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EXPERIMENTAL APPROACH REGARDING THE DEGRADATION PROCESS FOR DIFFERENT BIOMASS TYPES USING THE ANAEROBIC FERMENTATION

BY

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Abstract. The present study proposes to highlight the specific parameters for different varieties of biomass residues, both in terms of determining some of their main physical and chemical characteristics and in terms of behavior along the anaerobic fermentation process. Results related with the degradation mechanism are focused to indicating the general properties for the analysed materials (humidity content, ash content, Carbon and Nitrogen content, calorific value). First, a general description of the small-scale pilot built at the Mechanical Engineering Faculty of “Politehnica” University from Timişoara is given. The main purpose of the pilot is connected with analysing the behavior of the batches during the anaerobic fermentation process, the time variation of the main parameters that are to be considered, namely temperature and pH and detailed images of the material in different moments of the process, images obtained with the help of a binocular magnifier. Fig. 1 presents one of the analysed sorts of material, and Fig. 2 gives a detailed image of the material structure during the anaerobic fermentation process, connected with the degradation status.

Fig. 1 – Corn cobs.

Fig. 2 – Detail for the corn cob structure – 6×.

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The obtained conclusions in the paper will underline the importance of the used material, its general characteristics (Carbon/Nitrogen ratio is one of the most important parameter which is to be taken into consideration), the influence of the temperature regime and pH for the anaerobic fermentation and also observations related with the behavior of each material during the degradation process.

Key words: anaerobic fermentation; degradation, biomass.

1. Introduction

Current energy supplies in the world are dominated by fossil fuels (some 80% of the total use of over 400 EJ per year).

Nevertheless, about 10%...15% (or 45 ± 10 EJ) of this demand is covered by biomass resources (Faaij, 2006).

The use of renewable energy technologies would reduce the current global environmental problems as well as the national energy insecurity of a lot of countries related to the use of fossil fuels (Franco *et al*., 2005).

In rural areas of developing countries various cellulosic biomass (cattle dung, agricultural residues, etc.) are available in plenty which have a very good potential to cater to the energy demand, especially in the domestic sector (Yadvika *et al*., 2004).

Anaerobic digestion is the process of decomposition of organic matter by a microbial consortium in an oxygen-free environment (Ward *et al*., 2008).

The important processes in anaerobic digestion are: hydrolysis, fermentation, acetogenesis, and methanogenesis, where hydrolysis is subject to the fermentation process, while acetogenesis and methanogenesis are linked (Karellas *et al*., 2010).

The anaerobic digestion process is characterized by a series of biochemical transformations brought on by different consortia of bacteria.

Methane is produced by methanogenic bacteria from acetic acid, hydrogen and carbon dioxide and from other substrates of which formic acid and methanol are the most important (Fantozzi *et al*., 2009).

Next paragraph will underline the general presentation of the small scale installation and the materials which are to be taken into consideration during the experimental approach.

2. Materials and Method

In Fig. 3 is presented the schematics of the small scale installation built specifically for the study of the degradation process taken place for different sorts of biomass.

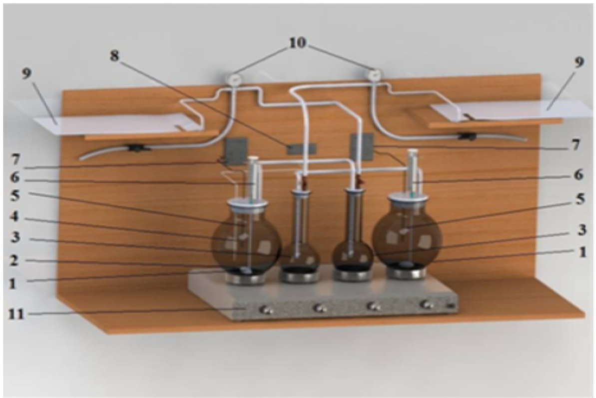

Fig. 3 – General schematics for the small scale installation; *1* – glass reactor with a total volume of 6 L; *2* – magnet place don the bottom of the 6 L glass reactors for magnetic stirring; *3* – small glass reactor for biogas washing with water, with a total volume of 500 mL; *4* – thermocouple; *5* – pH sensors; *6* – system for pH correction and sample collecting; *7* – pH controllers; *8* – temperature controller; *9* – gas bags for biogas samples; *10* – pressure gauges; *11* – heating system.

