Study on the correlation between volatile fatty acids and gas production in dry fermentation of kitchen waste

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Abstract. In this study, continuous kitchen waste fermentation and anaerobic digestion experiments were conducted to analyze the gas production potential, and to study the correlation between gas production rate and volatile fatty acid (VFAs) and its component concentration. During the experiment, the total solid(TS) concentration of the reaction system was increased by adding the kitchen waste, analysis of kitchen waste dry fermentation process to start, run, imbalance and imbalance after recovery and the parameters in the process of realizing the change trend and influencing factors of dry fermentation process, pH and ammonia concentration.

1. Introduction
Kichen waste from its literal meaning can be known as people in the production of life after the meal waste, as well as food waste during the process of cooking. The main places of kitchen waste generated are school canteens, families, catering enterprises, canteens of enterprises and institutions, etc., including food waste generated by residents during catering and processing, scraps and residual wastes of food and food during the production and processing, such as surplus fruits and vegetables and cooking oil, fat, after eating and not eating food, soup and so on[1,2].

The composition of kitchen waste is complex and can be analyzed from its physical and chemical properties. From the physical properties, kitchen waste including food processed leftovers, leftovers, fruits, vegetables, animal and vegetable oil and grease residue. From the chemical composition, kitchen waste containing starch, cellulose and semi cellulose, protein, animal and vegetable oils and fats such as organic matter and water, including inorganic salts, organic acid, rich variety of trace elements, such as K, Ca, Mg, Fe, P and other trace elements[3, 4, 5].

At present, domestic and foreign kitchen waste disposal technology, according to the processing medium can be divided into two categories of non-biological treatment and biological treatment technology. Non-biological treatment technology mainly refers to the traditional waste disposal methods, such as incineration, landfill, in addition to emerging dehydrated feed, vacuum fried feed, mechanical broken, etc.; and biological treatment technology, including anaerobic digestion and aerobic compost. The main treatment of municipal solid waste in China is landfill disposal, incineration and composting. These three kinds of treatment, landfill disposal technology has been the main treatment of municipal solid waste[6].

In today's rapid economic development, people's living standards are gradually improved, and more and more kitchen waste comes along with them. Because of its high water content, high organic
content and easy spoilage, kitchen waste can not only pollute the environment, but also cause waste of resources. Dry fermentation of anaerobic digestion of kitchen waste, the kitchen waste reduction, at the same time, the nutrients in the kitchen wastes to be fully utilized, into volatile fatty acids as well as carbon source for the use of sewage treatment plant, so that resource of kitchen waste.

At present, Europe, the United States, Japan and other developed countries anaerobic digestion technology, in the city of bio-organic waste management has extensive experience and has formed a mature technical system and widely used, especially single-phase anaerobic digestion. Anaerobic digestion with its system is simple, easy maintenance, gas production and other prominent features, accounting for more than 90% of the city's bio-organic waste anaerobic treatment market. In China, the technology of bio organic waste anaerobic digestion treatment more widely carried out in rural biogas digesters on anaerobic digestion of food waste and combined with technology of single-phase anaerobic digestion technology is still in its infancy, single-phase high solid anaerobic digestion and dry anaerobic digestion of less fermentation processing technology[7, 8, 9].

This study carried out continuous dry fermentation of kitchen waste anaerobic digestion experiment and the concentration of methane in biogas, and to study the correlation between gas production(The gases include methane, carbon dioxide, hydrogen sulfide, nitrogen and other gases) efficiency and volatile fatty acid (VFAs). From the beginning of the start, the concentration of total solid (TS) in the single-phase anaerobic fermentation reactor was gradually improved, and the recovery, operation, imbalance, recovery after imbalance, The effects of pH, ammonia concentration concentration on the experiment were analyzed by monitoring and changing the parameters of the whole process. Finally, the experimental data were collected, and the correlation curves of each data were drawn, and the correlation between volatile fatty acids and gas production was analyzed.

This study provides a basis for further research, and is conducive to the domestic development of dry fermentation and anaerobic digestion of kitchen waste.

2. Experimental materials and methods

2.1. Materials
The kitchen waste comes from the school canteen, which consists of a small amount of rice and steamed bread, vegetables , meat and other components. The kitchen waste into the food crusher crushed, will be shredded kitchen waste into the refrigerator at 4 ℃ stand. Take some rice, steamed bread, stir up the steamed bread and put it in the refrigerator.

The inoculation of the sludge used in the experiment was taken from the sewage treatment plant in the northern part of Shenyang.

