Experimental studies of obtaining biogas from waste of meat processing enterprises

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Abstract. A promising direction for the development of gas supply systems in rural areas is the production and use of biogas. In the developed countries of the world, biogas production and use systems are widely used. The amount of biogas produced depends on the type and chemical composition of the feedstock. The aim of this work is to study the dependence of the specific yield and chemical composition of biogas on the type of substrate used and the temperature of biomass in the digester. Waste from meat processing enterprises was used as an initial substrate for research: technical fat; intestines; bird blood; pulp. Two temperature settings were chosen for the study: 38 °C and 42 °C. As a result of the studies, the values of the optimal duration of fermentation of the studied types of substrate were determined: bird blood - 21 days, pulp - 25 days, intestines - 25 days, technical fat - 40 days. It has been established that the maximum value of the specific yield of biogas is observed during the fermentation of technical fat - 1509.8 l/kg, and the smallest from bird blood - 833.4 l/kg. At the same time, the highest methane content is observed during fermentation of technical fat - 66%, and the smallest from bird blood - 53.5%. It was also found that the biogas yield at a fermentation temperature of 42 °C is 7-8% higher than the biogas yield obtained at a temperature of 38 °C.

1. Introduction

At present, the level of gasification in the Russian Federation is 68.5%, including 72% in cities and urban-type settlements, and 59.2% in rural areas. At the same time, in all regions of the country, there is a lower level of gasification in rural areas compared to cities [1].

A promising direction for the development of gas supply systems in rural areas is the production and use of biogas in centralized gas supply systems. In the developed countries of the world, biogas production and use systems are widely used. The leaders in terms of the volume of biogas produced are China, Germany, Finland and Great Britain [2-4].

In operating biogas plants, waste from livestock, poultry and plant growing enterprises is often used as an initial substrate [5, 6]. The volume and composition of the produced biogas depend on the chemical composition of the type of substrate, namely on the content of proteins, fats and carbohydrates. It is known that the greatest amount of biogas is released during anaerobic fermentation of fats [7, 8]. A promising direction of use as initial substrates is the use of wastes from meat processing enterprises, which contain a large amount of fat [9-11]. At the same time, the waste of meat processing enterprises is often used as part of cosubstrates with other organic waste (manure, grass,
fruits and vegetables). This allows you to get more methane than the fermentation of one type of substrate [12-14].

Also an important factor influencing the efficiency of the biogas production process is the temperature of the biomass in the digester. It is known [15, 16] that the process of anaerobic fermentation of wastes from meat processing enterprises is more stable, and the biogas yield is higher in the mesophilic temperature regime, as compared to the thermophilic regime.

The aim of this work is to study the dependence of the specific yield of biogas and its chemical composition on the type of substrate used and the temperature of the biomass in the digester.

2. Materials and methods
Waste from meat processing enterprises of the Belgorod region was taken as the initial substrate for research:
- Technical fat;
- Intestines;
- Bird blood;
- Pulp.

Two temperatures were chosen for the study: 38 °C and 42 °C.

At the first stage of the experiment, the dry matter content in the original substrates was determined (Table 1).

| Name of substrate | The mass of ceramic crucibles, kg | Moisture W,% | Dry matter DM,% |
|-------------------|---------------------------------|-------------|----------------|
| Empty, m₁         | With initial substrate, m₁      | With dried substrate, m₂ | |
| Technical fat     | 52.65                           | 91.15       | 90.92          | 0.60 | 99.40 |
| Intestines        | 52.65                           | 91.15       | 92.47          | 62.73 | 74.49 | 25.31 |
| Bird blood        | 52.65                           | 98.45       | 60.82          | 82.17 | 74.53 | 17.83 |
| Pulp              | 52.65                           | 94.95       | 63.04          | 75.43 | 24.57 |

The study of the biogas production process was carried out on an experimental plant with a digester with a volume of 150 liters. The experimental setup is shown in Figure 1. The installation consists of a digester, a gas holder, devices for heating and mixing biomass, and instrumentation. The digester contains a mixing and heating system, a pipe for supplying the initial substrate, a pipe for draining biomass, and a pipe for removing the resulting biogas [17].

