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Research Paper

# Anaerobic digestion of ammonia-pretreated corn stover

*Hairong Yuan* [a], *Rongping Li* [b], *Yatian Zhang* [c], *Xiujin Li* [a,*], *Chunmei Liu* [a], *Ying Meng* [a], *Meina Lin* [a], *Ziyi Yang* [a]

[a] *Center for Resources and Environmental Research, Beijing University of Chemical Technology, Beijing 100029, China*

[b] *Beijing Environmental Sanitation Engineering Research Institute, Beijing 100028, China*

[c] *Capital Aerospace Machinery Company, Beijing 100076, China*

ARTICLE INFO

*Article history:*
Received 19 March 2014
Received in revised form
28 August 2014
Accepted 17 September 2014
Published online 3 November 2014

*Keywords:*
Anaerobic digestion
Ammonia-pretreated
Moisture content
Corn stover

The effect of ammonia pretreatment on the anaerobic digestibility of corn stover was investigated. Corn stover with different moisture contents (30%, 50%, 70%, and 90%) was pretreated with three concentrations of ammonia (2%, 4%, and 6%) at 35 ± 2 °C for the following batch digestion. Results showed that the reagent of 4% ammonia and 70% moisture content could achieve the highest anaerobic digestibility. In comparison with the untreated, the time needed to produce 90% of the maximum digester gas production ($T_{90}$) shortened from 52 d to 37 d. The total biogas production and the unit volatile solids (VS) biogas yield were 20,740 ml and 427.1 ml respectively, both 26.70% higher than the untreated. It was found that the digesters with high moisture contents of 70% and 90% were more stable and had shorter acidification periods relative to the low moisture contents of 30% and 50%. The decreases in cellulose, hemicelluloses and lignin indicated that ammonia pretreatment could destroy the lignocellulose (LCH) structure and furthermore enhance the biogas production. Following anaerobic digestion, 80.6% of cellulose and 68.52% of hemicelluloses were consumed where there was 4% ammonia and 70% moisture content, indicating why these conditions produced the highest level of biogas.



## 1. Introduction

China is one of the largest agricultural countries in the world, where approximately 0.79 billion tonnes of crop residues were generated in 2013. Corn is one of major crops, totalling 0.28 billion tonnes of residues (National Bureau of Statistics of the People's Republic of China, 2013). Although there are various methods for corn stover reutilisation such as energy production, animal feed, and return to agriculture as fertiliser, etc., more than 50 %–60 % of corn stover currently remains unused. Energy utilisation using corn stover as raw material has recently received more attention from researchers in China and in other countries.

Corn stover is lignocellulosic biomass. The complex structure of lignocellulosic biomass provides a primary protective barrier that prevents cell destruction by chemical or

* *Corresponding author*. Tel.: +86 136 6107 0453; fax: +86 10 6443 2281.
E-mail address: xjli@mail.buct.edu.cn (X. Li).
http://dx.doi.org/10.1016/j.biosystemseng.2014.09.010
1537-5110/

**Nomenclature**

| | |
|---|---|
| L/C | ratio of lignin to cellulose |
| TC | total carbon |
| LCH | lignocellulose, including lignin, cellulose, and hemicellulose |
| TN | total nitrogen |
| MLSS | mixed liquor suspended solids |
| TS | total solids |
| $T_{90}$ | time needed to produce 90% of the maximum digester gas production |
| VS | volatile solids |

biological methods (Chen, Zhen, Luo, Zou, & Fang, 2010), leading to lower digestion rate and biogas yield. Pretreatment prior to anaerobic digestion had been proven to be one of simple and effective methods to improve biodegradability and increase biogas production (Bruni, Jensen, & Angelidaki, 2010; Zhong, Zhang, & Luo, 2011; Zhong, Zhang, & Wei, 2011). There were a number of methods available for the pretreatment of crop residues, such as ammonia treatment, acidic and alkaline treatment, fungal biodegradation, etc. Ammonia treatment has the advantage of increasing nitrogen content and conditioning the C/N ratio making the corn stover more biodegradable. Oji, Etim, and Okoye (2007) reported that ammonia pretreatment could enhance the nitrogen content of corn stover effectively, while decreasing the cellulose and hemicellulose contents. Zhang and Zhang (1999) found that compared to the untreated whole straw, 2% ammonia treatment resulted in 17.5% higher biogas yield. Ma et al. (2011) reported that a 4% ammonia pretreatment of rice straw produced 34.8% higher biogas yield than the untreated straw.

