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COMBUSTION TESTS FOR BIOGAS OBTAINED FROM ANAEROBIC DIGESTION OF ANIMAL PROTEINS

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Abstract: *The paper reviews the benefits that biogas obtained through anaerobic fermentation can bring to the renewable energy which is strongly demanded in the past years to be used on many application, even in industrial scale. In this context, the leather industry has an advantage due to the high content of protein that wastes contains and makes them feasible to support an anaerobic digestion with a good quality of the biogas. On the other hand, the combustion of biogas is also a direction that needs to be well studied in order to have an efficient process synchronised with energetic characteristics and the different burners and devices needed to reach the good configuration of parameters. There were carried out tests in kinetic and diffusive regime and the experimental results proved to be* *relevant and admitted the usage for the wastes with a high concentration of protein, such as the ones coming from tanneries .*

Keywords: *anaerobic digestion, biogas, combustion, methane.*

INTRODUCTION

Biogas, the main product of anaerobic fermentation, has become recently one of the most efficient solution for the waste issue. Leather industry, in its preparation processes such as fleshing, trimmings, cuttings and chips from hides, produces large amounts of wastes with a high content of animal protein which makes feasible the possibility to use an anaerobic digester in order to treat them.Thus, besides the economic aspect (the biogas is an important source of energy that can be very well used in the internal manufacturing processes), this solution comes in more ecologically friendly than the direct combustion. Two dominant components characterize the quality of the biogas: CH_4 and CO_2, gases which can be found in approximate values of concentrations. Statistically speaking, it has been shown that the typical values for methane per unit mass of biogas production vary between 50% and 73%, usually attained after a 14 weeks anaerobic digestion process, while after a 10 week process corresponds to a 40%. (Lăzăroiu G., Mihăescu L, Mavrodin M., Bondrea A., 2017)

All the researchers highlight the negative impact of CO_2 on the combustion performances. The proportion of CH_4 varies in the limits of CO_2 = 30-70%, nitrogen in the limits of N_2 = 1-7%, the rest until 100% being represented by the concentration of CO_2. Lower calorific values have spread through 16.500-21.500 kJ/m^3_N. Also, a high content of CO_2 leads to a decrease of the initial temperature in the flame, low values for the velocity combustion and gives more constraints for the air concentrations needed for lighting and extinction limits. (Mavrodin, M. Mocanu C.R., Lăzăroiu G., 2015)

In order to make a proper thermodynamic characterisation of the flame, has apperead the necessity to use a specific criterion R, defined as the volume ratio of CH_4 content to CO_2 from the fuel:

$$R = \frac{CH_4}{CO_2} \qquad (1)$$

This criterion is totally different by the C/O proportion, used by many reasearchers for fuels with big concentrations of CH_4, H_2 and CO. The C/O criterion considers the combustion of the CO component, but in the case of the biogas the CO_2 component does not participate to the combustion and has no influence over this proportion. Through combustion, the oxygen from CO component is recovered, while the oxygen coming from CO_2 is lost. Taking into consideration this, the R criterion is more appropriate to be used for the biogas obtained from anaerobic fermentation.

In this paper is studied the possibility to use the biogas obtained from an anaerobic digester feeded with wastes coming a tannery, along with a clear characterization of the combustion process and the positive impact that this solution gives to leather industry.

EXPOSITION

Methodology

The first tests were carried out using a Bunsen burner connected to the discharge pipe of the anaerobic digester, as it can be seen in Fig. 1. The biogas has been obtained from a pilot installation using in cascade (three steps) fermentation process. The quality of the biogas obtained is characterized by two dominant components, CH_4 and CO_2, gases which can be found in approximate values of concentrations.

These tests proved the possibility of usage in energetic purposes of the biogas, due to the facts that the flame was stable, with a blue colour appearence such as burning the methane with excess air (λ>1). Since the quantity of delivered biogas is small and its quality varies in time, in order to study more the phenomena, there was decided to continue the experiments using pressure cylinders with mixture of gases similar with the ones obtained from the anaerobic digester.