2.2. Experiment scheme
The two reaction tanks were simultaneously tested to control the operating temperature at 37 ℃. Before the start of the experiment, take 1000g inoculation of sludge into the reaction tank, add 10L water, stir evenly, the inoculation of sludge for flocculation culture, adjust the reaction tank pH in 6.8~7.4. Anaerobic digestion starts, the kitchen waste starts with a feed of 300g. After stable operation, the feed rate of the kitchen waste can be adjusted according to the daily gas production in the reaction tank and the pH change. The experimental operation, every 24h discharge time, discharge analysis of samples of each parameter, total solid(TS) concentration above 20%, anaerobic digestion reaction is stable, gas production rate fluctuations, feeding and discharging amount is basically the same, by adjusting the reaction tank, the reaction towards the environment the experiment is conducive to the direction of experiment, stable operation of 60d.

2.3. Experimental items and methods of analysis

2.3.1. Determination of pH. After the sample was subjected to suction filtration, the supernatant was collected in a small beaker for pH measurement. The supernatant was poured into a beaker and
measured with a pH meter. Remove the electrode of the pH meter from the standard solution, rinse the electrode with deionized water, and then dried with the absorbent paper and placed in a beaker with supernatant. The data is recorded after the reading of the pH meter is stable.

2.3.2. Determination of ammonia nitrogen concentration. Ammonia concentration was measured using the Nessler reagent method. Take the sample broth 0.1ml in 100ml volumetric flask, add deionized water volume, shake. Take the diluted sample 50ml in the glass bottle, first add potassium tartrate solution 1ml, shake, then add 1.5ml Nessler reagent, shake and let stand for 10min. The ammonia concentration of the sample was measured with a 420 nm wavelength meter.

2.3.3. Determination of total solid (TS) concentration. Take the drying crucible, weigh its quality \( m_1 \), and then pour the sample into the crucible, the quantity is called \( m_2 \). The crucible is placed in a drying oven of 105°C and dried until the weight is constant, the quality is \( m_3 \). At this point the quality of the material is the total solid quality \((m_3 - m_1)\) g.

The formula for TS is:

\[
TS = \frac{m_3 - m_1}{m_2 - m_1} \times 100\%
\]  

In formula:  
- TS - percentage of solids in a sample;\%
- \( m_1 \) - the quality of the crucible; g
- \( m_2 \) - the total quantity of the sample and crucible; g
- \( m_3 \) - the total quantity of sample dry matter and crucible; g

2.3.4. Determination of volatile fatty acids (VFA) concentration. VFA was determined by liquid chromatography analyser. Formic acid, acetic acid, propionic acid and butyric acid were analyzed by standard liquid liquid chromatography to determine the peak time after chromatographic analysis of digestion, corresponding to the peak time of determining the content of volatile fatty acid components.

2.3.5. Determination of gas production. Gas production and gas production rate are recorded by gas recorder. The gas generated in the reaction tank is connected to the gas flow meter with a guide tube. When the gas passes through the flow, the total amount of gas and the rate of gas production are recorded.

3. Experimental result analysis

3.1. Gas production efficiency and TS change during dry fermentation

Figure 1 reflects the change of daily gas production curve with TS. From the figure we can intuitively divide the dry fermentation process into four periods: the adaptation period (0 - 15 days), the start-up period (15 - 30 days), the inhibition period (30 - 50 days), the recovery and stabilization period (50 - 70 days). In each period, the rate of change of the curve is different[10].

Adaptation period: the beginning of the experiment, the reactor has been inoculated sludge for flocculation culture, while add 300g kitchen waste. As the experiment is in the adaptation period, feeding once every three days, the beginning of the experiment, the reaction tank TS is 4.09% and gas production is 2496ml. With the anaerobic digestion reaction, TS gradually increased, gas production also increased.

Start-up period: after about 15 days of adaptation period, the dry fermentation and anaerobic digestion of kitchen waste enter the start-up period. In the start-up period, the gas production and TS increase gradually, reaching their own maximum value at one time, the maximum gas production reached 19751ml, and TS reached 17.08%.

Inhibition period: The inhibition period lasts about 20 days. During the inhibition period, the gas production and TS showed an obvious downward trend, and the gas production rate decreased
significantly. In this period, reaction was inhibited, reaction stagnation, the activity of inoculated sludge decreased.

Recovery and stabilization period: after the first three periods, the dry fermentation and anaerobic digestion of kitchen waste was ushered in recovery and stabilization. In this period, after the artificial adjustment, the reaction gradually recovered, the gas production rate and TS showed an upward trend, TS reached the peak, the gas production rate then reached the peak, reached the peak, TS and gas production rate is relatively stable, although the upper and lower fluctuating, but the dry fermentation reaction is still proceeding steadily.

