Anaerobic digestion of corn stalk for biogas production: ambient vs. mesophilic temperature

Gao Zhijian[1], Li Xiujin[1※], Yang Dongyan[1], Jiang Hongyin[2]
(1. Department of Environmental Engineering, Beijing University of Chemical Technology, Beijing 100029, China; 2. Anhui Demonstration Station of Farm Machinery, Heifei 230036, China)

Abstract: Anaerobic digestion technology for corn stalk conversion to biogas was investigated for corn stalk utilization and pollution reduction. Two temperatures (ambient and thermophilic) and three loading rates of 35, 50, 65 g/L were tested, and their effects on biogas production, total solid (TS) and volatile solid (VS) reduction were compared. The results showed that the loading rate of 50 g/L achieved highest cumulative biogas production for both temperatures. The temperature is one of major factors affecting efficiency and rate of anaerobic digestion of corn stalk. As compared with ambient temperature, mesophilic digestion with the loading rate of 50 g/L was able to achieve 63% higher cumulative biogas production, 33% and 49% more reduction of TS and VS and need 10 days less hydraulic retention time. Therefore, it had favorable economy and is recommended. This study could provide useful parameters for the design of large-scale anaerobic digester for corn stalk conversion for biogas production.

Key words: corn stalk; biogas; anaerobic digestion; mesophilic; ambient
CLC number: X37; X712 **Document code**: A **Article ID**: 1002-6819(2003)05-0214-04

1 Introduction

China is the largest agricultural country in the world. Currently, 0.9 billion peoples are farmers, accounting for about 70% of total population in the nation. Crop planting is major part of agricultural industry. Approximately, 0.7 billion tons of crop waste is generated annually. Corn is one of major crops and mainly planted in northern area, produces about 0.1 billion tons of corn stalk annually.

Disposal methods for corn stalk include fuel for household cooking and heating, open-field burning, animal feed, incorporating into soil, construction and erosion control materials. Open-field burning is one of main corn stalk disposal methods, causing great environmental and safe problems, such as air pollution, fire disaster, and impacts on traffic and aircraft safety. Therefore, it is necessary to find environmentally friendly alternatives for corn stalk disposal and utilization in a way that pollution is minimized.

Using anaerobic digestion technology to convert corn stalk to biogas is one of alternatives for corn stalk utilization. Anaerobic technology has been widely used for organic wastes conversion for biogas production, such as animal and human excreta[1,2]. However, little research has been conducted on anaerobic conversion of corn stalk to biogas. The main reason is that corn stalk contains high percent of lignocellulose, which is not readily biodegradable to anaerobic bacteria, leading to lower digestion rate and biogas production. There are various methods to improve the biogas production of corn stalk such as size reduction, steam explosion, fungi prebiodegradation, and ammonization[3]. Increasing digestion temperature is one of simple and effective methods to improve the biodegradation efficiency and biogas production since anaerobic bacteria is highly affected by temperature. According to previous study, there are three optimal temperature zones of 20℃, 33～35℃, 52～55℃, in which high effective anaerobic digestion could be achieved, and biodegradation efficiency would improve as temperature increases from low-temperature zone to high-temperature zone[4]. Thermophilic digestion needs more extra heat to maintain the temperature than it might generate, therefore, is not adopted. Ambient temperature does not need extra heat supply, but it is highly affected by environmental condition and normally has low digestion efficiency. Mesophilic temperature needs less or sometimes no extra heat supply while possibly generates more energy through more biogas production, thus was chosen for this study.

The purpose of this study is to investigate the effect of mesophilic and ambient temperatures on biogas

Received date: 2003-08-01
Foundation item: Special Fund for Renewable Energy Research from the Agricultural Ministry of China (Contract No: 01-02-03)
Biography: Gao Zhijian, graduate student, Department of Environmental Engineering, Beijing University of Chemical Technology, Beijing 100029, China. Major in research on solid waste management.
Corresponding author: Li Xiujin, professor and PhD, Department of Environmental Engineering, Beijing University of Chemical Technology, Beijing 100029, China. Tel: + 86-010-64427356, Email: xjli@mail.buct.edu.cn

production of corn stalk through anaerobic digestion at different loading rates, and provide useful parameters for the design of large-scale anaerobic digester for corn stalk conversion for biogas production.