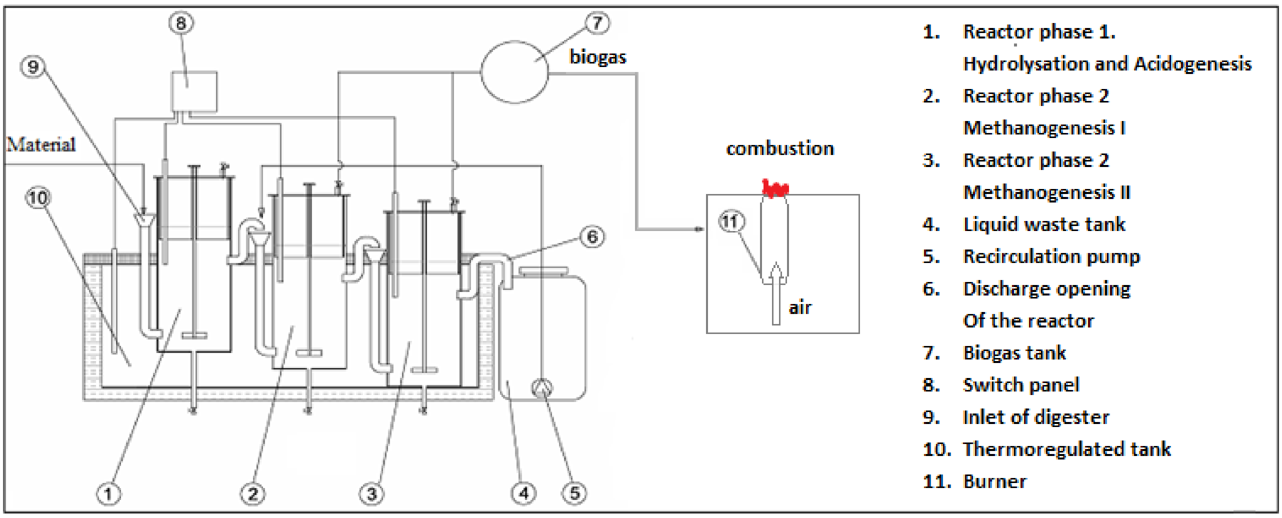


Fig.1. Burner position in the anaerobic fermentation site

Experiments were carried out with a gas prepared by Linde Company by blending in pressure cylinders a mixture of gases similar in concentrations with the one of the biogas obtained from the pilot plant of anaerobic fermentation.

There were prepared three versions of gas in order to have different CH_4 concentrations and give an image over the process evolution that supported two types of combustion: kinetic and diffusive. The highlighted cylinder from Table 1 has the most similar characteristics with average measurements of biogas obtained from the anaerobic digester.

Table 1. Biogas composition from the three pressure cylinders

	CH_4 [%]	CO_2 [%]	H_2 [%]	N_2 [%]	CH_4/CO_2 [%]	H^i_i [kJ/m^3_N]
Cylinder I	52	45	1	2	1.15	18 700
Cylinder II	60	32	1	7	1.87	21 550
Cylinder III	40	56	1	3	0.71	14 400

In order to be able to supply the burners, a two-stage pressure reducer head was fitted to the gas cylinder – fig. 2.

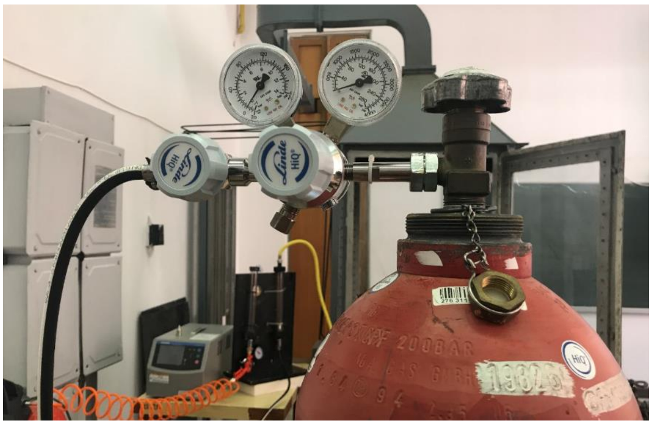


Fig.2. Pressure reducer head fitted to the gas cylinder

The experiments were conducted in the Gas Combustion Laboratory from the Technical Thermodynamics, Engines, Thermal and Refrigeration Department of the University "Politehnica" of Bucharest. In Fig. 3 is illustrated the experimental setup, fitted with a kinetic burner, a rothameter in order to maintain the 1 m^3_N/h gas flow used to perform the studies and a gas analyser to determine the values of the exhaust fumes components.