Ammonia treatment technology has been widely applied for conversion of organic wastes into animal feed and biomass conversion. During the ammonia pretreatment moisture content influences the hydrolysis of LCHs (lignocellulose) and the pretreatment efficiency. Commonly, 30 %–40 % moisture content has been used in most of studies. Caneque and Velasco (1998) found that with 40% moisture content at a temperature of 35 °C the best results were achieved for the digestibility and degradability of the lignocellulosic feed. Abdellatif, Santi, Florian, Abderrahim, and Xavier (2014) investigated dry chemo-mechanical pretreatments of lignocellulosic biomass with the moisture content of 30%. Kim and Lee (2007) showed that the treated corn stover exhibited enzymatic digestibility of 85% and 78% for glucan and xylan following soaking in aqueous ammonia at moderate temperature and 1:6 of solid: liquid ratio (equivalent to moisture content was 85.7%). However, limited research has been carried out to investigate the effect of combined effect of ammonia and moisture content on the pretreatment of corn stover for anaerobic biogas production.

Therefore, the objective of this study was to further investigate the effect of ammonia pretreatment and moisture content on anaerobic digestibility. Using corn stover as raw material, different reagents with ammonia additions of 2%, 4%, 6% and moisture contents of 30%, 50%, 70%, and 90% were applied to batch digestion. The pretreatment time, biogas production, digester stability, and corn stover composition changes were analysed.

## 2. Materials and methods

### 2.1. Materials

Corn stover was obtained from farmland at Beijing suburb of Shunyi. It was dried with the natural air and ground to <5 mm for later use. The amount of corn stover was calculated in accordance with total solids (TS) quality. The anaerobic sludge was collected from an operating anaerobic digester as inoculum sludge. The amount of inculum inoculant was calculated in accordance with the mixed liquor suspended solids (MLSS) quality. The characteristics of corn stover and inoculum sludge were presented in Table 1.

### 2.2. Experimental methods

The ammonia used in this study was 25% with 13.33 mol $l^{-1}$ at 20 °C. According to ammonia content, the additions of ammonia were respectively 2%, 4%, and 6% of dry weight of the corn stover. Different amounts of water were added to make sure samples of the corn stover had moisture contents of 30%, 50% and 70%, 90%. After the ammonia and water, were added the corn stover was put into a bottle and sealed and stored at the temperature of 30°C ± 2 °C. After pretreatment, the corn stover was dried and then used for the anaerobic digestion.

Batch anaerobic digestion was used in this study. The pretreated corn stover of 65 g [TS] $l^{-1}$ was loaded in a 1 l bottle. The inoculum sludge content in each bottle was15 [MLSS] g $l^{-1}$ with an effective volume of 0.8 l. Some corn stover that was dried at 105 °C in drying oven for 12 h was digested as the control without any ammonia and water.

After feeding, the 1 l bottles were placed in a shaker (Taicang DHZ-DA, China) and connected with the water displacement. The shaker kept at a mesophilic temperature (35 ± 2 °C) at 120 rpm shaking speed and 3 min $h^{-1}$ frequency. The duration of anaerobic digestion was 65 d.

**Table 1 – Characteristics of corn stover and inoculum sludge.**

| | TS (%) | VS (%) | Total carbon (%) | Total nitrogen (%) | Cellulose (%) | Hemicellulose (%) | Lignin (%) |
|---|---|---|---|---|---|---|---|
| Corn stover | 94.5 | 88.16 | 42.59 | 1.22 | 38.81 | 29.50 | 7.10 |
| Inoculum sludge | 8.45 | 5.29 | 30.13 | 3.27 | N/A | N/A | N/A |