2 Materials and methods

2.1 Experimental setup

The experimental set-up is shown in Fig. 1. It consisted of an erlenmeyer flask of 2 L, a bottle of 1 L, and a beaker of 1 L, which functioned as anaerobic digester, biogas volume recorder, and receiver for the water discharged from the recorder, respectively[5]. The biogas generated in the digester was introduced by a rubber pipe into the headspace of the bottle and pressed the water in the bottle out and flowed to the water receiver. The volume of the discharged water from the bottle represents the volume of biogas generated in the digester. Different amount of ground corn stalk was used for each temperature test and put into the same flask digester with a working volume of 1.5 L, and made three loading rates of dry matter 35, 50, and 65 g/L, respectively. The three flask digesters for mesophilic test were sit in a shaker with temperature controlled at 35 ℃, and other three flask digesters for ambient temperature test in another shaker without temperature control. Both shakers were always kept shaking at the same speed of 120 r/min.

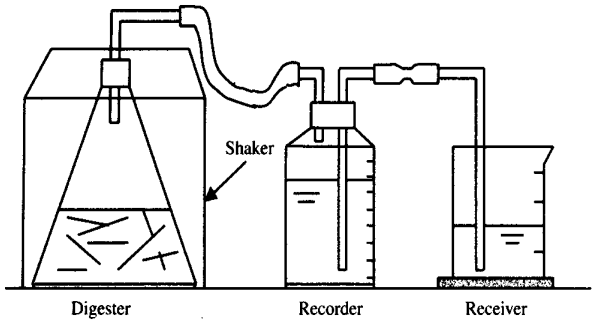

Fig. 1 Experimental setup of anaerobic digestion

2.2 Materials

Corn stalk used in this study was obtained from Tong County of Beijing. The corn stalk was first chopped and then ground into 2~3 cm pieces by a hammer mill. Size reduction helps biodegradation by rupturing cell walls and making the biodegradable components more accessible to microorganisms, meanwhile, facilitates sampling. The corn stalk contained 96.8% of dry matter (DM) and volatile solid (VS) was 80.2% of total solid (TS). Anaerobic sludge was used as seed, which was obtained from an anaerobic digester in Gaobeidian Wastewater Treatment Plant of Beijing. The sludge contained TS 34400 mg/L, VS 17340 mg/L, and suspended solid (SS) 33090 mg/L. Mixed liquor suspended solid (MLSS) in each digester was the same and maintained at 15000 mg/L, which was selected based on the research result from Zhang[3]. The carbon-to-nitrogen ratio (C/N) of corn stalk was about 75, so a certain amount of NH_4Cl was added to adjust the C/N ratio to about 25, which is believed the appropriate one for anaerobic bacteria growth.

2.3 Sampling and analysis methods

The daily biogas production for each flask digester was recorded every day and the corresponding cumulative biogas production was calculated. The initial total TS that includes both corn stalk used and sludge added and the final TS that actually is the mixture of digested corn stalk and left sludge was measured. TS, VS were analyzed according to AHPA.

3 Results and discussion

3.1 Ambient temperature

The daily biogas production at ambient temperature is shown in Fig. 2. Similar trends of daily biogas production were found for the three loading rates. The biogas production for each digester started to increase after seeding and reached its peak value, then decreased gradually. The difference was the peak value and the time reaching peak value. It can be seen that the loading rate of 50 g/L reached its peak value of 845 mL/d on the 31th day, which is 80 and 340 mL/d higher than the loading rates of 35, and 65 g/L, respectively. However, the order of the time reaching peak value was 35, 50, and 65 g/L. This implies that relatively shorter hydraulic retention time (HRT) is required for the digestion at lower loading rates.

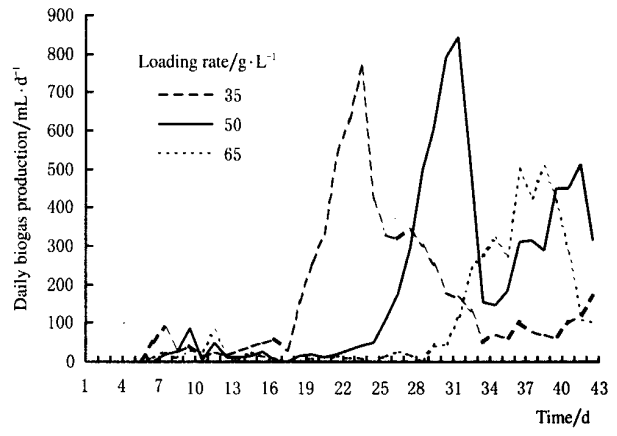

Fig. 2 Daily biogas production at ambient temperature

The cumulative biogas production for the three loading rates is shown in Fig. 3. The final cumulative biogas production was 6400, 7400, and 4000 mL for the loading rates of 35, 50, and 65 g/L, respectively, indicating the loading rate of 35 g/L was too low, while 65 g/L was too high for anaerobic bacteria to effectively digest corn stalk. The loading rate of 50 g/L is believed the best due to its highest biogas production achieved, therefore, is recommended.