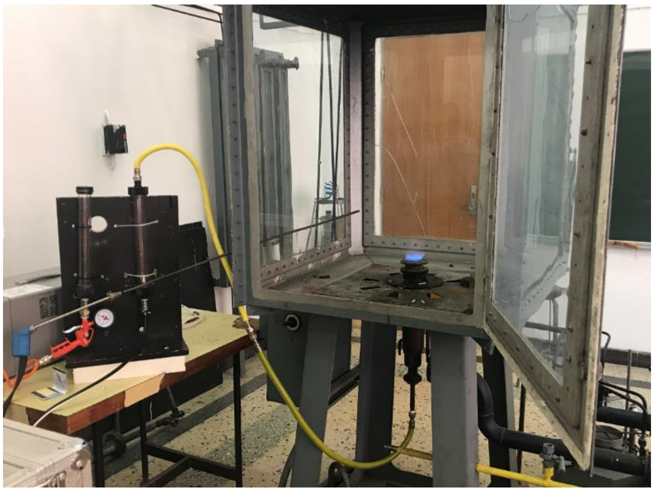


Fig.3. Experimental setup

In the experiments was also used SMART VIEW 4.1.Flucke IR Camera to measure the flame temperature and have a good visibility of the process (Fig.4).

Fig.4. SMART VIEW 4.1. Flucke IR Camera during the kinetic measurements

There were performed tests using both available technologies for burning the gaseous fuels: kinetic (combustion of the premixture with air) and diffusive.

At the configuration of the two burners there was used Wobbe criterion, because the calorific power and density have different values from ones of the methane (CH_4):

$$W_0 = \sqrt{\Delta p}\,\frac{H_i^i}{\sqrt{\rho}} \qquad (2)$$

where: Δp is the overpressure at the admission in the burner;

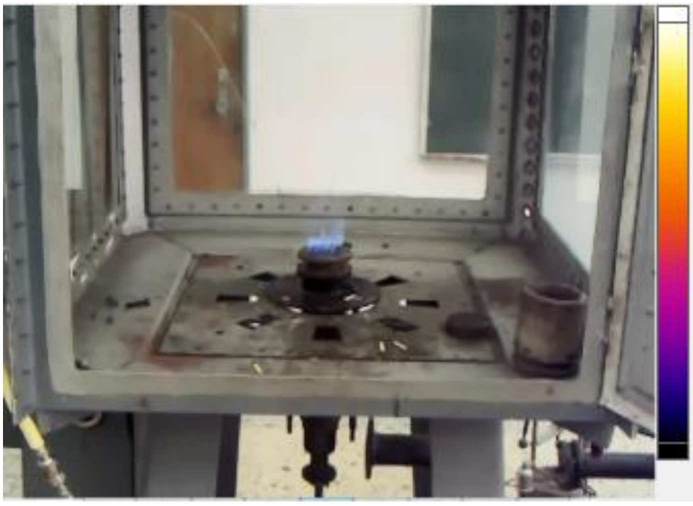
H_i^i – lower heating value;

ρ - gas density.