In Figs. 4,…,6 are presented the materials which are to be analysed in the paper.

Fig. 4 – Degraded rye.

Fig. 5 – Degraded two row barley.

Fig. 6 – Corn cobs.

In the figures above are presented the three types of material, the first two were analysed during the same batch of material and the third one (corn cobs) is to be used as a comparison material from the point of view of the aspect during the degradation process.

The presented results were made during a 30 day period of time, in order to observe the characteristics of the analysed material from the point of view of the general parameters (determined characteristics of material before the process, temperature, pH) and aspect during the degradation process.

3. Results

Before presenting the parameter variation during the anaerobic fermentation process, there are to be indicated some of the material general properties determined for each type of analysed biomass.

In Table 1 are presented the general properties of the analysed materials.

Table 1
General Properties for the Analysed Materials

No	Name	Water content %	Ash content (db), [%]	Carbon content (db), [%]	Nitrogen content (db), [%]	Net calorific value (db), [MJ/kg]
1	Two-row barley	13.0	3.7	45.19	2.18	16.6
2	Rye	12.9	2.9	45.74	1.82	16.8
3	Corn cobs	19.7	3.6	45.74	0.66	17.2

In Figs. 7 and 8 are presented the parameter variation (pH and temperature) for the batch with degraded two-row barley and degraded rye.

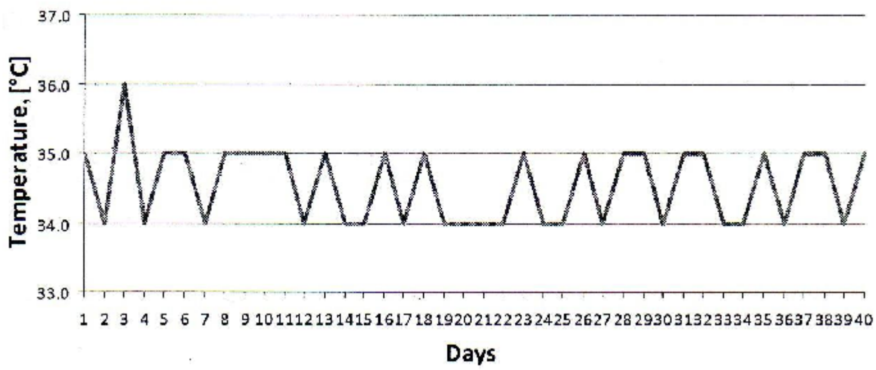

Fig. 7 – Temperature variation for two row barley and rye batches.

From Fig. 7 it can be observed that the temperature is compared between 34° and 36°C (mesophilic regime) with a peak involved at the value of 36°C and a general average value of about 35°C.

In Fig. 8 it can be observed that the pH variation is different for the two batches of material, with tendencies to low values (acid) in the first stage of the process, being needed the pH correction, and in the second part of the remaining time, the values tend to the neutral domain and are even slightly alkaline.

