

Research Article

Biogas Yield Potential Research of the Wastes from Banana Manufacturing Process under Mesophilic Anaerobic Fermentation

Zhang Zhengyun, Xu Rui, Duan Huanyun, Wang Qiuxia, Yang Bin, Han Jiahong,
Yuan Yage and Wang Fuxian
Yunnan Normal University, Yunnan Kunming 650092, China

Abstract: In this study is to verify the feasibility of the biogas yield potential of the wastes from banana manufacturing process and the feasibility of practical application through testing the fermentation performance of banana stalk and peel respectively at mesophilic temperature (35°C) under different concentration of fermentation. The research results indicated that the banana stalk and peel could be used as raw materials of anaerobic fermentation. The effect of gas production of low concentration of banana peel fermentation was the best and the biogas yield potential was 758 mL/g TS and 856 mL/g VS. But the fermentative broth acidified rapidly after the fermentation starting in high concentration of fermentation with banana peel. Therefore, the fermentation technology should be optimized during the practical application.

Keywords: Anaerobic fermentation, banana stalk, banana peel, biogas yield potential, mesophilic fermentation

INTRODUCTION

China is a large banana planting country. With bananas produced, a large number of banana stems, leaves and other wastes are produced. The banana-growing area achieved 228,400 hectares in China in 2003 and the banana production was 5.903 million tons. Which also produced about 6 million tons of banana stems and leaves, 1.8 million tons of banana peels and other wastes (Sang *et al.*, 2006). According to literature reports, banana stalks are mainly used to produce feeds (Yang and Lu, 2000). After fermenting, the banana stalk can be used to produce mushroom (Tao and Bai, 1999). In addition, the banana stalk can be used as study making raw materials because of the high contain of study making fiber. For banana peel, it can be used to produce feeds (Wei and Zhou, 2001). Besides, we can extract pectin (Ye, 1995) and dietary fiber (Wei, 1995) from banana peel. What's more, it can be used to absorb the heavy metals in sewage.

The research made by Zhang Xiao indicated that banana stalk is a good raw material for anaerobic fermentation. It is reported that the banana peel used in dry fermentation at 35°C compared to 25°C, the fermentation period can be shortened about 10 days. While the impact of the total solids concentration of the fermentative broth has not been reported.

This experiment can not only obtained the fermentation performance in different concentration of these two raw materials, but also can get the basic parameters of the energy conversion. Providing basis to improve the efficiency of biogas production which fermented by banana stalk and peel.

Table 1: Characters of raw materials

Raw materials	TS%	VS%	pH
Banana stalk	7.95	80.53	5.5
Banana peel	11.51	88.52	5.5
Inoculum	11.59	78.04	7.3

MATERIALS AND METHODS

Fermentation materials and inoculums: In this study, banana stalks and banana peels were from a fruit wholesale market in Kunming. Which were cut into small pieces about 0.5cm before the experiment. The Inoculum was the activated sludge which used cow dung as raw materials in anaerobic fermentation in our laboratory. The measured values of TS, VS and pH in fermentation feedstock are shown in Table 1.

Experimental design and setup:

- **Experimental design:** In this study, banana stalk and peel fermented at mesophilic temperature (35°C) and the volume fraction of inoculum was 30%. The concentration of fermentative broth was set to 5% and 7%, respectively. Each of the group has three parallels. There was one control group which was treated by distilled water. The total volume of each group was 400mL. The specific ratio of materials are shown in Table 2.

The experimental device: The experiment used 500mL controllable thermostat batch fermentation device (Fig. 1).

Table 2: The ratio of different components

Groups	Materials	The ratio
Experimental group one	Banana stalk	Banana stalk 77g, Inoculum 120 mL, add water to 400 mL.
Experimental group two	Banana stalk	Banana stalk 177g, Inoculum 120 mL, Add water to 400 mL.
Experimental group three	Banana peel	Banana peel 53g, Inoculum 120 mL, Add water to 400 mL.
Experimental group four	Banana peel	Banana peel 122g, Inoculum 120 mL, Add water to 400 mL.
Control group	Inoculum	Inoculum 120 mL, Add water to 400 mL.

