Influence of dry anaerobic fermentation manure-straw ratio on volumetric biogas yield

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Abstract. For better conversion and application of sugarcane leaf dry anaerobic fermentation biogas technology, the self-made cylinder type fermentation tank pilot system was established through a 150-day pilot test by using continuous biogas model. The results showed that there was no significant difference in the volumetric biogas yield within the manure-straw ratio range of 0.25 at the 0.01 level. The average volumetric biogas production was between 1047.30 L·(m³·d)-1 and 1192.20 L·(m³·d)-1. The mean volumetric biogas yield of the manure-straw ratio of 3 was only 174.74 L·(m³·d)-1, which was significantly lower than the remaining manure-straw ratio less than 0.0001. On the level of 0.6346, the fermentation temperature will not affect the volumetric biogas yield within the controlled range. The optimum manure-straw ratio ranges from 0.25 to 2. When the volume is too small or too large, the volumetric biogas yield will significantly decline, which can reduce the difficulty of preparing the raw material manure-straw ratio and is beneficial for the promotion of sugarcane leaf dry anaerobic fermentation biogas technology and the pilot test equipment.

1. Introduction
The area of sugar cane planting in China is about 1.2 million hectares, with a total amount of discarded sugarcane leaves up to 27 million tons every year [1]. Sugarcane leaf with high total carbon content is an excellent raw material for biogas production and can be converted into biomass energy by dry fermentation technology [2, 3]. In recent years, the technology of mixing it with pig manure, biogas residue, and inoculum for producing biogas has made significant progress [4]. The remaining biogas residue from biogas production can also be made into organic fertilizer, which is of great significance for agricultural production, environmental protection and people's livelihood. Manure-straw ratio is an important factor affecting dry fermentation and biodegradability. So studying the effect of manure-straw ratio on dry fermentation biogas yield, and then providing feasible, reliable and scientific process parameters for biogas production for scientific regulation of the dry fermentation system is of great significance for guiding dry fermentation engineering [5,6]. In this paper, 150-day continuous test on sugarcane dry fermentation biogas technology was performed to study the influence of manure-straw ratio on volumetric biogas yield, in order to obtain the best manure-straw ratio range and optimize dry fermentation process.

2. Materials and Methods

2.1. Test Materials
Pig manure: selected from a pig farm in Gaoyang of Zhanjiang City, with a total solid mass fraction of 25%.
Sugarcane leaf: Dry yellow sugarcane leaves after harvesting in the test filed of South Subtropical Crop Research Institute, China Academy of Tropical Agricultural Sciences were selected and grinded into 2-5 cm irregular pieces with a total solid mass fraction of 87%.

Biogas residue: selected from the fermentation substrate in the cylinder type fermentation tank during the pilot test.

2.2. Test Apparatus and Methods
A cylinder type fermentation tank made by Institute of agricultural machinery research, Chinese Academy of Tropical Agricultural Sciences with a volume of 2m³ was used as the test apparatus, as shown in figure 1.

![Figure 1. Self-made 2m³ cylinder type fermentation tank](image)

The actual biogas production system can continuously produce biogas. Close to the actual production test, the equipment has been operating normally for more than half a year. In the production process, the fermentation tank was supplemented with feedstock and discharged once a day. The pig manure and sugar cane leaves were poured into the spiral mixer in the test ratio. The pig manure was calculated by dry biomass, and the sugar cane was fixed by quality. After being fully blended, they were put into cylinder type fermentation tank with one time discharge per day, and returned to tank after mixing with new materials. The feed end of the cylinder type fermentation tank was equipped with an air gas vent connection filter and a flow meter. The flow data was read and recorded at 17 o'clock every day, and the real-time fermentation temperature was recorded.

Manure-straw ratio was set at five levels: 0.25, 0.50, 1.00, 2.00, and 3.00, with the dry matter concentration at each level set as 20%. The gas production at each level was observed for 30 days, and the remaining influencing factors were fixed at the optimal level obtained from the previous test (directly list the optimal level of the previous test), fermentation time continued for 150 days.