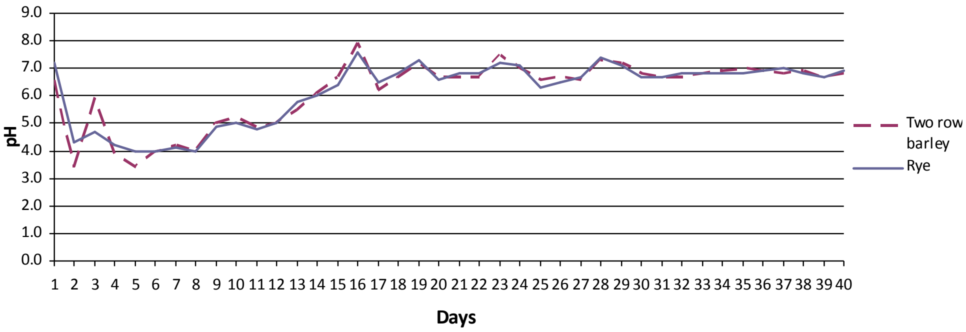

Fig. 8 – pH variation for two row barley and rye batches

In Figs. 9,…,16 are presented pictures of the degraded material from the two batches in different stages of the degradation process.

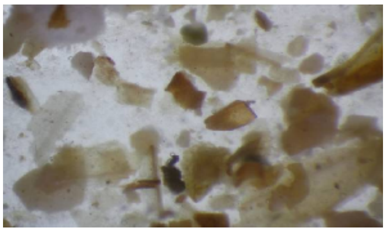

Fig. 9 – Degraded two row barley batch, 15 ×; first stage degradation.

Fig. 10 – Degraded rye batch, 15 ×; first stage degradation.

Figure 11 – Degraded two row barley batch, 20 ×; second stage degradation.

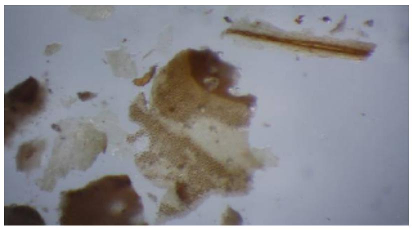

Fig. 12 – Degraded rye batch, 20 ×; second stage degradation.

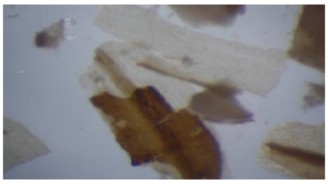

Fig. 13 – Degraded two row barley batch, 30 ×; third stage degradation.

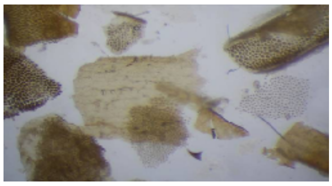

Fig. 14 – Degraded rye batch, 30 ×; third stage degradation.

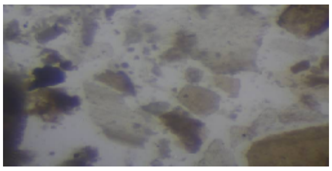

Fig. 15 – Degraded two row barley batch, 50 ×; fourth stage degradation.

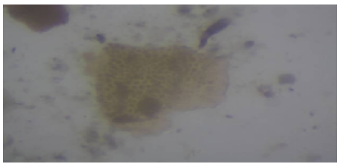

Fig. 16 – Degraded rye batch, 50 ×; fourth stage degradation.

In Figs. 17,…,20 are presented pictures of the general aspect of the corn cobs batch during the degradation process.

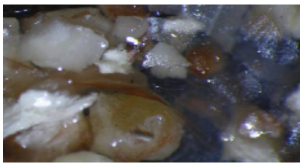

Fig. 17 – General aspect – corn cobs batch, 15 ×; first stage degradation.

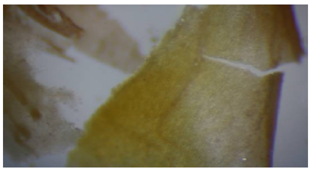

Fig. 18 – Corn cobs batch, 30 ×; second stage degradation.

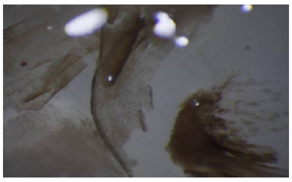

Fig. 19 – Corn cobs batch, 20 ×; third stage degradation.

