Biogas Production through Anaerobic Digestion of some Agro-Industrial Residues

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Biogas production from vagetables residues is of growing importance because it could offer an important additional source of fuel gases. The study presented in this paper was carried out on anaerobic digestion of damaged corn kernels and wheat bran in a biogas pilot plant under mesophilic temperature conditions. In order to ensure process stability and consequently a good rate of digestion and a high biogas production (CH_4 and CO_2), the system temperature and its pH have been monitored and maintained at acceptable levels over 65 days of retention time period. Conclusions were taken over the obtained results in terms of quality and quantity of the produced biogas with consideration of the cereal substrate potential under the used technology.

Keywords: biomass, anaerobic digestion, biogas, methane yield

According to European Renewable Energy Directive (2009/28/CE) [1], 20 % of the final energy consumption has to be provided by renewable sources by 2020 [2,3]. Under the framework of this Directive, biogas industry has aroused a particular attention, gradually leaving its basic activities of waste cleanup and treatment and getting involved in energy production.

The term “biogas” incorporates all gas produced from organic matter under anaerobic conditions. There are three major biogas production channels: landfills (35.9% of production), urban wastewater and industrial effluent treatment plants (12.1%) and purpose-designed energy conversion methanisation plants (anaerobic digesters) (52%). The latter include methanisation units on farms that generally convert slurry, crop residues and increasing quantities of energy crops; food-processing industry methanisation plants; solid waste methanisation plants that specialize in household waste treatment and green waste; and multi-product methanisation plants [4].

There are four fundamental steps of anaerobic digestion that include hydrolysis, acidogenesis, acetogenesis, and methanogenesis. In the absence of oxygen various types of bacteria break down the feedstock to form a burnable gas which mainly consists of methane and carbon dioxide. The biogas also contains small amounts of hydrogen sulphide and other sulphur compounds, siloxanes, aromatic and halogenated compounds.

The speed of the digestion process and the composition of the biogas are influenced by the composition of the used feedstock [5-7]. Thus, biogas from sewage digesters contains 55 – 65 % CH_4, 35 – 45% CO_2 and the biogas from organic waste digesters contains 60 – 70 % CH_4, 30 – 40% CO_2. In landfills, biogas contains 45 – 55 % CH_4 and 30 – 40 % CO_2 [8].

Biogas can be used to generate electricity, heat and biofuels. The secondary product, fermentation residue (digestate) can be used as fertilizer.

The largest biogas producing countries in the EU are Germany and UK. These countries produce around 2/3 of EU biogas utilised as energy. In 2009, European primary energy production from biogas has increased with 4.3% comparing to 2008 [4, 9]. The literature data concerning concrete biogas production is very diffuse, with important lacking.

The aim of this study was to provide data about the biogas production and the methane yield from two different substrates: wheat bran and damaged corn kernels.

Experimental part

Substrates

Wheat bran and damaged corn kernels were used as substrates. The general characteristics of these substrates are given in table 1.

The substrates were stored at room temperature until further use.

Table 1
MAIN FEEDSTOCK PARAMETERS

No.	Substrates	Humidity [%]	Ash content [%]	Lower heating value [kJ/kg]	Carbon content (C) [%]	Nitrogen content (N) [%]	C/N
1	Damaged corn kernels	13.91	1.88	14488	46.58	0.47	99.1
2	Wheat bran	10.1	4.35	15400	45.04	0.51	88.3