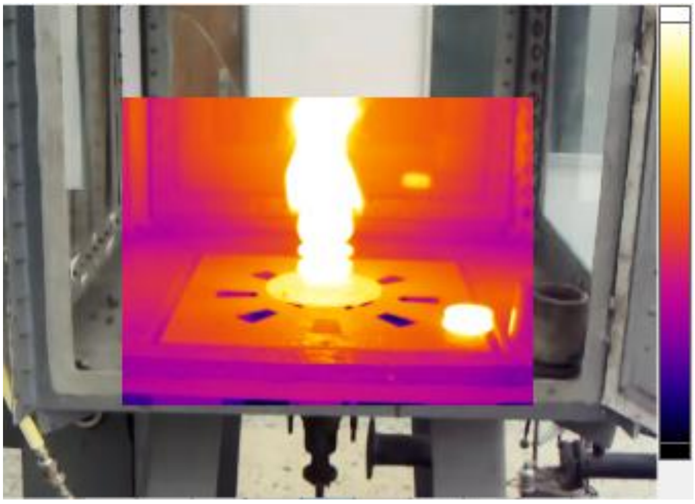
Using Wobbe criterion, the conducted experiments had a good paramether configuration for all the three types of gas and for both type of burners, being able to have a stable, complete flame with low pollutant emissions. (Mihăescu, L., 2004)

The thermic distribution of the flame for the kinetic burner with premixture of air using the gas from cylinder I is presented in Fig. 5. The obtained temperatures in the flame were situated between 700 and 1650 °C, as indicated in the histogram from Fig.5.

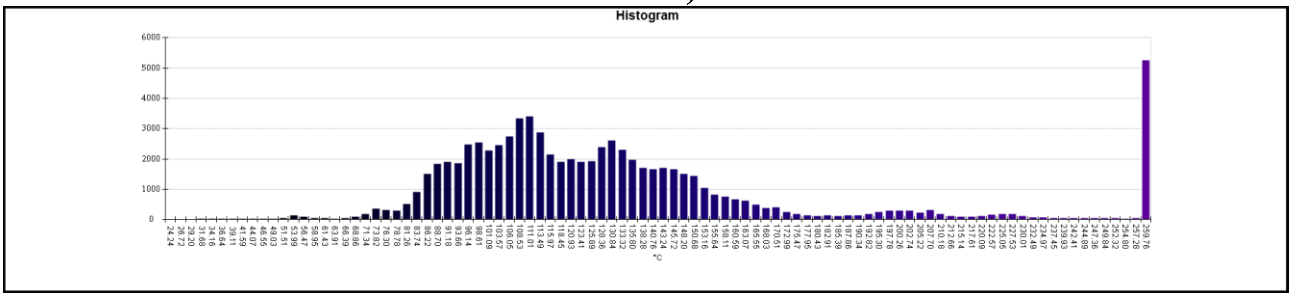
The histogram indicates a good combustion, with excess air value close to1. Also the flame is concentrated at the bottom of the burner and a completion of the postflame, according to the theoretical kinetic flame.



a)



b)



c)

Fig.5. Thermic distribution of the combustion of gas from cylinder I : a) General view of the kinetic flame ; b) thermic distribution with IR view; c) Histogram of temperatures

A gas analyser was used in order to measure the concentrations of NO_x and CO during the combustion process. At the end of the flame, the emissions values were of max 40 ppm, values which comply with the legislation, using an excess air of λ = 1,02-1,03.

CONCLUSIONS

The paper offers a complete view over the configuration of the combustion process for the biogas obtained from anaerobic fermentation of tannery wastes, using the characteristic burners for CH_4 : kinetic and difussional.

Tests were carried out using a synthesis gas, which by three versions of concentration has successfully supplied the qualities and quantities needed for tests and offered the dispersion needed in order to have a close view of the real situation

By complying with the proper configuration of parameters, a good combustion process was obtained for both versions of technology (premixture of gas-air (kinetic) and diffusion).

Pollutant emissions comply with the environmental rules, which means that the direct usage of the biogas does not bring any negatibe effects by its exhaust fumes.

Another positive aspect is the direct usage of the biogas, without any special preparation or additional flammable substances.

The experiments covers up the the burner with a premixture of air, with a stabilizer in order to divide the flame. The temperatures obtained and the pollutant emissions indicate a good performance of the combustion process.

Due to high content of animal protein found in wastes from tanneries, the biogas production and combustion can be easily applied in leather industry.

Experiments showed that the minimum quality of the used biogas in energetic purposes must comply with a value of 0.71 for the R criterion.

ACKNOWLEDGMENTS

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