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BIOGAS PRODUCTION FROM BAKERY WASTES – DYNAMICS, RETENTION TIME AND BIOGAS POTENTIAL

Summary

This paper presents results of bakery-waste methane-fermentation. The scope of the study covers the determination of basic physicochemical parameters, process dynamics and retention time as well as biogas composition and biogas efficiency. Methane fermentation process was carried out in accordance with German Standard DIN 38414 S8 and under condition of 38°C. Conclusion: bakery wastes have big potential for biogas production.
***Key words**: biogas, methane fermentation dynamics, bakery wastes*

PRODUKCJA BIOGAZU Z ODPADÓW PIEKARNICZYCH – DYNAMIKA, CZAS RETENCJI I POTENCJAŁ BIOGAZOWY

Streszczenie

W artykule przedstawiono badania dotyczące możliwości wykorzystania odpadów piekarniczych w kierunku produkcji biogazu. Zakres badań obejmował określenie podstawowych parametrów fizykochemicznych, dynamiki procesu oraz czasu retencji, składu biogazu oraz ilości otrzymanego biogazu. Badania fermentacji metanowej prowadzono w temperaturze 38°C zgodnie z Niemiecką Normą DIN 38414 S8. Odpady piekarnicze mają duży potencjał biogazowy i stanowią cenny substrat do produkcji biogazu.
***Słowa kluczowe**: biogaz, dynamika procesu fermentacji, odpady piekarnicze*

1. Introduction

Overproduction of food and appearance of resulting biowastes can motivate us, in the context of Directive of the European Parliament 2009/28/EC (“3x20”), to their utilization for energy production.

Bakery wastes are an interesting substrate for biogas production. Approximately 170.000 Mg of bakery products produced each year in Poland, are classified as waste. In accordance with current law, bread that is returned back to bakery and those that have left the area of bakery, should be excluded from secondary processing due to sanitary-epidemiological reasons [1, 2]. During storage of bakery products, various physical and chemical changes occur, including changes in taste, aroma, water absorption or starch content, commonly called choking, which affect negatively sensory properties of bakery products. Bread is characterized by a relatively high energy value, which depends on composition. It contains between 50-60% of carbohydrates, including up to 5% of simple sugars and disaccharides – the vast majority of which is sucrose. The protein content of bread ranges from 4-10%, while fat content is 1-5%. So, expired bakery products can potentially be used for biogas production in biogas plants.

In the literature, there is some information about biogas yields from bakery wastes under laboratory conditions. The processes utilized various temperatures from mesophilic range: 37°C for fermentation of pastry wastes, sweet creams and other bakery residues, 36.5°C for bread, which passed its expiration date, 33°C for wheat roll, bread and jam donut and 30°C for whole wheat bread [3–7]. It is not clear what exact procedure was used for the fermentation process; only one research team mentioned DIN 38414 S8 [7]. Bakery wastes are also a component in organic fraction of municipal solid wastes [5, 8]. There is not much information about biogas yield, dynamics of methane fermentation and retention time of such substrates under laboratory conditions according to DIN 38414 S8 (i.e. 38°C).

The main objective of this paper is to analyze the potential of using bakery wastes for methane fermentation and to compare the results obtained with available data. The scope of conducted research included physical and chemical analysis of bakery wastes, determination of methane fermentation dynamics and retention time and determination of biogas yield and composition.

2. Materials and methods

The studies were conducted in the Biogas Laboratory of the Institute of Fluid-Flow Machinery Polish Academy of Sciences in Gdansk. The experiments related to biogas production were carried out in accordance with German norm DIN 38414 S8 and biogas guidance issued by Association of German Engineers in Dresden VDI 4630, while physicochemical analyses of substrates were based on Polish Standards.

2.1. Substrate and inoculum

The substrates used for biogas production were purchased from one of the Gdansk bakeries. The study used bakery waste such as wheat bread, wheat roll, rye bread and bun (sweet roll). In preparation for the experiment, stale bakery-wastes were crushed in a laboratory mill. Inoculum was taken from an agricultural biogas-plant working under mesophilic conditions using maize silage and cow slurry.