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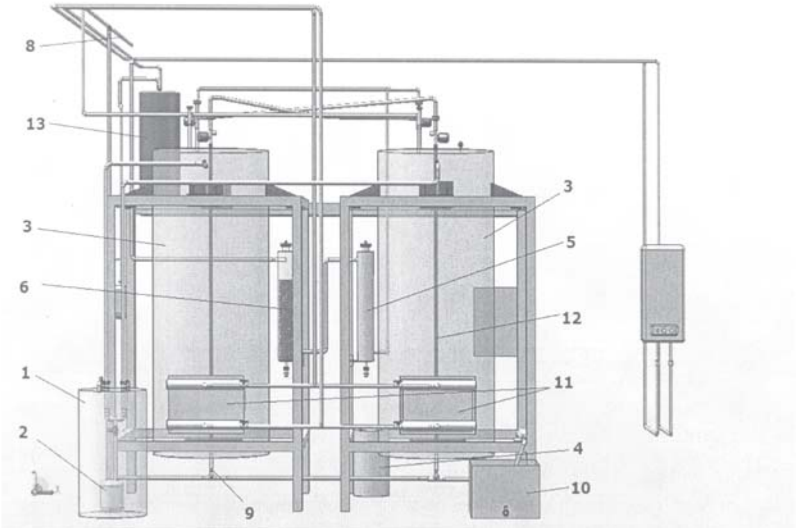

Fig. 1. Schematic configuration of pilot plant used to produce biogas from biomass

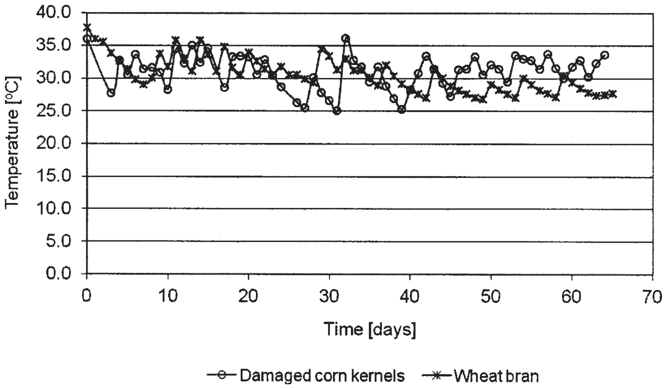

Fig. 2. Temperature dynamics during anaerobic digestion process

Description of pilot plant

The pilot plant used for producing biogas from biomass through anaerobic digestion is presented in figure 1.

From the biomass deposit, the used material is passed through a mill, and then it is sent to the tank where the preparation of the suspension of biomass is made (1). The biomass suspension is transported with the help of the pump (2) and introduced into the fermentation reactors (3). The correction agent tank for the *p*H assures, through the control system, the conditions for the process of anaerobic fermentation. The resulted biogas is passed through a filter for retaining the H_2S (5) and after that, through a system used for retaining CO_2 (6). The CO_2 saturated liquid is treated for CO_2 desorption and its compression in an adjacent system. The purified biogas is sent for being used (8). The used material is discharged through the means of a gravimetric system (9), and the solid material is retained for being dried using the natural drying, and after that is sent to a compost deposit for being used as a soil fertilizer. A part of the resulting liquid is neutralized when the case, in the system (10) and sent to the sewerage network, or is transported by the recirculation pump (2) from the suspension preparation tank (1). The fermentation reactors are thermostat heated with the system (11). For the homogenization of the suspension is used a bubbling system (12) made by polypropylene pipes to avoid the possible corrosion. Also, for depositing small quantities of biogas for the purpose of analyzing, the installation is equipped with a small tank (13) positioned at the top of the reservoirs.

The reactors were feed at the beginning of the experiment with approximately 75 kg dry biomass and 2000 L water. Biogas production was measured daily, the pressure difference being dropped with the help of a semi-automated system and after wards through a gas counter. Methane (CH_4) and carbon dioxide (CO_2) compositions (v/v) were measured using a Delta 1600 IV gas analyzer. Temperature and *p*H were also continuously measured online.

Results and discussions

Anaerobic digesters can operate at psychrophilic (cryophilic), mesophilic or thermophilic temperature. The anaerobic digestion temperature has an important role on the gas yield and methane content due to active microbial communities which are different from one temperature range to another. Studies of different temperature conditions have conflicting results [10, 11].

The temperature dynamics during anaerobic digestion process of two studied substrates is presented in figure 2.

