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Analysis about Influence of Dry Anaerobic Fermentation on Main Nutrients of Biogas Residue

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Abstract. In order to boost the use value of biogas residue, main factors in dry fermentation were chosen to design an experiment to observe nutrient changes under different conditions before and after dry fermentation. The effects of manure-crop ratio, inoculum size, dry matter concentration and fermentation temperature on main nutrients before and after anaerobic fermentation were studied in this paper. Multivariant linear analysis of two comprehensive indicators shows that pretreatment has a significant effect on the increase in the content of rapidly available phosphorus and rapidly available potassium; manure-crop ratio shows a significant effect on the rise of organic content; the influence of other factors is not significant

Introduction

Biogas residue is made by composting the residues after dry anaerobic fermentation of sugarcane leaves and pig manure. It is rich in organic matters and essential nutrients, so it is a good bio-organic fertilizer. The methane is fermented slowly, and the consumption of organic matters is low. Besides, the loss of nitrogen, phosphorus and potassium is small. The recovery rate of nitrogen can reach 95%, and recovery rate of kalium exceeds 90%. Biogas residue can be used a few days later after the fermentation. In the previous experiments, sugarcane leave biogas residue plays an obvious promotion role for dragon fruit, hot pepper and okra etc.

To further improve the position of biogas residue among organic fertilizers, the effects of manure-crop ratio, inoculum size, dry matter concentration and fermentation temperature on main nutrients before and after anaerobic fermentation were studied through single-factor experiment in this paper. Through regression analysis of experimental data, the optimal fermentation process parameters have been found out.

Materials and method

Experimental materials and devices. Raw materials: dry and yellow sugarcane leaves from the sugarcane field around Zhanjiang Huguang Farm, which were smashed to 2-5cm irregular chippings with a pulverizer, with the total solid mass fraction of 87%; pig manure from an individual pig breeder near Gaoyang, Zhanjiang, with the total solid mass fraction of 25%.

Inoculum: enriched materials from moderate-temperature and dry anaerobic fermentation of sugarcane leaves and pig manure. The enrichment time is greater than 2 months, and the total solid mass fraction is 20%.

Experiment design and method. The following experiment program was designed to explore main technological parameters of anaerobic fermentation of sugarcane leaves and their influence on biogas residue and confirm the optimal technological parameters through single factor analysis and regression analysis. 5 factors and 4 levels were chosen. In the single factor experiment, other factors were fixed at the optimal level gained from the feasibility experiment in the early stage. Before and after the anaerobic fermentation, samples were taken to measure the content of moisture, nitrogen, phosphorus, potassium and organic matters. After the experiment started, the temperature in the fermentation tank, daily gas output and methane content (may be measured at the time interval of 2-3d) were measured every day.

Table 1 Experiment program

Observation	Pretreatment/h	Manure-crop ratio	Inoculum size kg	Dry matter concentration %	Fermentation temperature℃
1	11.90	1.00	3.50	20.00	38.00
2	12.00	1.00	3.50	20.00	38.00
3	48.00	1.00	3.50	20.00	38.00
4	84.00	1.00	3.50	20.00	38.00
5	12.00	0.00	3.50	20.00	38.00
6	12.00	0.50	3.50	20.00	38.00
7	12.00	1.00	3.50	20.00	38.00
8	12.00	2.00	3.50	20.00	38.00
9	12.00	2.00	2.30	20.00	38.00
10	12.00	2.00	3.50	20.00	38.00
11	12.00	2.00	4.60	20.00	38.00
12	12.00	2.00	5.80	20.00	38.00
13	12.00	2.00	5.80	15.00	38.00
14	12.00	2.00	5.80	20.00	38.00
15	12.00	2.00	5.80	25.00	38.00
16	12.00	2.00	5.80	30.00	38.00
17	12.00	2.00	5.80	20.00	25.00
18	12.00	2.00	5.80	20.00	35.00
19	12.00	2.00	5.80	20.00	37.50
20	12.00	2.00	5.80	20.00	40.00

Note: level of factor pretreatment = 0.5 x wetting time of sugarcane leaves + 0.5 x composting time. In the formula, the unit of each variable is hour.