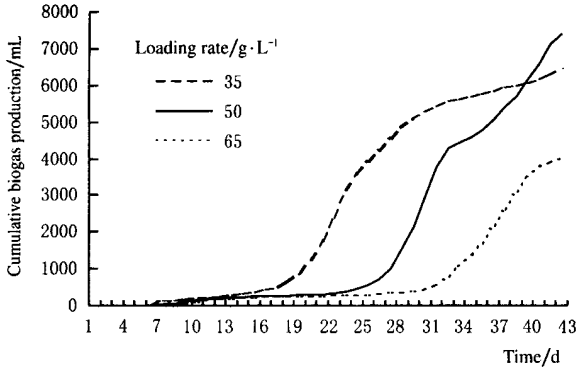

Fig. 3 Cumulative biogas production at ambient temperature

3.2 Mesophilic temperature

The daily biogas production at mesophilic temperature is shown in Fig. 4. It was found that the trend of daily biogas production at mesophilic temperature is very similar to that at ambient temperature as shown in Fig. 3. However, for the three loading rates tested, the peak value of daily biogas production at mesophilic temperature was obviously higher than that at ambient temperature, and was reached in earlier time. This result shows that more corn stalk have been converted at higher digestion rate at mesophilic temperature than at ambient temperature, which was further verified by higher cumulative biogas production and more TS and VS reduction at higher temperature condition.

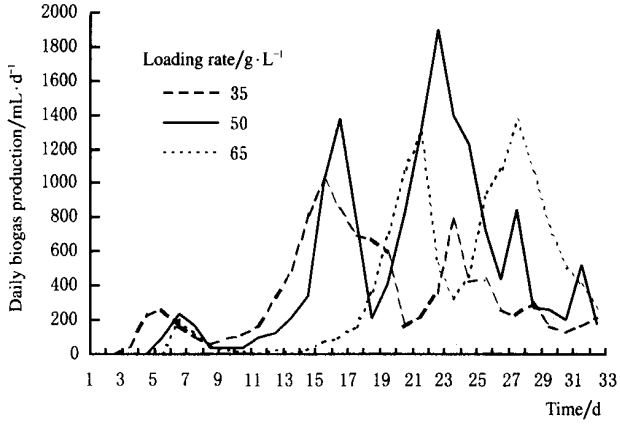

Fig. 4 Daily biogas production at mesophilic temperature

The cumulative biogas production for the three loading rates at mesophilic temperature is shown in Fig. 5. The final cumulative biogas production was 10500, 15200, 11900 mL for the loading rates of 35, 50, and 65 g/L, respectively. The highest biogas production was achieved with loading rate of 65 g/L, indicating this loading rate is best suitable to the anaerobic digestion of corn stalk.

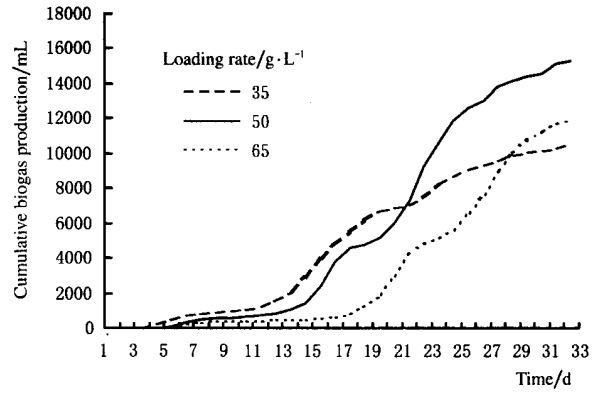

Fig. 5 Cumulative biogas production at mesophilic temperature

3.3 Relationship between biogas production and TS and VS reduction

The relationship between biogas production and TS and VS reduction at different temperatures is shown in Fig. 6 and 7. The results from both temperatures showed that the more cumulative biogas was obtained, the more TS and VS reduced. For the loading rate of 50 g/L, biogas conversion rates of 247 mL/gTS reduced and 390 mL/g VS reduced, and 380 mL/g TS reduced and 447 mL/g VS reduced were obtained at ambient temperature and mesophilic temperature, respectively. The result further verified that mesophilic condition could obviously improve anaerobic conversion efficiency, therefore, increase biogas production.