The main indicator of the biogas production process is the specific biogas yield, measured in liters per kilogram of dry matter (DM). When assessing the chemical composition of biogas, the main indicator is the percentage of methane and carbon dioxide.

Specific biogas yield is determined by the formula $V$ (l/kg):

$$ V = \frac{V_B}{m \cdot DM} $$

where $V_B$ – the volume of biogas produced, l; $m$ – the mass of the substrate, kg; $DM$ - dry matter content, %.

To determine the volume of biogas produced, a VK-G1.6T gas meter is used. The FP-34 gas analyzer is used to determine the chemical composition of biogas. This type of equipment is a portable measuring device for continuous monitoring of CH4 and CO2 concentration.

The moisture content of the substrate is determined by the formula:

$$ W = m_1 - m_2 \right m_1 - m_3 $$

(2)
where $m_1$ – is the mass of crucibles with the initial substrate, kg; $m_2$ – is the mass of crucibles with dried substrate, kg; $m_3$ – is the mass of crucibles without substrate, kg.

![Figure 1](image_url)

**Figure 1.** The experimental setup: 1 - branch pipe for loading the initial substrate; 2 - biomass discharge branch pipe; 3 - anaerobic digester; 4 - bubbling pipeline; 5 - temperature regulator; 6 - thermometer; 7 - biogas outlet branch pipe; 8 - manometer; 9 - ball valve; 10 - compressor; 11 - electric motor; 12 - pressure regulator; 13 - gas supply pipeline for mixing biomass; 14 - biogas purification filter; 15 - gas meter; 16 - gas holder.

To determine the moisture, empty dried ceramic crucibles were taken and weighed. Then, the crucibles filled with the substrate were placed in a drying cabinet at a temperature of 106 °C for 4 hours. Next, the crucibles with the dried substrate were re-weighed.

The dry matter content was determined from the moisture:

$$DM = 100 - W.$$  \hspace{1cm} (3)

To determine the mass and moisture of the raw materials, laboratory electronic scales NVT6401 / 2 and drying cabinet IIIC-80-01 were used.

3. Results and discussion

3.1. Technical fat

The results of studying the specific yield and composition of biogas depending on the temperature and duration of fermentation of technical fat are presented in Figure 2 and Figure 3.
Figure 2. Graph of dependence of biogas yield on the duration of fermentation of technical fat.

Figure 3. Graph of dependence of biogas composition on the duration of fermentation of technical fat.

From Figure 2, the maximum daily values of biogas yield are observed from 1 to 41 days of the experiment, which is 93% of the total biogas yield. At the same time, the total biogas yield obtained at a temperature of 42 °C was 1509.8 l / kg, which is 7.77% more than at a temperature of 38 °C (1400.9 l / kg).

Analysis of the chemical composition of biogas shows (Figure 3) that the methane content has maximum values in the period from 1 to 41 days of the experiment, then a drop in the methane content is observed. At the same time, the maximum methane value was recorded on day 34 at 38 °C and on 21 days at 42 °C, and are 68.8% and 69.2%, respectively. The average methane content at 42 °C was 67.4%, and at 38 °C - 66%. Thus, we can conclude that the optimal duration of fermentation of technical fat is a period of 40 days.

3.2. Intestines
The results of the study of the specific yield and composition of biogas depending on the temperature and duration of the experiment of anaerobic fermentation of the intestines are presented in Figure 4 and Figure 5.

Figure 4 shows that the maximum daily readings of biogas yield are observed from 1 to 25 days of the experiment, which is 73% of the total biogas yield. In this case, the total yield of biogas obtained at a temperature of 42 °C was 1091.7 l / kg, which is 8.22% more than at a temperature of 38 °C (1008.8 l / kg).

Analysis of the chemical composition of biogas shows (Figure 5) that the methane content has stable values from 1 to 25 days, then a drop in the methane content is observed. At the same time, the maximum value of methane at temperatures of 38 ° C and 42 ° C for 21 days is 64.9% and 65.5%,
respectively. The average methane content at 42 °C was 62.7%, and at 38 °C - 61.5%. Thus, it can be concluded that the optimal duration of gut fermentation is 25 days.