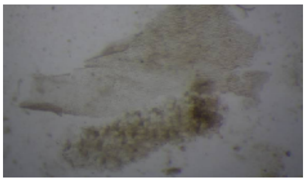

Fig. 20 – Corn cobs batch, 30 ×; fourth stage degradation.

In Figs. 17,…,20 is underlined the general evolution of the degradation process from the first stage where the material is not under the influence of the anaerobic bacteria until the last stage, where the process is developed in the entire mass of the batch.

4. Discussions

From the figures it can be observed the parallel degradation for the two different types of degraded agricultural biomass, from the first stage (Figs. 9

and 10), to the second stage where it can be observed the start of the degradation process on the surrounding surface of the batch material (Figs. 11 and 12), to the third stage of degradation in which the colour of the material starts to disappear and the process is extended in all the mass and it can be observed almost at cellular level (Figs. 13 and 14). In Figs. 15 and 16 it can be seen the detailed cellular structure of the material without colour and in an advanced stage of degradation. Also, for the corn cobs batch there can be observed the general process of degradation from the initial phase (Fig. 17) where the material is not degraded, after approximately 10 days, it can be observed that there are starting to appear degradation signs on the periphery part (Fig. 18), the colour of the material starts to disappear and there can be observed large portions of degraded material at cellular level (Fig. 19) and in the last stage studied there can be observed formations of bacteria on the degraded parts of exposed material and also the complete lack of colour (Fig. 20).

5. Conclusions

One of the usual ways of biomass capitalization is represented by the biogas production through different technologies, one of them being the anaerobic fermentation process.

One important factor that has to be kept in mind is the C / N ratio which represents an indicator of the potential for obtaining biogas from different types of material.

It can be observed that during the process, the pH variation, considering the same temperature domain, is different for each used material, being necessary to use correction liquid in order to bring the pH to a neutral level

After the 30 days period, the general aspect is without colour and there is presented large colonies of bacteria in different parts, as it can be seen in the detailed images.

As a general conclusion, the degradation process takes place at a relatively large scale for the used batches and also the specific odour presented during the last 10…15 days is a good indicator that the anaerobic fermentation takes place in good conditions.

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ABORDARE EXPERIMENTALĂ CONEXĂ CU PROCESUL DE DEGRADARE PENTRU DIFERITE TIPURI DE BIOMASĂ UTILIZÂND FERMENTAȚIA ANAEROBĂ

(Rezumat)

Biomasa este una dintre cele mai reprezentative resurse energetice din România. În paralel cu utilizarea resurselor convenționale trebuie găsite soluții bazate pe sisteme energetice conexe ca disponibilitate şi sustenabilitate. Prezentul studiu propune o evidențiere a parametrilor specifici pentru diferite sorturi de biomasă reziduală atât în termeni de determinare a unora din principalele caracteristici fizice şi chimice, cât şi în ceea ce priveşte comportarea în decursul procesului de fermentație anaerobă. Rezultatele legate de mecanismul de degradare sunt concentrate pe indicarea proprietăților generale ale materialelor analizate (conținut de umiditate, cenuşă, C, N, putere calorică). Mai întâi este prezentată o descriere generală a instalației de mici dimensiuni realizată în cadrul Facultății de Mecanică a Universității „Politehnica” din Timişoara. Scopul acesteia este acela de a analiza comportamentul şarjelor de material în timpul procesului de fermentație anaerobă, variația în timp a temperaturii şi pH-ului. De asemenea s-au obținut imagini detaliate ale materialului în diferite momente ale procesului de fermentație anaerobă cu ajutorul unui microscop.

Concluziile stabilite în lucrare subliniază importanța materialului utilizat, caracteristicile sale generale, influența regimului de temperatură şi pH-ului pentru fermentația anaerobă precum şi observații cu privire la comportarea materialului de-a lungul procesului de degradare.