The evolution of temperatures presented in figure 2, indicates a two stage regime (mesophilic and cryophilic) for both substrates. These variations were chosen in order to better observe the general behaviour from the point of view of biogas production in time related with the used domain of temperature.

It can be observed the temperature input on a relatively periodically basis varies from values of 25 – 26 °C to 35 – 37 °C, with an average value of 30 – 31°C, a value situated in the range of mesophilic regime.

Another parameter that has a great influence on the anaerobic digestion is the *p*H. The ideal *p*H range for anaerobic digestion is in the range 6.8 – 7.4. Fresh waste must go through acidogenesis and acetogenesis stages before methane formation can begin. This results in an initial dip in *p*H levels, which can be easily combated with the addition of bicarbonate alkalinity to buffer the system. The optimum *p*H of hydrolysis and acidogenesis has been reported as being between 5.5 and 6.5, while the optimal *p*H of methanogenesis is around 7.0 [11]. The *p*H dynamics during anaerobic digestion process is presented in figure 3. The *p*H state presented in the figure indicates a time evolution from acid values in the first part of the process, characteristic to the acid hydrolysis, to neutral values with peaks for alkaline values related to the corrections made using dosing pumps for the damaged corn kernels. It can also be observed that the time evolution for the wheat bran batch is more linear, indicating a good behaviour relative to the indicated temperature regime and

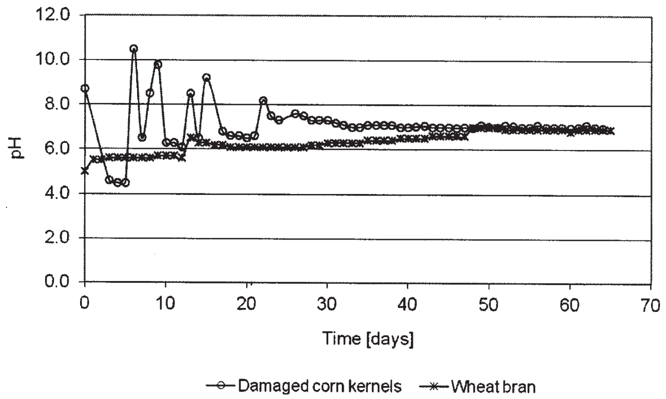

Fig. 3. The pH dynamics during anaerobic digestion process

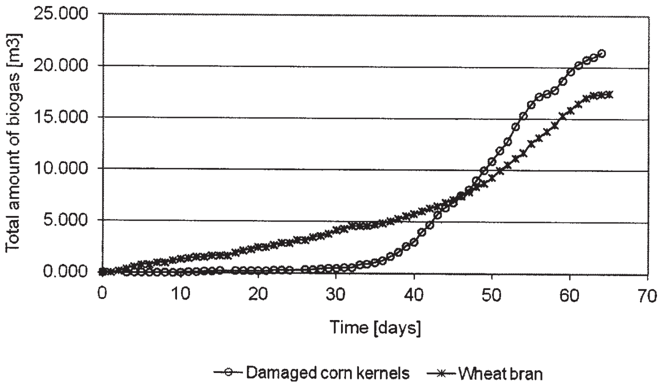

Fig. 4. Cumulative biogas production

Table 2
BIOGAS YIELDS DURING ANAEROBIC DIGESTION OF THE STUDIED SUBSTRATEs

No.	Substrates	Digestion time, [days]	Biogas yield, [m^3]	Biogas yield, [m^3/t DS]
1	Dameged corn kernels	65	21.878	291.707
2	Wheat bran	65	17.773	236.973

