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The study of influencing factors to Corn straw mixed with pig effluent anaerobic fermentation

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***Abstract*—This paper mix pig effluent and corn stalk to anaerobic fermentation in order to raise the effect of biogas generation during anaerobic fermentation. An orthogonal experiment program was carried out to determine effects of granularities of corn stalk, temperature, the quality ratio between pig effluent and corn stalk, feed ratio on biogas production of anaerobic fermentation moisture, time and on the degradation rate. Results show that four factors had significant influence effect on biogas production. The optimal conditions for anaerobic fermentation were corn stalk keeping 4-6cm,35℃in temperature, the quality ratio between corn stalk and pig manure to 1.5:1 and 90% in feed ratio. Under such conditions, the biogas production is much better than the others and the yield peaked higher. The highest number of daily biogas production reached 2120mL. During the 30 days of fermentation period cumulative biogas production attain to the 25230 mL**

Keywords- corn straw; orthogonal experiment program

I. INTRODUCTION

According to statistics, the production of corn stalks about 2.7 billion t in China 2005, which accounting for 33.8% of the total types of straw [1-2]. Most of these were abandoned in the field or combustion directly, which not only a waste of valuable resources, but also cause some environmental problems. Therefore the study of suitable approach for the use of straw to achieve its resource optimization, will be the one of the most important methods to ease the three critical of "food, energy, environment"[3]. Straw anaerobic fermentation biogas technology is one of the important way to use the energy of the straw. It can be achieved the use of high-quality of straw and other biomass resources under the conditions of a smaller scale and less capital investment. That more suitable for the rural areas and urban or rural enterprises of developing countries [4-5].

Large amount of straw resources in northern China, however, the technical requirements of Pretreatment of the current method of fermentation technology is higher, which need greater economic cost and the lack of reasonable technical guidance and specific characteristics of climate in the north system of fermentation technology in rural areas (such as the ratio of raw materials, fermentation conditions, etc.) [6-7]. Fermentation of corn straw as a single material has not been accepted by the majority of farmers, because of its own characteristics such as carbon-nitrogen ratio and fiber lignin are high and the content of available nutrients is low.

And the surface layer has wax, which Is not conducive to microbial attachment, and the degradation rate is low, anaerobic digestion for a long time, prone to floating layer, crust, and it is also difficult to pool the material. Mixed fermentation with manure and corn stalks, which can make up for the disadvantages of the fermentation as raw materials , solution the shortage of resources to improve utilization of corn stalks [8-9].

In this study, the status of corn straw and pig manure as the research object, simulate the anaerobic fermentation conditions in rural areas of northern China to do the anaerobic fermentation test, without stirring or no to adjust pH artificially. Use of orthogonal experiments L9 (3^4) to analysis the effect of the stalk particle size of corn and temperature, mass ratio of straw and manure, straw and feed rate on the anaerobic digestion of pig manure biogas production. By observing the daily and cumulative gas production to determine the appropriate conditions for fermentation, to get a scientific basis and technical guidance about the anaerobic fermentation technology for the northern rural areas.

II. MATERIALS AND METHODS

A. *Fermented materials*

Test corn stalks came from the biogas model village, Qingyuan town, Liaoning Province, the corn stalk C / N = 58.77:1. Trial used incompletely dry corn stalks which cut small pieces of about 10cm, by the natural dried (about 10% moisture content) storage backup; each test, the experimental particle size needed to conduct straw hand-cutting or machine. Pig manure of experiment was from the breeding plants of Ecological Park of Shenyang Architecture University, water content was 20%, pig manure C/N = 13.97:1.

Inoculum used in the experiment from a model village biogas slurry and laboratory anaerobic fermentation tank which after fermentation sludge in Qingyuan County, Liaoning Province, slurry and sludge mass ratio of 5:3, the amount of inoculum reactants 20% of the total.

B. *Experimental Materials*

The test used anaerobic fermentation devices which made by the laboratory, mainly included two rubber stoppers sealed 2500 ml and wide mouth bottles and a 1000 ml beaker, which are used fermentation bottles, cylinders and record collection bottles. The fermentation carried out in the incubator with temperature controlled. Accordance with the gas production during the test to determined in the fermentation period, the specific reactor shown in Figure 1:

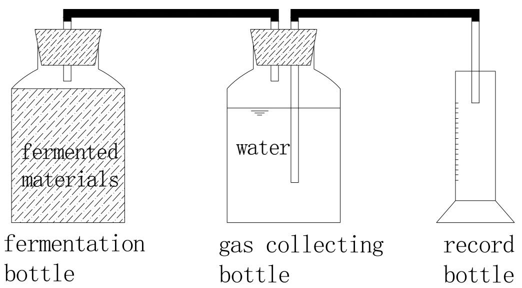

Figure 1. Device of anaerobic fermentation.