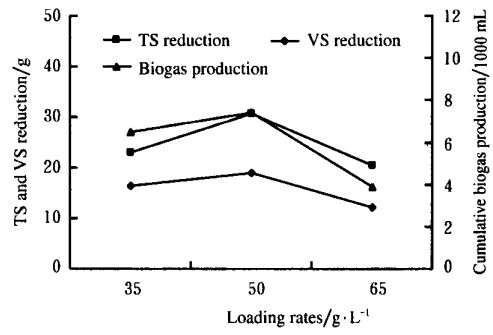

Fig. 6 Relationship between biogas production, TS, VS reduction and loading rate at ambient temperature

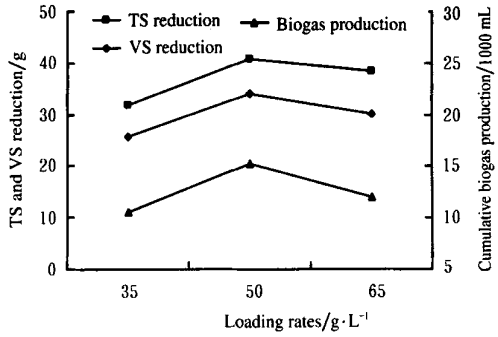

Fig. 7 Relationship between biogas production, TS, VS reduction and loading rate at mesophilic temperature

4 Conclusions

Temperature is one of major factors affecting efficiency and rate of anaerobic digestion of corn stalk. As compared to ambient and thermophilic temperatures, mesophilic temperature needs less or sometimes no extra heat supply while possibly generates more energy through more biogas production, thus was used in this study. Two temperatures (ambient and mesophilic), and three loading rates (35, 50, 65 g/L) were tested. The loading rate of 50 g/L was found to achieve highest cumulative biogas production for both temperatures. As compared with ambient temperature, mesophilic digestion with the loading rate of 50 g/L was able to achieve 63% higher cumulative biogas production, 33% and 49% more TS and VS reduction, and need 10 days shorter hydraulic retention time, therefore, has favorable economy and is recommended.

[**References**]

[1] Bian Yousheng. The Treatment and Reutilization of Waste in Ecological Agriculture[M]. Beijing: Chemistry Industry Press, 2001, 208~219.

[2] Zhang Chenglong. Comprehensive utilization technology of agricultural wastes[J]. Natural Ecology Conservation, 2002, 1: 22~23.

[3] Zhang Ruihong, Zhang Zhiqin. Biogasification of rice straw with an anaerobic-phased solids digester system[J]. Bioresource Technology, 1999, 68: 235~245.

[4] He Yanling. Wastewater Anaerobic Treatment Engineering[M]. Beijing: Environmental Science Press, 1998, 42~47.

[5] Tan Tiepeng. Study of the anaerobic biological treatment of downfollow sludge at high middle and low temperatures [J]. Yunnan Chemical Engineering, 1995, 3, 51~55.

玉米秸中温与常温厌氧生物气化的比较研究

高志坚[1]，李秀金[1※]，杨懂艳[1]，江洪银[2]

(1. 北京化工大学环境工程系，北京 100029； 2. 安徽省农机推广站，合肥 230036)

摘 要：为解决玉米秸的资源化利用问题，提出通过厌氧消化的方法把其转化成生物气体。比较了在中温和常温条件下，不同负荷率(35、50、65 g/L)对玉米秸秆日产气量、累积产气量、总干物质(TS)和挥发性有机物(VS)消化率的影响。试验结果显示，不论是在中温还是在常温条件下，50 g/L TS 负荷率都获得了较高的累积产气量；相对于常温而言，中温厌氧消化的累积产气量提高了 63%，总干物质(TS)和有机物(VS)消化率分别增加 33% 和 49%，产气速率也明显提高。因此，使用 50 g TS/L 负荷率，在中温条件下对玉米秸秆进行厌氧消化是比较好的。该试验结果可为玉米秸秆的大规模生物气化提供重要设计依据。

关键词：玉米秸秆；生物气；厌氧消化；中温；常温