Biogas yields during anaerobic co-digestion of corn stover and cattle manure with different proportions

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Abstract. The biogas production characteristics of anaerobic fermentation of cattle manure and corn stover with different proportions were studied to provide basis for improving efficiency. The dry matter mass ratio of corn stover and cattle manure was set as 1:1, 1:2, 1:3 and 2:1 respectively. The anaerobic co-digestion was carried out under the fermentation conditions of 8% TS and medium temperature (35±1°C), analysing the change rule of each biomethane production index. The results showed that when the mass ratio of corn stover to cattle manure was 2:1, daily biogas production was up to 80 mL; compared with 1:2 and 1:3, the maximum cumulative biomethane production volume of 4540mL increased by 21.67% and 30.12% respectively. The highest volume fraction of methane is 72%.

1. Introduction

Energy and environment are two major problems facing mankind today. The use of agricultural waste in biogas fermentation is of great significance for improving rural environment and reducing energy consumption[1]. China is one of the largest agricultural countries in the world, with abundant agricultural residues, livestock manure and other biomass resources[2]. Chinese crop residue production first in the world, it is estimated that a total of more than 800t every year millions of crop straw and corn straw, rice straw and wheat straw accounted for 80.5% of total output (40.6%, 24.2% and 15.7%, respectively)[3]. The total production of animal manure from large-scale concentrated farms is about 837 million tons, 208 million tons (24.9 percent) of pig manure and most of the ungenerated manure is treated harmfully, posing a serious threat to soil, water, air and livestock and poultry[4]. China produces a large number of livestock manure and crop stover every year, the utilization rate of both is less than 80%. Untreated livestock and poultry feces contain a lot of heavy metals, pathogenic microorganisms and other harmful substances, which pollute underground water bodies and cultivated land, and easily form malodorous gases, affecting the quality of life of surrounding residential areas[5]. Anaerobic digestion is a biological treatment method that can simultaneously generate renewable energy, process energy, biogas, waste and alleviate related environmental problems[6]. Anaerobic digestion has many environmental benefits, including the production of renewable energy carriers, the possibility of nutrient recycling, and the reduction of waste volumes[7]. The production of biogas by anaerobic fermentation is one of the main methods for
the effective utilization of animal manure and crop stover[8]. In China, biogas plants are developing rapidly, and they mostly adopt liquid anaerobic digestion of single raw materials, especially livestock and poultry feces[9]. C/N is an important factor in the anaerobic fermentation process[10]. The research shows that the biomethane production effect of single raw material anaerobic fermentation is obviously worse than that of mixed raw material. Li et al. reported operational limits on organic load when livestock manure were digested as a single waste. By co-digestion with low nitrogen biomass, the shortcomings of single digestion of feces were solved, the carbon nitrogen ratio (C/N) was improved, and the limitations of ammonia production were overcome [11]. In co-digestion, it is important to consider the effects of different incoming waste streams. Mix solid waste with diluted waste for better treatment and digestion. In addition, the successful mixing of different wastes can improve digestion performance by increasing nutrient content and even reducing the negative effects of toxic compounds on the digestive process[12]. Moreover, mixed fermentation of livestock manure and crop stover can also realize resource utilization of crop stover, so as to improve the sustainability and stability of biogas operation[13]. It has been reported that increased biogas production using co-digestion anaerobic fermentation is due to a better balance of nutrients that will support microbial growth for effective digestion and improve buffering capacity of AD, helping to maintain a stable system[14]. In a continuous stirred tank reactor (CSTR), the medium-temperature anaerobic co-digestion of cattle manure and fruit and vegetable waste was carried out at 35°C. Callaghan et al. found that increasing the ratio of FVW from 20% to 50% could increase methane production from 230 L/kg VS to 450 L/kg VS [15]. However, involving two or more different types of substrates and requires careful selection of raw materials and mixing ratios to ensure and even improve efficiency[16].

In this study, corn stover and cattle manure were used as the objects of anaerobic fermentation to produce biogas. By analyzing the change rule of various indexes of biomethane production, the material ratio of corn stover and cattle manure anaerobic co-digestion was studied. In order to provide technical guidance for the resource utilization of crop stover and livestock manure.

2. Methods

2.1. Raw material and inoculum

| Material       | TS (%) | VS (%) | C/N ratio |
|----------------|--------|--------|-----------|
| Cattle manure  | 79.34  | 39.57  | 13.03     |
| Corn stover    | 61.26  | 71.55  | 27.45     |
| Inoculum       | 5.53   | 74.32  | —         |

The corn stover used in this experiment was taken from the Maozhuang production base of Henan Agricultural University, and the cattle manure was taken from the farmer's cattle in the third living area of Henan Agricultural University. The inoculum required for biogas fermentation in the experiment was taken from a normal operating medium temperature anaerobic reactor in the laboratory. The physical and chemical indexes of cattle manure, corn stover and inoculum used in this experiment are shown in Table 1. The corn stover used in this experiment is crushed by a grinder until the particle size is between 0.5 and 1 cm. The right amount of distilled water will be added to the crushed corn stover after being placed in the barrel sealed composting. The cattle manure sealed in the experiment was placed in a cool place and composting.

2.2. Experimental methods

The ratio of corn stover to cattle manure (TS ratio) was set as 1:1(T1), 1:2(T2), 1:3(T3) and 2:1(T4). The inoculating amount is 30% of the total material quality. Material TS concentration is 8%. Three parallel fermentation groups were set for each fermentation unit, and the total mass of each fermentation unit was 350g. Medium temperature fermentation was selected and the reaction temperature was controlled at (35±1) °C. After adding the fermentation substrate, nitrogen is pumped into the fermentation unit for 2 min and discharged into the air of the anaerobic bottle, making the
fermentation in an anaerobic environment. Air bags were removed every two days to measure the volume of biomethane produced and biomethane samples were collected for determination of CH$_4$ content. Every two days, the fermentation liquid is collected with a syringe through the sampling port for pH determination and analysis.