C. *Test Method*

Corn straw particle size, temperature, mass ratio of straw and manure, feed rate were selected for the four main factors, the significant differences between the factors were sdudied according to a common three levels orthogonal design [L_9 (3^4)] with 9 tests and 3 repeats for each factor.

Table 1 Designing of the anaerobic fermentation test

Test No.	Factors			
	Particle size (cm)	Temperature (℃)	Mass ratio of straw and manure	Feed rate (%)
1	<1	25	1:1	50%
2	<1	35	1.5:1	70%
3	<1	45	2:1	90%
4	1-3	25	1.5:1	90%
5	1-3	35	2:1	50%
6	1-3	45	1:1	70%
7	4-6	25	2:1	70%
8	4-6	35	1:1	90%
9	4-6	45	1.5:1	50%

A certain amount of pretreatment corn straw and pig manure were mixed and placed in 2500 ml sealed fermentation bottles, then the normal anaerobic fermentation slurry and sludge were inoculated for batch fermentation with the total inoculation amount of 20% and the total solid state concentration of 10%. The significant differences of these factors on the gas production of anaerobic fermentation was studied simultaneously.

The optimum level of each factor was combined after the analyzing of orthogonal design results, then the normal anaerobic fermentation slurry and sludge were inoculated with the total inoculation amount of 20% and the total solid state concentration of 10% for anaerobic fermentation. Daily and cumulative gas production were investigated respectively for the verification of this optimum combination above.

Daily and cumulative gas production were both the important indexes in the anaerobic fermentation process, drainage method was used in this study for the measurement of the daily and cumulative gas production. In order to measure the gas production amount, the volume of water which was equivalent to the gas production amount was measured with the measuring cylinder at 10:30 am every day during the reaction period.

Variance analysis and correlate analysis were done using SPSS 17.0 software, the significant difference among the treatments was analyzed by LSD test method (least significant difference method), the figures were done by Excel 2003.

III. RESULTS AND DISCUSSION

A. *Orthogonal design results of corn straw and pig manure*

Orthogonal design results were analyzed by the observation of cumulative gas production under different conditions, and thenthe optimum levels were combined. Orthogonal test results were shown in Table 2.

Table 2 Orthogonal experiment and rangeanalysis of cumulative biogas yield

Test No.	Factors				Cumulative gas production (mL)
	Particle size (cm)	Temperature (℃)	Mass ratio of straw and manure	Feed rate (%)	
1	<1	25	1:1	50%	1620
2	<1	35	1.5:1	70%	20560
3	<1	45	2:1	90%	2660
4	1-3	25	1.5:1	90%	5600
5	1-3	35	2:1	50%	13560
6	1-3	45	1:1	70%	3520
4	4-6	25	2:1	70%	2640
8	4-6	35	1:1	90%	22090
9	4-6	45	1.5:1	50%	12160
K_1	8280	3286.7	9076.7	9113.3	
K_2	7560	18736.7	12773.3	8906.7	
K_3	12296.7	6113.3	6286.7	10116.7	
R	4736.7	15450	6486.7	1210	

K1, K2, K3 —factors were observed average value under the appropriate level

According to the analysis of the Ki (average observation value of each factor level i), the maximum value of each factor level were K3 12296.7, K2 18736.7, K2 12773.3 and

K3 10116.7 respectively. Therefore the optimum experiment design was as follows: straw particle size 4-6cm, fermentation temperature 35 ℃, straw and manure mass ratio 1.5:1, feed rate 90%. This design was not included in the Orthogonal design above, so further experiments were required to verify whether the cumulative gas production was the highest one under this new design.

The effect degrees of each factors were different on the gas production according to Table 2. R was used for the measurement of effect degrees, and the effect degree was increased with R value[9].

Table 3 Analysis of Variance

variance Source	sum of squares of deviations	degree of freedom	mean square deviation	F value	P value
1	116.225	2	58.112	393.103	0.000
2	1211.135	2	605.567	4096.387	0.000
3	194.815	2	97.408	658.918	0.000
4	9.429	2	4.715	31.891	0.000
5	2.661	18	0.148		

1- particle size；2- temperature；3- Mass ratio of straw and manure 4- Feed rate；5- 2.deviation

The P value of each factors were less than 0.05 Through the analysis of SPSS from the results of table 3. It is show that all four factors have significant and similar influence to the cumulative gas production .So in practice we must take four factors into account to increase the rate of producing gas.