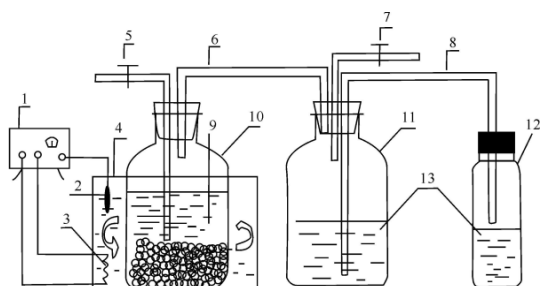


Fig. 1: Sketch map of an anaerobic fermentation reactor
 1. Temperature controlling box; 2. Temperature sensor; 3. Heating wire; 4. Water thermostat system; 5. Sampling place; 6. Airway; 7. Gas outlet; 8. Aqueduct; 9. Fermentation liquid; 10. Fermentor; 11. Biogas collecting bottle; 12. Measuring cylinder; 13. Saturated NaHCO₃ solution

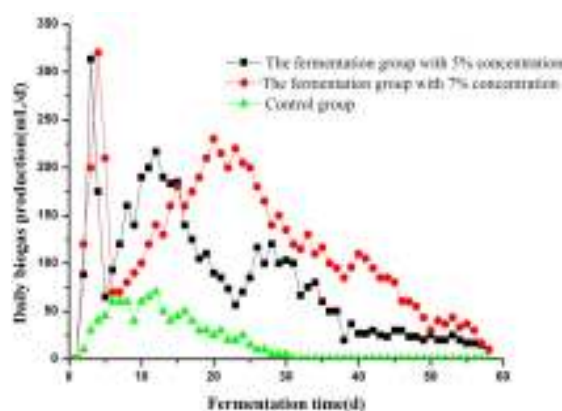


Fig. 2: Biogas production from different concentration of fermentation of banana stalk

Analysis and test:

- TS, VS: Using conventional analysis methods
- pH value: Measured by the precision pH test strips
- Biogas production: Measured by the drainage gas gathering method. After starting the experiment, recorded the biogas production of each group daily regularly and calculated the average biogas production of each group as the characterization of daily biogas production
- Methane content: Measured by the methane content and flame color standard card method

RESULT

The impact of the different concentration of fermentation to banana stalk and peel fermentation:

- **The effect of biogas production which used banana stalk as raw materials in different concentration of fermentation:** Figure 2 shows the biogas production from different concentration of fermentation of banana stalk. As shown in Fig. 3, the pH value has declined in each banana stalk fermentation system at the early stage of fermentation. It is mainly because that the hydrolysis stage is the initial stage of anaerobic fermentation, the methanogens are the non-advantage flora in this stage and the growth of them is lagging behind, they are unable to catabolize the organic acid which produced by hydrolytic bacteria and H₂-producing acetogenic

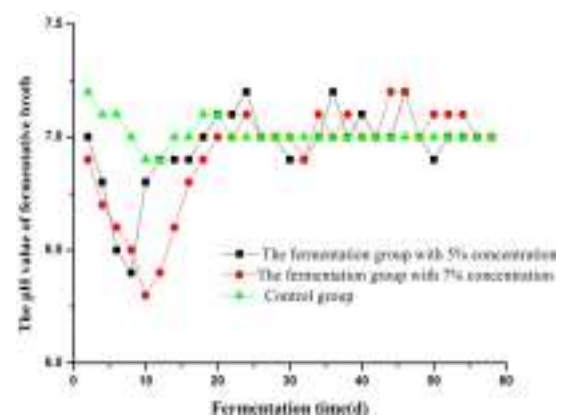


Fig. 3: pH variation of fermentative broth in fermentation process

bacteria. Thus, acid accumulated in the fermentation system. Since then, with the amplification of methanogenic flora, their ability of acid metabolism became strong and the pH value gradually increased, the fermentation system produced biogas normally. The banana stalk fermentation group with 5% concentration, after 3 days starting, the fermentation system produced 313 mL biogas as the maximum biogas production. Lighting of the gas, the combustion was not continuous. Controlled method standard, the CH₄ content in the biogas was about 10%. At the 12th day after starting the experiment, the daily biogas production reached to the second small peak which produced 217 mL biogas, which flame was orange and the CH₄ content of which was about 60%. The total fermentation time of this system were 58 days and the cumulative gas yield achieved 4765 mL.

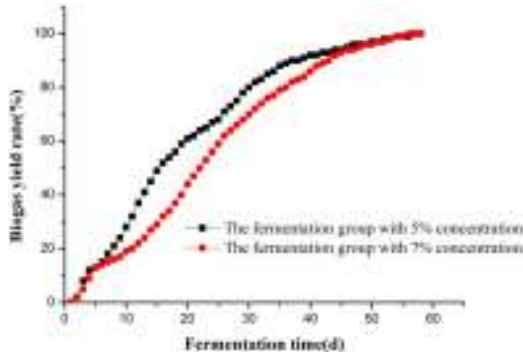


Fig. 4: Biogas yield rate of different concentration of fermentation of banana stalk