2.3. Experimental device

The experimental unit used in this experiment is mainly composed of anaerobic co-digestion unit and gas collection unit. The anaerobic co-digestion unit adopts 500 mL wide-mouth bottle, the bottle mouth is sealed with rubber plug and sealed with sealed rubber. The rubber plug is punched to connect the air bag and the gas produced by anaerobic fermentation is collected and stored in the 1L air bag. Another hole is drilled into the latex pipe and sealed with a sealing clamp for collecting the material liquid during the test. The test device is shown in Figure 1.

![Diagram of anaerobic generator](image)

1. Air bag; 2. Anaerobic fermentation area

Fig.1 Diagram of anaerobic generator

2.4. Analytic methods

The volume of methane production is measured regularly every two days. The cumulative biomethane production is the sum of the biomethane production per day. Methane volume fraction was collected once every 2 days to produce biogas from each treatment group, which was determined by Agilent 7890B GC gas chromatograph. A small amount of liquid was absorbed from the sampling port every 2 days and pH value was determined by PHS-3C pH meter.

3. Results and discussion

3.1. Daily biomethane production

Under the condition of 35°C, the biogas output of each treatment group depends on the nature of fermented materials. If the material ratio is appropriate and the nutrient composition is sufficient and balanced, it is conducive to rapidly increase the number and activity of microorganisms in the fermentation liquid, accelerating the hydrolysis rate of the fermentation material, and thus improve the biomethane production. The daily biomethane output of biogas produced by anaerobic co-digestion of each treatment group is shown in Figure 2. Two fermentation peaks occurred in each treatment group during the whole fermentation process. T$_4$ reached the first peak of biomethane production on the 4th day, with biomethane production of 145 mL, and then decreased rapidly. The second biomethane production peak appeared on the 24th day, with a production of 280 mL. T$_1$ reached the first peak of biomethane production on day 4, with biomethane production of 120 mL, and then decreased rapidly. The second peak biomethane production reached on the 20th day, with a production of 240 mL. T$_2$ and T$_3$ to reach the peak of biomethane production on the 20th and 22nd days, with yields of 249 mL and...
209 mL, respectively. T4 biomethane production rate was significantly higher than that of the other three groups.

![Daily Biomethane Production](image1)

**Fig. 2** Daily biomethane production of co-digestion of cattle manure and corn stover with different proportions

### 3.2. Cumulative Biomethane Production

Cumulative biomethane production of each treatment group is shown in Figure 3. The cumulative biomethane production trend of the four treatment groups was roughly the same. The biomethane production rate was slow in the early stage, accelerated in the late stage, and was flat in the late stage of fermentation. T4 cumulative biomethane production is the highest, at 4540 mL. The cumulative biomethane production of T1 is 3986 mL. The cumulative biomethane production of T2 and T3 is 3556 mL and 3172 mL, respectively. On the 45th day of fermentation, the cumulative biomethane
production of each treatment group was significantly different, and the sequence from high to low was T4 > T1 > T2 > T3. Compared with T2 and T3, T4 increased 21.67% and 30.12%. This indicates that with the increase of the proportion of mixed corn stover, the cumulative biomethane production also tends to increase, which may be related to the favorable anaerobic fermentation of mixed materials for promoting microbial enrichment and metabolic activities.

3.3. Methane production

![Methane concentration of co-digestion with cattle manure and corn stover with different proportions](image)

The methane volume fraction of each treatment group is shown in Figure 4. On the whole, the volume fraction of methane in the treatment group increased first, then decreased and gradually stabilized with the passage of fermentation time. After 16 days of fermentation, the volume fraction of methane in each treatment group reached more than 50%. At this time, the number of methanogens increased and gradually entered the active stage, which could rapidly decompose and utilize the small molecular organic acids generated in the acid production stage to convert them into methane. After 24 days of fermentation, the volume fraction of methane in each treatment group gradually reached its peak value, when methanogens entered the reactive active stage. After 35 days of fermentation, the volume fraction of methane in each treatment group decreased slightly but remained at about 50% until the end of the reaction. Although organic matter in the reaction substrates is decreasing and biomethane production is decreasing, methanogens have formed stable flora, so the ability to produce methane can still be maintained at a high level.

4. Conclusions

Corn stover and cattle manure were mixed for anaerobic fermentation. Under the condition of total dry matter mass of the material being 8% and fermentation temperature being (35±1) °C, when the corn stover and cattle manure dry matter mass ratio was 2:1, the biogas production performance was superior to other treatments. Daily biogas production up to 80mL; compared with 1:2 and 1:3, the maximum cumulative biomethane production volume of 4540mL increased by 21.67% and 30.12% respectively. The highest volume fraction of methane is 72%. The relationship between the ratio of corn stover and cattle manure and the fermentation stage during the fermentation period was judged by combining the changes of daily biogas production and volume fraction of methane: the peak and
active change of biogas production were observed on the 10th to 25th days, and the stable decline of biogas production was observed on the 26th to 44th days.

Acknowledgement
Thanks to the tutor for their assistance in the experimental process. And financial support from the key technology research project of biomass mixed anaerobic fermentation (No. 2018015); Henan Science and Technology Open Cooperation Project (182106000012).

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