2.2. Experimental set-up and procedure

Before fermentation, substrates and inoculum were analyzed to determine dry matter (TS) and organic matter content. Determination of these parameters is necessary to calculate the biogas production efficiency (ratio of produced biogas volume and substrate weight - $m^3 \cdot Mg^{-1}$ of dry organic matter (VS)). The pH was measured using Elmetron set-up.

The fermentation process was carried out in a set-up consisting of 15 fermenters of about 2 dm^3 capacity. The appropriate amount of substrate and inoculum were placed in the reactors, then purged with nitrogen to create anaerobic conditions for biogas production and placed in a water container with regulated temperature (38±2°C). The biogas produced in each digester was transferred to a separate cylinder filled with barrier liquid. All experiments were performed in triplicate together with a control sample.

The biogas volume was measured every day, while the gas composition was checked, when at least 0.5 dm^3 of biogas was produced. The biogas composition was measured using a gas analyzer (GA 5000). The analyzer enables the detection of gaseous compounds in various ranges: 0-25% O_2, 0-100% CO_2, 0-100% CH_4, 0-1000ppm H_2 and 0-5000 ppm H_2S. Calibration of the analyzer was performed before the experiment.

The fermentation process was conducted until the daily biogas production was less than 1% of its previous total production.

3. Results and discussion

Before fermentation, chemical and physical parameters of biowastes related to wheat rolls, bread, rye bread and bun have been analyzed. As it is shown in Table 1, organic matter content (VS) for all substrates was high, over 96%, which confirms the data known from literature [4, 5]. The considered substrates are characterized by similar acidity, with acid level, pH ~ 5.3-6.0.

Table 1. Physical and chemical parameters of substrates
Tab. 1. Parametry fizykochemiczne substratów

Substrate	pH	VS [% TS]
wheat roll	6.02	97,45
wheat bread	5.63	97,14
rye bread	5.36	96,52
bun	5.7	97,53

Source: own work / Źródło: opracowanie własne

The methane fermentation processes proceeded smoothly, without any disturbance. Results of cumulative methane production, biogas efficiencies and methane concentrations obtained for the considered bakery wastes are presented in Table 2 and Figure 1.

One sees in Table 2 that the highest methane and biogas yields from 1 Mg of dry organic matter were obtained for bun wastes, respectively 666 and 1283 m^3. Results obtained for other bakery wastes are lower than for bun; 36-46% and 33-38%, respectively for methane and biogas yields. Most agricultural substrates have lower biogas efficiencies [9]. Much better results of cumulative biogas, methane and its concentration for bun wastes are due to the higher content of carbohydrates and fats. The results obtained for cumulative methane production during the experiments are in good agreement with data [3], for fermentation performed at 37°C.

Table 2. Cumulative biogas and methane production from bakery wastes
Tab. 2. Skumulowana produkcja biogazu i biometanu z odpadów piekarniczych

Substrate	Methane content [%]	Cumulative methane [$m^3 \cdot Mg^{-1}VS$]	Cumulative biogas [$m^3 \cdot Mg^{-1}VS$]
wheat roll	47,7	400,6	839,3
wheat bread	45,8	359,1	784,2
rye bread	48,9	420,2	859,6
bun	52,1	666,8	1283,5

Source: own work / Źródło: opracowanie własne

The highest concentration of methane in biogas was observed for bun wastes (52%). This was 6-13% more than for rolls and bread; the average concentration of methane in biogas for all bakery wastes was 49%. The results obtained during experiment under process temperature 38°C are significantly lower than results in experiment conducted at 33°C (61% methane in biogas) [7]. There was no information whether or not the biogas barrier was used. During the experiment very high H_2S content in biogas was observed from 2100 to almost 5000 ppm. Kafle et al. [4] also observed a high concentration of hydrogen sulphide in range 900-3270 ppm.