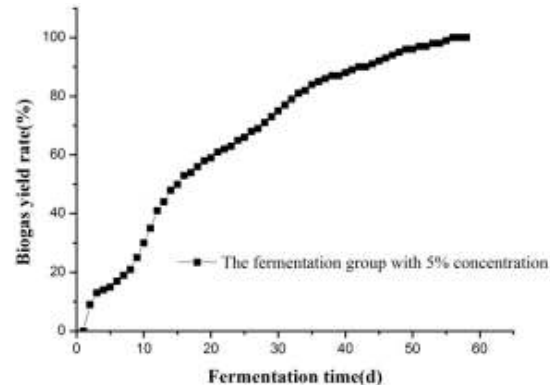


Fig. 7: Biogas yield rate of low concentration fermentation of banana peel

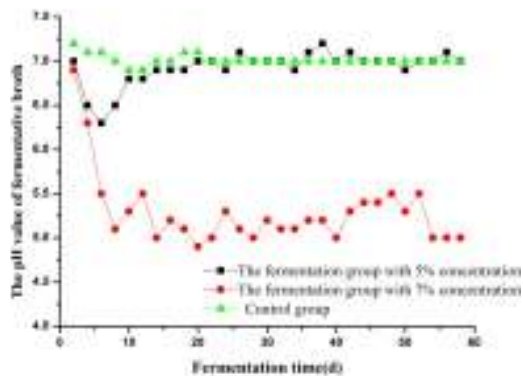


Fig. 5: pH variation of fermentative broth in fermentation process

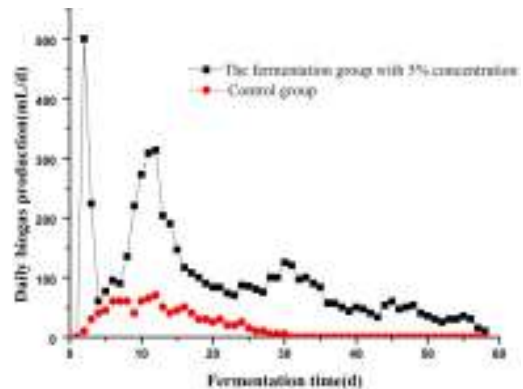


Fig. 6: Biogas production of low concentration of fermentation of banana peel

The concentration of fermentation raised to 7%, the system produced biogas rapidly in two days after starting the experiment. Since then, the biogas production increased rapidly and which reached 320 mL on the fourth day. Controlled method standard, the CH₄ content of which was about 10%. However, the biogas production decreased because of the pH decreased, the gas production was 70 mL as the lowest gas production at the first seven days. Since then, the biogas production gradually increased and reached

another small peak which produced 230 mL biogas in the first 20 days. The CH₄ content in the biogas was about 60%. The total fermentation time of this system were 58 days and the cumulative gas production achieved 6788 mL.

Biogas yield rate in the banana stalk fermentation group with 5% concentration is shown in Fig. 4: The cumulative gas production of the first 35 days was 87.76% of the total gas production. Which indicated that the banana stalk fermentation with 5% concentration was basically concentrated in the first 35 days under this reaction conditions. But the cumulative biogas production of the first 40 days in the banana stalk fermentation group with 7% concentration was 86.07% of the total biogas production. Which indicated that the fermentation was basically concentrated in the first 40 days under this reaction conditions.

- **The effect of biogas production which used banana peel as raw materials in different fermentation concentration:** As shown in Fig. 5, the pH value has declined in each banana peel fermentation system at the early stage of fermentation. It is mainly because the total sugar content in the banana peel is higher than other components, while the sugar is susceptible to hydrolyze by the bacteria producing organic acids. The pH value in the fermentation system was decreased due to the accumulation of organic acids. The pH value of the banana peel fermentation group with 5% concentration declined in a brief time and then rose gradually and restored to produce gas normally; however, the banana peel fermentation group with 7% concentration acidified seriously in the first 7 days and stopped to produce biogas.

As shown in Fig. 6, in the banana peel fermentation group with 5% concentration, 2 days after starting the experiment, the fermentation system began to produce biogas. Controlled method standard, the CH₄ content in

Table 3: Fermentative broth's TS and VS value

Groups	Before the fermentation		After the fermentation	
	TS%	VS%	TS%	VS%
The banana stalk fermentation group with 5% concentration	4.97	81.16	3.43	67.84
The banana stalk fermentation group with 7% concentration	6.75	82.54	4.55	69.98
The banana peel fermentation group with 5% concentration	4.96	81.79	3.69	65.28

Table 4: The biogas yield potential of different raw materials

Groups	Cumulative biogas production (mL)	Gas yield rate of raw materials (mL/g)	TS gas yield rate (mL/g·TS)	VS gas yield rate (mL/g·VS)
The banana stalk fermentation group with 5% concentration	4765	49	616	756
The banana stalk fermentation group with 7% concentration	6788	33	412	512
The banana peel fermentation group with 5% concentration	5620	87	758	856

the biogas was low. Since the main content of biogas was CO₂. It was mainly because that in the starting stage the metabolism of hydrolytic bacteria generated a lot of CO₂, but the methanogens were not active. The reaction weakened and the biogas production declined as the pH value of fermentative broth decreased. Because of the metabolic activities of methanogens consumed the organic acids, the daily biogas production increased and produced a large number of biogas. This can also be verified by the increase of methane content in biogas. 12 days after starting the experiment, the daily biogas production reached to the second small peak which produced 313mL biogas, the CH₄ content in the biogas was about 65%. The total fermentation time of this system were 58 days and the cumulative biogas production achieved 5620mL.