Results and analyses

Nutrient increment characteristics before and after fermentation. The difference between nutrient measurement results before and after the fermentation is called nutrient increment. 20 observations gained from the experiment show that the content of total nitrogen and rapidly available nitrogen changes little; the content of organic matters both decreases and increases, but the decrease is dominated; the content of rapidly available phosphorus and rapidly available potassium rises, and the increase range of rapidly available phosphorus is greater than that of rapidly available potassium in most observations, as shown in Fig.1.

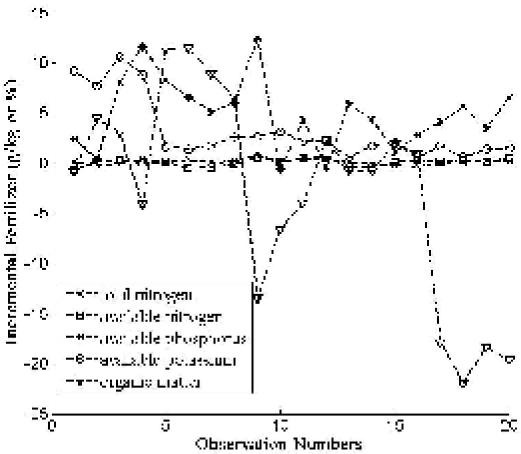

Fig.1 Nutrient increment characteristics of biogas residue before and after fermentation

Nutrient increment synthesis before and after fermentation. Since it was not easy to clearly see the change rules through observing the 5 nutrient increment indicators, principal component analysis was used to synthesize 5 nutrient increment indicators into 2 comprehensive indicators.

Table 2 Characteristics of nutrient increment comprehensive indicators CI

CI	Variance	Variance increment	Variance ratio	Accumulative variance ratio
CI_1	108.3442	95.1481	0.8310	0.8310
CI_2	13.1961	4.5363	0.1012	0.9322
CI_3	8.6598	8.5356	0.0664	0.9987
CI_4	0.1243	0.0752	0.0010	0.9996
CI_5	0.0490		0.0004	1.0000

As shown in Table 2, variance ratio of the first comprehensive indicator CI_1 (the first principal component) is as high as 83.10%, while variance ratio of the second comprehensive indicator CI_2 (the second principal component) reaches 10.12%. The accumulative variance ratio is 93.22%. Thus, the two indicators are needed to discuss the characteristics of nutrient increment.

Table 3 Structure mode of nutrient increment comprehensive indicators CI

Nutrient increment	CI_1	CI_2
Total nitrogen (y_1)	-0.0069	0.0344
Rapidly available nitrogen (y_2)	-0.0161	0.0009
Rapidly available phosphorus (y_3)	-0.0332	0.9216
Rapidly available potassium (y_4)	0.0619	0.3866
organic matter (y_5)	0.9974	0.0069

As shown in Table 3, CI_1 mainly represents the increment of organic matters before and after the fermentation. Large CI_1 value means positive increment of organic matters is large. Small CI_1 value means positive increment of organic matters is small and even the increment is negative.

As shown in Table 3, CI_2 mainly represents the increment of rapidly available phosphorus and rapidly available potassium before and after the fermentation. The ratio of rapidly available phosphorus is about 2.4 times of that of rapidly available potassium. Large CI_2 value means positive increment of rapidly available phosphorus and rapidly available potassium is large (especially rapidly available phosphorus). Small CI_2 value means positive increment of rapidly available phosphorus and rapidly available potassium is small and even the increment is negative.

Computational formulas of CI_1 and CI_2 are as follows:

$$CI_1 = -0.0069y_1 - 0.0161y_2 - 0.0332y_3 + 0.0619y_4 + 0.9974y_5$$
$$CI_2 = 0.0344y_1 + 0.0009y_2 + 0.9216y_3 + 0.3866y_4 + 0.0069y_5$$

Optimal parameters for fermentation technology. The values of CI_1 and CI_2 in the 20 experiments were figured out. Then, the values are sorted according to CI_1in ascending order. The results are shown in Table 4.