![Figure 1. Curve of daily gas production and TS in dry fermentation.](image1)

![Figure 2. curves of daily output and TS in dry fermentation process.](image2)

3.2. **Gas production rate and variation of pH**

As shown in Figure 2, the correlation between pH and daily gas production is shown. From the figure we can see that the change in pH can also be divided into four periods, that is, adaptation period, start-up period, inhibition period and recovery and stabilization period. In the experiment of the adaptation period, pH is 5.33, with the reaction, pH decreased gradually, this is because of the fermentation reaction, kitchen waste to produce organic acid in the decomposition process. Then the reaction entered the start-up period, pH remained at a low value during this period, and the digestive juice self-regulation in the reaction tank does not have a good effect. Reaction into the inhibition period, due to the inhibition stage, the reaction is inhibited, the reaction process is slow, slow decomposition of kitchen waste, only a small part of the kitchen waste decomposition, resulting in relatively little
organic acid, the pH has risen. The reaction enters the recovery and stabilization period. At this period, the pH of the fermentor is adjusted by adding a solution of sodium hydroxide (NaOH) to adjust the pH, and reach steady state. Although the pH in this process fluctuates somewhat, the reaction is stable and the gas production rate is stable.

3.3. Correlation of volatile fatty acids with gas production

Figure 3 shows the correlation between volatile fatty acids and gas production during the anaerobic digestion of kitchen waste. During the adaptation period, the amount of gas produced and the amount of VFAs were relatively low at 2496 ml/d and 19.97g/L, the reaction in the start-up period, the gas production and TS gradually increased, the gas production fluctuated obviously, at the same time VFAs concentration began to decline, the gas production and VFAs showed the opposite trend. This period due to the increase of TS concentration, the organic matter in kitchen waste that was easily hydrolyzed began to be hydrolyzed. The hydrolyzed product was a small molecule organic acid. After an 15 days acclimation period, The adaptability of kitchen waste gradually increases, and some small organic acids that are hydrolyzed are converted into biogas, resulting in an increase of daily gas production and a decrease of the concentration of VFAs. Then, the reaction enters the inhibition period, during which the system gas production dropped, the pH of the digestive solution continued to decrease, the amount of feeding decreased, the reaction was almost near stagnation. At this period, the fermentation of small molecules in the accumulation of organic acids, the system can’t adjust their own through the regulation of pH, so the VFAs concentration greatly improved. After the inhibition period of the reaction, the reaction proceeds to the recovery and stabilization period. During this period, sodium hydroxide was added dropwise to adjust the pH of the system, and the gas production increased with the increase of pH. During the inhibition period, a large amount of organic matter and small molecules of organic acids accumulated in the bacteria. The concentration of VFAs began to show a decreasing trend. After the stabilization period, the gas production and VFAs fluctuated, but remained within a certain range, and the experiment began to run stably.

3.4. Concentration analysis of volatile fatty acids in each component

Figure 4 shows the changes in VFAs components during the dry fermentation of kitchen waste. In the period of the reaction, the content of butyric acid was higher than that of the other five acids, accounting for 25% of the total organic acid content, the content of propionic acid was relatively low, accounting for 11% of the total organic acid content Butyric acid almost no change, accounting for 14.4% of the total organic acid content, acetic acid content accounting for 18.2% of the total organic acid content.

During the adaptive period, the concentration of organic acids showed an upward trend. At the start-up period, the concentration of organic acids was increased. In the inhibition period, the concentration of organic acids was relatively high due to the near-stagnation of the experimental reaction, resulting in the accumulation of organic acids. At recovery and stabilization period, the experimental reaction gradually recovered, the organic acid accumulated in the inhibition period began to be decomposed, the concentration of organic acid showed a downward trend, although the concentration of organic acid fluctuating, but always maintained within a certain range, dry fermentation reaction stable operation.
Figure 4. Variation trend of VFAs concentration

4. Conclusions
According to the data obtained after the experiment and the results show that the anaerobic digestion reaction of the kitchen waste can be divided into four periods: the adaptation period, the start-up period, the inhibition period, the recovery period and the stabilization period. Each period due to the different amount of feeding to show a different gas production and gas production rate.

pH has a significant effect on the gas production, VFAs and so on during the dry fermentation of kitchen waste. The pH is too low and the gas production during the reaction will be relatively low. When the pH is adjusted, the gas production will be improved obviously, the concentration of VFAs will decrease, the ammonia concentration will increase and TS will gradually increase.

The concentration of VFAs and gas production showed a negative correlation. During the reaction, organics in kitchen waste began to be hydrolyzed to produce small molecules of VFAs. As the reaction proceeded, more and more VFAs were produced. Anaerobic digestion of methanogenic bacteria decomposed VFAs to produce gases and increase gas yields, VFAs concentration decreased. During the inhibition period, the activity of anaerobic bacteria was inhibited, and the accumulation of
VFA\textsuperscript{s} was accumulated and the gas production was less. During the recovery and stabilization period, the bacterial activity began to increase, and the accumulated VFA\textsuperscript{s} was decomposed, and the concentration of VFA\textsuperscript{s} began to decrease, and the gas production increase. After the reaction is stable, VFA\textsuperscript{s} concentration and gas production are relatively stable, fluctuating within a small range. Volatile fatty acids while generating side decomposition, at a lower concentration value, gas production is relatively high.

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