B. The anaerobic fermentation Under the condition of The most suitable factor combination.

The 10th deal's conditions for anaerobic fermentation were corn stalk keeping 4-6cm,35℃in temperature, the quality ratio between corn stalk and pig manure to 1.5:1 and 90% in feed ratio. Then carry out Anaerobic fermentation tests in 10th deal's conditions. When the other conditions don't change. The cumulative change of gas production is summarized in Fig.2.

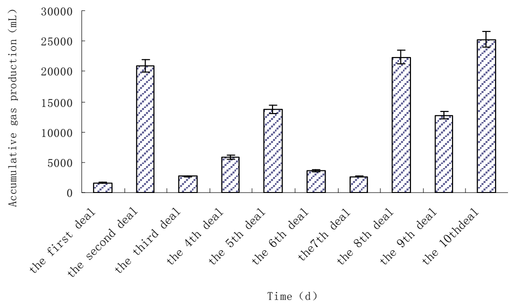

Figure 2. Cumulative change of gas production in every way

The cumulative gas production in same anaerobic fermentation conditions are obviously different in 30 days. From highest to lowest are: (the 10th deal)>(the 8th deal)>(the second deal)>(the 6th deal)>(the third deal)>(the 7th deal)>(the first deal).The 10th deal had the best effect on biogas production. The cumulative biogas production of the 10th deal attain to the 25230 mL. It illustrated the resualt of Orthogonal experiment and the practical requirements can be met by the optimal parameters. So it can be applied in the practice

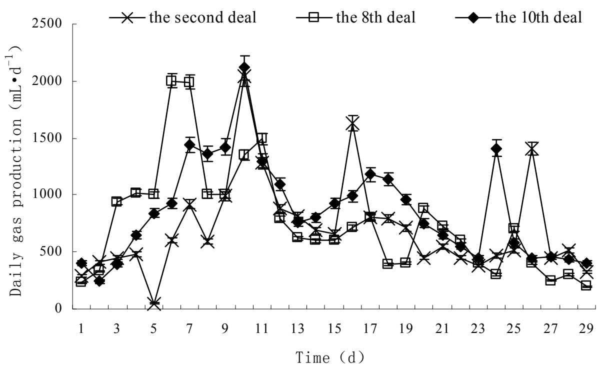

Figure 3. The difference of daily biogas production

Daily gas production is also a significant indicator in anaerobic fermentation. So the Test analyzed accumulative gas production and daily gas production of the 10th deal, the 8th deal and the second deal, which the rate of producing gas were much higher. As can be seen from the graph, the treatment of different deal appeared the same trend, but producing gas peak were different in the whole fermentation. The highest number of daily biogas production of the 10th deal is the best and it appeared the 11th, the 18th and the 25th day. The maximum daily biogas production appeared the 11th days reached 2040mL·d-1 and kept up five days. The highest number of daily biogas production of the 8th deal appeared the 7th days and kept up eight days. The highest number of daily biogas production of the second deal appeared the 11th, the 17th and the 27th day. The maximum daily biogas production appeared 11th days reached 2040mL·d-1 but The highest number of daily biogas production did not last a few days. Through the analysis of daily biogas production, it illustrated that the 10th deal had the greatest effect on biogas production with the best level for each factor. Taking into account the practical and economy, the 10th deal is the best combination. The reason of three peaks in the fermentation was that the pig manure continuously declined by the use of bacterial in inoculum at initial fermentation, while cellulose in straw had not been degraded. Therefore, the fermentation liquid fell gradually after the first peak. But as the reaction continued, the cellulose in straw was continuously degraded. The organic acids produced and accumulated at initial fermentation were oxidized and decomposed into acids and molecular hydrogen by producing acid and hydrogen bacteria, then produced methane by methanogen, which led to the second peak[10]. With the reaction, the pig manure exhausted, while the degradation rate of lignin and cellulose continued to raised, the efficiency of anaerobic biological conversion of straw increased, so the third peak appeared. However, the duration of the peak was short because the lignocellulosic material which could be degraded easily in corn stalk was limited.

IV. CONCLUTION

The effects of granularities of corn stalk, temperature, the quality ratio between pig effluent and corn stalk, feed ratio on the behavior of producing gas are investigated. It is show that all four factors have significant and similar influence to the rate of producing gas. The optimal conditions for anaerobic fermentation were corn stalk keeping 4-6cm, 35℃ in temperature, the quality ratio between corn stalk and pig manure to 1.5:1 and 90% in feed ratio. Under such conditions, the biogas production is much better than the others and the yield peaked higher. The highest number of daily biogas production reached 2120mL. So in practice we must take four factors into account to increase the rate of producing gas. The remarkable conditions from fore factor experiments are simple operation and convenient. It is suitable for anaerobic fermentation in rural, especially in the north and worthy to be popularized in practice

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