Table 4 CI and ranking in the 20 experiments

Observation	Pretreatment	Manure-crop ratio	Inoculum size	Dry matter	Fermentation temperature	CI_1	CI_2
18	12	2	5.8	20	35	-22.0768	5.3342
20	12	2	5.8	20	40	-19.7081	6.4872
19	12	2	5.8	20	37.5	-18.3073	3.7259
17	12	2	5.8	20	25	-17.8262	4.3902
9	12	2	2.3	20	38	-13.6981	12.4633
10	12	2	3.5	20	38	-6.2992	0.6770
11	12	2	4.6	20	38	-3.9310	4.8614
4	84	1	3.5	20	38	-3.8613	14.1546
13	12	2	5.8	15	38	-0.8112	5.7194
14	12	2	5.8	20	38	-0.7767	4.6870
1	11.9	1	3.5	20	38	-0.2672	5.7463
16	12	2	5.8	30	38	0.9274	2.8271
15	12	2	5.8	25	38	2.0727	1.9000
12	12	2	5.8	20	38	2.4595	0.4336
3	48	1	3.5	20	38	3.4526	11.6463
2	12	1	3.5	20	38	4.9796	3.4132
8	12	2	3.5	20	38	6.5672	6.6495
7	12	1	3.5	20	38	8.8507	5.5312
5	12	0	3.5	20	38	11.2566	8.4072
6	12	0.5	3.5	20	38	11.3752	6.7296

As shown in Table 4, in the 20 observations, there are many negative values of CI_1, while there are a few positive values. Besides, the absolute values of negative values are also large. This means the content of organic matters usually decreases after the fermentation. The values of CI_2 are positive, which indicates the content of both rapidly available phosphorus and rapidly available potassium increases after the fermentation. The content of total nitrogen and rapidly available nitrogen changes little after the fermentation. Thus, nutrients of biogas residue mainly contain rapidly available phosphorus and rapidly available potassium after the fermentation.

In conclusion, the larger, the better for the content of rapidly available phosphorus, rapidly available potassium and organic matters in biogas residue after the fermentation. Based on this standard, the optimal parameters of fermentation technology were sought. In accordance with Table 8, the three groups of observations with the contents of observation number, CI_1 and CI_2 (3,3.4526,11.6463), (5,11.2566,8.4072) and (6,11.3752,6.7296) are superior to other observations. The parameters of fermentation technology corresponding to No.3 observation are as follows: (wetting for 24h + composting for 3d, manure-crop ratio 1:1, inoculum size 3.5, dry matter concentration 20 and fermentation temperature 38℃). The parameters of fermentation technology corresponding to No.5 observation are as follows: (wetting for 24h + composting for 0d, manure-crop ratio 0:1, inoculum size 3.5, dry matter concentration 20 and fermentation temperature 38℃). The parameters of fermentation technology corresponding to No.6 observation are as follows:

(wetting for 24h + composting for 0d, manure-crop ratio 1:2, inoculum size 3.5, dry matter concentration 20 and fermentation temperature 38℃). The optimal parameters of fermentation technology can be chosen from one of the above 3 experiments.

Conclusion

Principal component analysis and regression analysis were made for the increment of 5 nutrients after and before dry anaerobic fermentation. The results show that,

The content change of total nitrogen and rapidly available nitrogen is not significant. The content of organic matters decreases significantly. The content of rapidly available phosphorus and rapidly available potassium rises significantly, and the growing range of rapidly available phosphorus is generally greater than that of rapidly available potassium.

3 groups of relatively excellent parameters are gained, i.e. (wetting sugarcane leaves for 24h + composting for 3d, manure-crop ratio 1:1, inoculum size 3.5kg, dry matter concentration 20% and fermentation temperature 38℃), (wetting sugarcane leaves for 24h + composting for 0d, manure-crop ratio 0:1, inoculum size 3.5kg, dry matter concentration 20% and fermentation temperature 38℃) and (wetting sugarcane leaves for 24h + composting for 0d, manure-crop ratio 1:2, inoculum size 3.5kg, dry matter concentration 20% and fermentation temperature 38℃). The content of rapidly available phosphorus, rapidly available potassium and organic matters in biogas residue can increase significantly through using the three groups of technological parameters. Further experiment and exploration are still required to seek the optimal technological parameters.

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