Biogas yield rate in the banana peel fermentation group with 5% concentration is shown in Fig. 7: The cumulative gas production of the first 35 days was 83.63% of the total gas production. It indicated that the banana peel fermentation group with 5% concentration was basically concentrated in the first 35 days under this reaction conditions.

The comparative analysis between banana stalk and peel of the biogas yield potential: The TS and VS values in the fermentative broth were determined before the start of the experiment and after the end of the experiment; the results are shown in Table 3.

It can be seen from the Table 3, TS and VS value in fermentative broth of various fermentation groups have undergone significant changes. Which showed that the raw materials were degraded to generate biogas during the fermentation process.

The biogas yield potential of the two materials at different concentration of fermentation were calculated, changing the fermentative broth and the biogas production in each experimental group before and after the fermentation. As shown in Table 4, in the fermentation group which used banana stalk as raw materials, increasing the concentration of the

fermentative broth to 7%, the cumulative biogas production had increased, but compared with the banana stalk fermentation group with 5% concentration, the gas yield rate of raw materials, TS gas yield rate and VS gas yield rate were not satisfied. This indicated that the banana stalk can be degraded easier in low concentration fermentation. With the increasing of the concentration of fermentation, the cumulative biogas production increased, but the utilization of the raw materials decreased and the biogas production peak delayed. Cellulose is the main components of the banana pseudo-stem fiber, accounting for the total amount of 55.591%, which is difficult to use by fermentative microorganisms; While the total sugar content of banana peel is high, which is susceptible to use by microbes. Therefore, in low concentration of fermentation condition, the TS gas yield rate, VS gas yield rate and the cumulative biogas production in banana peel fermentation group were higher than banana stalk fermentation group.

CONCLUSION

Through comparing the indicators of anaerobic fermentation process which used banana stalk and peel as the raw material under different concentration, we can draw the following conclusions:

- Banana stalk and peel can be used as raw material of anaerobic fermentation. When the two raw materials have been used in an anaerobic fermentation, the concentration of fermentation has an important impact for its gas production levels.
- The biogas yield potential of the banana stalk fermentation group with 5% concentration was 616mL/g TS and 756 mL/g VS. Improving the concentration, the biogas yield potential of banana stalk decreased, it was 412 mL/g TS and 512 mL/g VS respectively. The banana stalk can be degraded easier in low concentration. With the increasing of concentration, the biogas production peak delayed.

- The biogas yield potential of the banana peel fermentation group with 5% concentration was 758 mL/g TS and 856 mL/g VS. But the fermentative broth acidified rapidly after increasing the concentration of fermentation.
- In low concentration fermentation condition, the TS gas yield rate, VS gas yield rate and the cumulative biogas production in banana peel fermentation group were higher than banana stalk fermentation group.

ACKNOWLEDGMENT

This study was financially supported by the Yunnan Provincial Natural Science Foundation (2010CD051), National Natural Science Foundation (51166014) and MISEREOR grant (335-031-1015Z) "Facilitating Community Driven Sustainable Development". I would like to express my sincere gratitude to professor Guan Huilin and professor Zhang Wudi for the editing assistance.

REFERENCES

- Sang, L., L. Li and F. Zheng, 2006. Study on the comprehensive utilization of banana by-product [J]. *Heilongjiang Agric. Sci.*, 4: 96-98.
- Tao, Y. and H. Bai, 1995. The method of the banana cauloid used as cow feed. *Yunnan Agric.*, 5: 21.
- Wei, D., 1995. The test which used banana stalks and waste bacteria tube to produce bacteria feed to feeding pigs [J]. *Fujian Sci. Technol. Trop. Crops*, 20(1): 22-24.
- Wei, Y. and L. Zhou, 2001. Testing in feed lactating cows with banana leaf and stem [J]. *J. Guangxi Agric. Biol. Sci.*, 20(1): 34-36.
- Yang, L. and H. Lu, 2000. Study on conversion of banana stalk and leaf into feedstuff [J]. *J. Yunnan Trop. Crop. Sci. Technol.*, 23(4): 11-12.
- Ye, Y., 1995. The technology which used banana stem to produce bacterial protein feed additive and used the products to feed the chickens [J]. *Fujian Sci. Technol. Trop. Crops*, 20(1): 19-21.