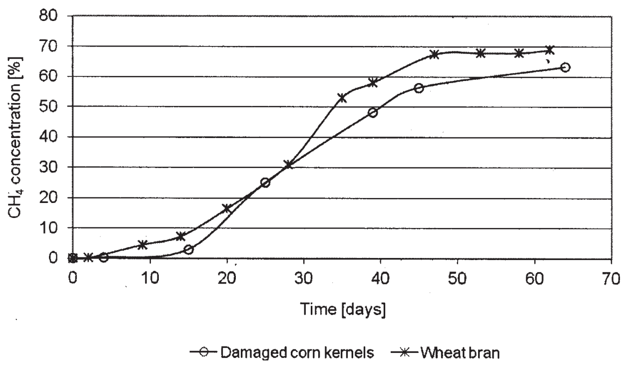

Fig. 5. Evolution of methane concentration in time for the two studied substrates

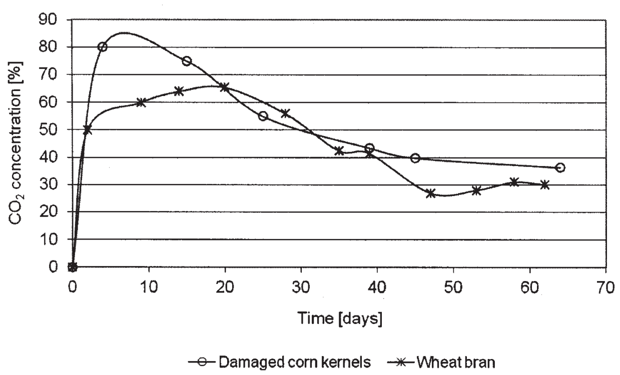

Fig. 6. Evolution of CO_2 concentration in time for the two studied substrates

biogas production in time.

The second part of the process is characterized by values in range of neutral domain, a good indicator for the process of methane production in the basic composition of biogas.

The cumulative biogas production through anaerobic digestion of two agro-industrial residues has been underlined in figure 4.

From the mentioned figure, it can been seen that biogas production from wheat bran increased progressively from day 3 till day 65 of digestion, while in the case of damage corn kernels the biogas production started after day 30. From that day till the end of the test, the biogas production rate was higher for damage corn kernels.

At the end of the digestion time, was revealed the fact that the corn kernels have a better behaviour inside the anaerobic digestion process related to the total produced biogas, that wheat bran (table 2).

For damaged corn kernels, a yield of 291.707 m^3 biogas per ton organic dry substance has been obtained, while for wheat bran, a 236.973 m^3 biogas per ton organic dry substance has been produced.

In figures 5 and 6, the methane and CO_2 variations in the biogas produced by anaerobic digestion of damaged corn kernels and wheat bran substrates are presented.

Related to the CH_4 evolution in time, it can be observed that wheat bran batch has a more abrupt evolution over time, with a maximum value of approximately 69% methane in the produced biogas.

The damaged corn kernels batch presents a slower time evolution than the wheat bran batch, with a maximum value of 62 – 63% in volume for the produced methane in the biogas general composition.

Connected with the methane time evolution, for both batches it can be observed that the CO_2 concentrations are decreasing accordingly, ranging from 28 – 31% for the wheat bran batch to 37 – 39% for the damaged corn kernels batch. The wheat bran batch had better results in terms of biogas quality over time raising the perspective of using the potential of a recipe between damaged corn kernels and wheat bran in order to obtain good quality biogas.

Conclusions

Biogas production by anaerobic digestion of agro-industrial residues, is a process with good answer to coupled energy and environmental requirements.

The experimental results outlined in the previous sections of this study have showed that damaged corn kernels and wheat bran are very suitable substrates for anaerobic digestion.

The cumulative biogas yield over 65 days of retention time period was found as 21.878 m^3 for damaged corn kernels and 17.773 m^3 for wheat bran anaerobic digestion meaning that the produced biogas by anaerobic digestion of dameged corn kernels was 23% higher than the biogas produced by anaerobic digestion of wheat bran. The observed values of methane concentration in the produced biogas from damaged corn kernels have showed a lower methane percentage than the produced biogas from wheat bran. That means that the quality of biogas produced by anaerobic digestion of wheat bran is better.

These findings have suggested that a combination of considered substrates could lead to a better biogas production from both qualitative and quantitative point of view.

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