3. Result and Analysis

3.1. Daily Change of Different Manure-Straw Ratio Volumetric Biogas Yield
Volumetric biogas yield at four manure-straw ratio levels from 0.25 to 2 was mostly maintained at 1000 L/(m³·d) to 1500 L/(m³·d), and the volumetric biogas yield in some specific days was higher or lower than the above range. There exists intersection in the fluctuation of volumetric biogas yield. The volumetric biogas yield of the manure-straw ratio 3 was lower than 500 L/(m³·d), which was significantly different from the aforementioned 4 levels of biogas yield (see Figure 2).
3.2. Influence of Different Manure-Straw Ratios on Biogas Yield

With manure-straw ratio as a factor variable, daily volumetric biogas yield as the response variable, and material fermentation temperature in the tank was used as a covariate, abnormal data was excluded. Through covariance analysis and Duncan mean multiple comparisons [7] by using SAS software; main results are obtained, as shown in Table 1 and Table 2.

**Table 1.** Analysis on the covariance of pilot test results

| Source of variation       | Degree of freedom | Sum of squares | Mean square | F value | Pr>F       |
|---------------------------|-------------------|----------------|-------------|---------|------------|
| Model                     | 5                 | 18574743.12    | 3714948.62  | 28.58   | <.0001     |
| Manure-straw ratio        | 4                 | 18545241.60    | 4636310.40  | 35.66   | <.0001     |
| Manure-straw ratio        | 1                 | 29501.52       | 29501.52    | 0.23    | 0.6346     |
| Error                     | 131               | 17030286.69    | 130002.19   |         |            |
| Correction of total sum of square | 136               | 35605029.81    |             |         |            |

**Table 2.** Multiple comparison of Duncan means of pilot test results

| Manure-straw ratio | Average volumetric biogas yield L/m3·d | Observation number | 0.01 level significance |
|--------------------|------------------------------------------|--------------------|-------------------------|
| 2                  | 1192.20                                  | 31                 | A                       |
| 0.5                | 1129.87                                  | 30                 | A                       |
| 0.25               | 1098.12                                  | 20                 | A                       |
| 1                  | 1047.30                                  | 31                 | A                       |
| 3                  | 174.74                                   | 25                 | B                       |

It can be seen from Table 1, the covariance model effect was significant at a level less than 0.0001, the manure-straw ratio effect was significant at a level less than 0.0001, and the fermentation temperature was not significant at a level of 0.6346. The results showed that manure-straw ratio had a significant effect on volumetric biogas yield within the selected test level range, and the fermentation temperature did not affect the volumetric biogas yield within the controlled range.
It can be seen from Table 2, there was no significant difference in the amount of volumetric biogas yield with manure-straw ratio of 0.25~2 at 0.01 level, and the average volumetric biogas yield was close. The volumetric biogas yield with manure-straw ratio of 3 was significantly different from the rest of manure-straw ratio. Considering results of the previous tests, when manure-straw ratio was 0, the material could not be fermented effectively without biogas produced. When manure-straw ratio was less than 0.25, the biogas produced was insufficient because of inadequate material fermentation. It is easy to speculate from after summarizing from pilot test results that too small and too large manure-straw ratio would greatly reduce the volumetric biogas yield and the optimal manure-straw ratio should be controlled at 0.25 to 2.

4. Conclusion
The cylinder fermentation tank with easy structure and continent operation was used in the test by using a continuous biogas production model. Test results can be used for guiding actual application.

The test results showed that there was no significant difference in the volumetric biogas yield with manure-straw ratio range of 0.25 to 2 at level of 0.01. The average volumetric biogas yield was between 1047.30 L/ (m³·d) and 1192.20 L/ (m³·d). The average volumetric biogas yield with manure-straw ratio of 3 was only 174.74 L/ (m³·d), which was significantly lower than the remaining manure-straw ratio at the level less than 0.0001. The significance level of 0.6346 showed that the fermentation temperature had little influence on the volumetric biogas yield within the controlled range. Too small and too large manure-straw ratio would greatly reduce the volumetric biogas yield and the optimal manure-straw ratio should be controlled at 0.25 to 2. This can reduce the difficulty to prepare the raw material manure-straw ratio, and can help to promote sugarcane leaf dry anaerobic fermentation technology and relevant fermentation equipment.

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