandoned that serious polluted the rural living environment. Pollution-free disposal become one of the key problems of rural urbanization in China which need to be solved urgently. Co-digestion is a highly promising, and environmentally friendly technology for the beneficial use of organic waste. It offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. In fact, proper functioning of biogas systems can provide multiple benefits for treating organic waste, such as generating biogas as renewable energy, reducing greenhouse gas emissions, and producing organic fertilizer to the users and the community resulting in resource conservation and environmental protection, play a very important role in China’s rural areas where the energy demand is rapid rise in recently years.

Wheat straw is the residual structure of the plant after grain harvesting, which is mainly composed of cellulose, has the lower efficiency of biogas production because the C/N is lower [1]. Adjusting the ratio of C/N can effectively improve the biogas production rate of straw. Literature review has indicated that the combine of wheat straw and the animal manure increase the biogas yield [2]. As it has the positive synergisms established in the digestion medium and improve the biogas process through (1) supplementing nutrients to increase in the organic content inside the digester, eliciting better utilization
of the digester volume; (2) balancing the C/N ratio to 20-30; (3) diluting inhibitory and/or toxic compounds to enhancement of the digestate stabilization; (4) establishing the required moisture content, with an easier handling of blended wastes; (5) improving the handling of mixed waste streams; (6) economic advantages from the sharing of equipment and costs; (7) stabilizing the pH via an increased buffer capacity; and (8) large reduction of the emission of greenhouse gases into the atmosphere [3-9].

In this work, the utilization of cow dung and wheat straw mixtures for biogas production and the effects of cow dung and wheat straw ratio were investigated with using anaerobic batch digestion test. The co-digestion process and the synergetic effects in different mixture ratio were further investigated by determining methane yield.

2. Materials and Methods

2.1. Collection of Substrates and Inoculums

Wheat straw was collected from the farmers in the near of Lanzhou, Gansu, China. After shredding to paste shape was less than 0.5 cm, was stored at 4 °C. Cow dung was obtained from the cattle farm in Huazhuang. The characteristics of food waste and head cabbages are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>TS (%)</th>
<th>VS (%)</th>
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<tbody>
<tr>
<td>WS</td>
<td>91.90</td>
<td>42.03</td>
</tr>
<tr>
<td>CD</td>
<td>14.74</td>
<td>3.58</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of typical wheat straw (WS) and cow dung (CD) from a northern China city.

As the Fig. 1, the temperature of fermentor is controlled by heating water. The temperature of the fermentor which has good heat preservation is controlled by 37 ± 1 °C. The last fermentor keeps consistent with the environment temperature. Use the BioGas Check to determination of gas components, as methane and carbon dioxide measurement accuracy are ± 3.0 %, hydrogen sulfide measurement range is 0-5000 ppm, measurement accuracy is ± 25 ppm. Gas production is measured by wet test meter that accuracy is ± 1 %.

Anaerobic batch digestion tests were carried out in triplicates under mesophilic conditions (37 °C). The mesophilic inoculum (37 °C) was obtained from a large digester which treating dairy cattle processing wastewater in Huazhuang (the plastic bucket inoculum was sealed transport). The TS and VS content were 4.23 % and 1.51 %, respectively. Each reactor with 8L capacities contained 2.4L of inoculum. The compositions in different batch setups are summarized in Table 1. The total solid of the initial concentrations for inoculum and raw wastes was 8 %. The tests had been operated for 45 days at (37 ± 1) °C. The digester was equipped with inlet and outlet ports for feeding and effluent discharging, and a port for gas collection. Test mixture ratios of CD: WS based on mass were 3:7, 1:1 and 7:3.

3. Results and Discussion

3.1. Effect of Mixed Ratio on pH of the Anaerobic Fermentation

The PH value (or acid-base balance) is the result of the combined effects which contain the dissolved balance of CO2, H2S in the gas-liquid two-phase; the acid-base balance in the liquid phase; and the ion dissolved balance between liquid and solid phase in
the system. And this balance has related to biochemical reactions within the reactor. Therefore, to study the nature of the acid-base balance in the anaerobic digestion process is very important.

As the Fig. 2 shown, the curves trend is similarity in different mixed ratio, pH is significantly lower in the initial stage of the anaerobic fermentation, that is, this state is the acidification stage of fermentation. As the increase of cow dung ratio, the shorter of acidification stage. Braun also reported a mean value of 140 days HRT in the mono-digestion of energy crops and 50 days when equal amounts of crops and manure are co-digested.