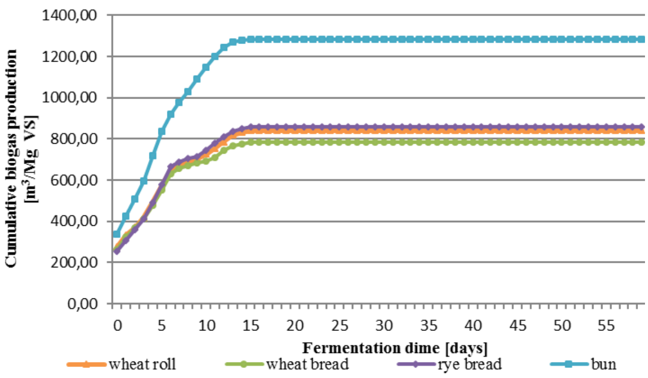

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Fig. 1. Cumulative biogas production from bakery wastes [$m^3 \cdot Mg^{-1}$ VS]
Rys. 1. Skumulowana produkcja biogazu z odpadów piekarniczych [$m^3 \cdot Mg^{-1}$ VS]

Dynamics of fermentation process for one of the substrates – bun – is shown in Figure 2. During the fermentation under mesophilic conditions one distinctive peak of biogas production was observed at Day One of digestion; this indicates hydrolysis of simple compounds. The collapse of biogas production between 6th and 9th day may indicate a process inhibition. The multiple local peaks are due to digestion of complex compounds. The dynamic of methane fermentation for other bakery wastes are very similar.

Complete methane fermentation process for all substrates was achieved in 15-16 days (Table 3). After 6 days of digestion process the mean cumulative methane was about 46%, while after 12 days this value was about 85%. The fermentation time is shorter compared with literature data [7] due to higher temperature process.

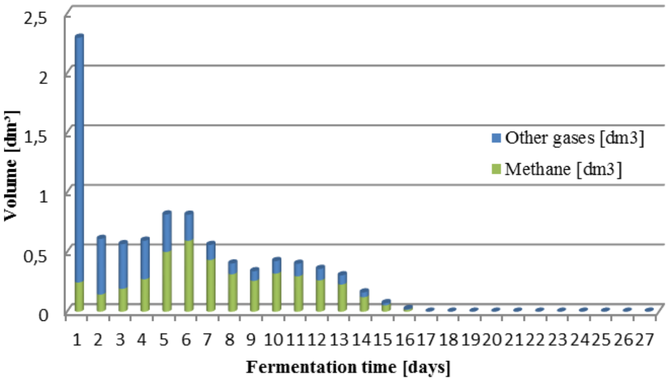

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Fig. 2. Dynamics of methane fermentation process of bun
Rys. 2. Dynamika fermentacji metanowej na przykładzie drożdżówki

Table 3. Retention time of bakery wastes
Tab. 3. Czas retencji odpadów piekarniczych

Substrate	Retention time (HRT) [days]	Cumulative metane [%] after 6 days	Cumulative methane [%] after 12 days
wheat roll	16	45,2	82,8
wheat bread	16	47,6	83,8
rye bread	16	46,7	85,8
bun	15	45,8	90,1

Source: own work / Źródło: opracowanie własne

4. Conclusions

In this work anaerobic digestion of bakery wastes was studied. The results obtained for mesophilic conditions (38°C) have to be considered as a preliminary data. They indicate the anaerobic biodegradability of bakery wastes.

Based on conducted research, the following conclusions should be underlined:

1. Stale bakery wastes related to: wheat bread, rolls, rye bread and buns, can be valuable substrates for biogas production in biogas plants.
2. Substrates used in the experiments have good biogas efficiency (even above 1280 $m^3 \cdot Mg^{-1}VS$), which is higher than that for most agricultural substrates. This is especially the case for sweet bakery wastes, e.g. buns.
3. Methane concentration in biogas is not too high (up to 52%).
4. Bakery wastes, due to their ready availability, may be a valuable high energy substrate in co-fermentation process.

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