3.3. Bird blood
The results of the study of the specific yield and composition of biogas depending on the temperature and duration of the experiment of anaerobic fermentation of bird blood are presented in Figure 6 and Figure 7.

![Figure 6](image1.png) **Figure 6.** Graph of the dependence of biogas yield on the duration of fermentation of bird blood.

![Figure 7](image2.png) **Figure 7.** Graph of the dependence of the biogas composition on the duration of fermentation of bird blood.

Figure 6 shows that the maximum daily readings of biogas yield are observed from 1 to 21 days of the experiment, which is 84% of the total biogas yield. At the same time, the total biogas yield obtained at a temperature of 42 °C was 833.4 l/kg, which is 7.94% more than at a temperature of 38 °C (772.1 l/kg).

Analysis of the chemical composition of biogas shows (Figure 7) that the methane content readings have stable values from 1 to 21 days, then a drop in the methane content is observed. At the same time, the maximum value of methane was recorded at temperatures of 38 °C and 42 °C on the 6th day, and is 60.6% and 62.0%, respectively. The average methane content at 42 °C was 54.8%, and at 38 °C - 53.3%. The absolute difference in methane yield at different temperature conditions was 1.5%. Thus, it can be concluded that the optimal fermentation period for bird blood is 21 days.

3.4. Pulp
The results of the study of the specific yield and composition of biogas, depending on the temperature and duration of the experiment of anaerobic fermentation of pulp are presented in Figure 8 and Figure 9.

![Figure 8](image3.png) **Figure 8.** Graph of the dependence of biogas yield on the duration of pulp fermentation.

![Figure 9](image4.png) **Figure 9.** Graph of the dependence of the biogas composition on the duration of pulp fermentation.
Figure 8 shows that the maximum daily readings of biogas yield are observed from 1 to 25 days of the experiment, which is 80% of the total biogas yield. At the same time, the total biogas yield obtained at a temperature of 42 °C was 1292.2 l/kg, which is 8.21% more than at a temperature of 38 °C (1194.1 l/kg).

The analysis of the chemical composition of biogas shows (Figure 9) that the methane content is stable from 1 to 25 days, then a drop in the methane content is observed. At the same time, the maximum methane value was recorded at temperatures of 38 °C and 42 °C on the 6th day, and is 64.7% and 65.7%, respectively. The average methane content at 42 °C was 63.7%, and at 38 °C - 61.7%. The absolute difference in methane yield at different temperature conditions was 2.0%.

Thus, it can be concluded that the optimal duration of pulp fermentation is 25 days.

4. Summary
Experimental studies of the biogas production process were carried out on an experimental installation with a digester volume of 150 liters. The nature of the influence of the process temperature on the specific yield and chemical composition of biogas during anaerobic fermentation of wastes from meat processing enterprises in a mesophilic temperature regime has been established. Specific biogas yield at a fermentation temperature of 42 °C is 7 ... 8% higher than the biogas yield obtained at a temperature of 38 °C. It should be noted that the process of biogas evolution at 42 °C stops 5 days earlier.

Graphical dependences of the specific yield of biogas and methane content on the duration and temperature of the fermentation process were obtained. It was found that the highest value of the specific yield of biogas is observed during the fermentation of technical fat - 1509.8 l/kg, and the lowest from bird blood - 833.41 l/kg. At the same time, the highest methane content is observed during fermentation of technical fat - 66%, and the smallest from bird blood - 53.5%.

The values of the optimal duration of fermentation of the studied types of substrate have been determined. The shortest duration is characterized by bird blood - 21 days, and the greatest duration is technical fat - 40 days. Duration of fermentation of pulp and intestines is 25 days.

The results obtained on the biogas yield and methane content showed that the wastes of meat processing enterprises are good sources of biogas with a high methane content. These data allow us to conclude that it is advisable to widely use waste from meat processing enterprises to obtain an alternative source of energy - biogas.

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