3.2. Effect of Mixed Ratio on Biogas Production of the Anaerobic Fermentation

When straw is the only fermentation material, the fermentation process is instability because the material has too high ratio of C/N (22, 23), low nutrients content, and weak buffering capacity [13] which restricted the use in AD. Currently there are two ways in the study of the problems to solve the straw in the fermentation process. One is to increase mineral nutrition, improve the ability of degradation and methane production [10]. Such as Nges [11] added trace element into the energy crops such as sugar beet and corn and black wheat. From the economic consideration is not appropriate as this way leads to the increase of the cost in the operation. Another way is co-digestion by adding the complementary matrix. Animal waste has strong buffering capacity by high nitrogen content which often co-digestion with high carbon materials such as straw [12].

From the Fig. 3, 4, the biogas production rate of the only cow dung is higher than the mixed fermentation at the beginning of the fermentation, showing that co-anaerobic fermentation rate in start-up phase does not improve compare with the easy degradation matrix, it is a compatible manner of cost-effective and environmental protection. The trend of the curves is the same. Biogas production has two peaks, although some are not obvious. The biogas has lower methane content in first days due to the remaining part of the air in the reactor, which to make the aerobic micro-organism metabolism produced large amounts of carbon dioxide. It is obvious that the reactor in gas production peak time is different. The time that reach peak production rate is 13, 14, 22 and 18d. The cumulative gas production was 193.10L under the mixing ratio is m1:m2=7:3 which more 67.48 %, 42.15 % and 76.96 % than the m1:m2=1:0,3:7, 1:1 respectively, as the cumulative gas production is 115.30, 135.84, 109.12 respectively. The gas production with the whole phase was showed a trend that first increased then decreased while were fluctuated in the intermediate phase. With the consumption of organic matter and the accumulation of harmful material, biogas production rate is slow decline, until the rate is zero.

3.3. Analysis of Biogas Composition

Biogas, a clean and renewable form of energy, could very well be a substitute for conventional...
The most important biogas components are methane, carbon dioxide, and sulfuric components [13]. The gas is generally composed of methane (55–65 %), carbon dioxide (35–45 %), nitrogen (0–3 %), hydrogen (0–1 %), and hydrogen sulfide (0–1 %) [14]. As we knew, the heating value of 1 kg of methane (55.5 MJ kg⁻¹) is equivalent to 1.2 kg of diesel or 3.7 kg of wood [15, 16]. That was the reason why anaerobic digestion technology attracting more and more attention after the Second World War.

The methane content was increasing rapidly after the acidogenesis phase (Fig. 5) until it reached its peak and kept a period of time expect of the 3:7. During this period is also producing biogas effective period, the methane content can reach 50 % under different mixing ratio, and then gradually decline until the experiment is over.

From the Fig. 6, CO₂ content was declined with the time changing. The reason for this might be the producing hydrogen methanogens which utilizing the CO₂ to form methane when the reactor environment is stable.

Fig. 7 shown H₂S content is sharp increased more than 5000 ppm at the initial stage because the sulfate-reducing bacteria can use a wider range of matrix, and has more widely environmental conditions than methane-producing bacteria such as temperature, oxidation reduction potential.

The reactor with the mixing ratio is m₁:m₂=7:3,1:1 and 3:7 remains at a high values from 2 days to 15 days, rapidly reduce after 15 days in 500 ppm while the reactor with m₁:m₂=1:0 remain 2000 ppm after 11 days. With the extension of fermentation time, the change trend of decline, as the methane bacteria metabolism, methane content increase lead to hydrogen sulfide begin to decline.

4. Conclusions

1) The biogas production rate of the only cow dung is higher than the mixed fermentation at the beginning of the fermentation, showing that co-anaerobic fermentation rate in start-up phase does not improve compare with the easy degradation matrix, it is a compatible manner of cost-effective and environmental protection.

2) The cumulative gas production was 193.10L under the mixing ratio is m₁:m₂=7:3 which more 67.48 %, 42.15 % and 76.96 % than the m₁:m₂=1:0,3:7, 1:1 respectively, and the cumulative gas production is 115.30, 135.84, 109.12 respectively.

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