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THE MODELLING OF THE AMARANTH BIOMASS FERMENTATION AND THE MEASURMENT OF BIOGAS MICRO FLOW

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ABSTRACT
The aim of the article is oriented at a measurement of biogas micro flow which springs up while amaranth biomass decomposition. The fermentation runs strictly under anaerobic conditions, the possibility of biogas production is primarily tested as four-level mathematical model. The mechanism of four-level decomposition is described by a vector equation, which presents a first order mechanism with regard to all reaction components. For analytical solution is Laplace transformation used. The designed mathematical model is verified by an experimental measurement. Experimental device is supplemented by visualization program which is designed in programming environment Control Web. Archived data are compared with actual measured values.
Keywords: amaranth, anaerobic decay, amaranth mass exploitation

1. INTRODUCTION
Amaranth [Amaranthus hypochondriacus, A. cruentus (grain), A. tricolor (vegetable)] is a plant with an up-right growth habit, cultivated for both its seeds, which are used as grain, and its leaves, which are used as a vegetable. Both the leaves and seeds contain protein of an unusually high quality. The grains are milled for flour or popped like popcorn. The leaves of both the grain and vegetable types may be eaten raw or cooked [1].
Amaranth produces many thousands of tiny seeds having very valuable contents. The crop has high nutritional values, contains remarkable amounts of protein with high portion of essential amino-acids and other considerable substances, like squalene and flavonoids (rutin). As a result, amaranth starts to be exploited especially in the food industry to produce new products, conducive against civilization diseases. Amaranth has a wide variety of applications in the food industry, it can be used in a number of food products including breakfast cereals, confectionery products, salad condiments, baked products, etc. This utilization is dominant [2]. On the other hand, amaranth starts to be used also in medicine, pharmaceutics and cosmetics. Research is in progress, for example in the area of amaranth biomass treatment where gaps in present amaranth exploitation are. Fermentation of amaranth mass runs in anaerobic decay, however this way of amaranth exploitation is not often used. Therefore we are interested in experiments which prove the possibility of amaranth biogas production.
It is known, that the description of fermentation is possible by mathematical equations of the decay process. We assumed the mechanism of four-level decomposition, which is depicted by a vector equation. The formula presents a first-order mechanism with regard to all reaction components. For analytical solution of equation system we used Laplace transformation [3]. The experimental measurement runs in experiments for gas production monitoring we compiled in laboratory conditions. As a source of anaerobic bacteria we used anaerobic sludge from the sewerage plant. The

purpose of our present experiments is to prove that amaranth biomass is suitable for anaerobic decomposition and that the produced gas can be successfully employed in practice.

2. THEORY

2.1. Anaerobic decay of amaranth biomass

Microbial anaerobic decay is a collection of sectional biological processes, continuing on each other, in which several cardinal functional groups of anaerobic microorganisms participate. Degradation of organic substances to final products – methane and carbon dioxide – involves their coordinated metabolic cooperation. A product of one microorganism group turns into substrate for other groups, therefore insufficient activity of only one group can evoke contravention of running balance in the whole system and abatement of process efficiency.

The major processes of anaerobic decay are:

- hydrolysis – the first stadium of the decay, macro dissolved and undissolved organic substances (polysaccharides, lipids, proteins) are rotted into water-soluble micro elements by means of extra cellular hydrolytic enzymes, which are especially produced by fermentative bacteria;
- acidogenesis – products of hydrolysis are inside the cell rotted into simpler organic substances (acids, alcohols, carbon dioxide, molecular hydrogen);
- acetogenesis – in this stadium of the decay substances, which are produced by acid genesis, are decomposed into molecular oxygen, carbon dioxide and vinegar acid;
- methanegenesis – the last stadium of the decay, methanogene microorganisms rot substrates which are acceptable for them (some one-oxide substances, like methanol, methylamine, carbon dioxide, ant acid, molecular hydrogen) and from more-oxide vinegar acid only [3].

Production of methane is a complex process, in which partake several bacterial groups. Methanogenesis can be described in two types of reactions:

1. Without reduction and carbon dioxide utilization.
   $CH_3COOH \rightarrow CH_4 + CO_2$
2. With reduction and utilization of carbon dioxide as hydrogen acceptor.
   $2CH_3CH_2OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$

The speed of methane production in anaerobic reactors is often limited by destruction speed of biologically separable polymers and efficiency of metabolic interaction between hydrolytic bacteria and other groups of anaerobic ecosystem [3].

2.2. Mathematical model of anaerobic decay

One of the purposes of the article is to check out the anaerobic decay efficiency of amaranth in laboratory conditions. Generally, anaerobic decay proceeds in four stadiums, therefore mathematical model of four-level decomposition is used.

Mathematical simulation of anaerobic decay of amaranth biomass will progress in these presumptive steps:

- degradation
- hydrolysis
- acetolysis
- methane genesis.

This could be expressed in the following scheme:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C \xrightarrow{k_3} D \xrightarrow{k_4} E$$

where k_1, k_2, k_3, k_4 are speed constants each subsequent reaction. The constants dependent on the sludge activity. In the first approach the mechanisms of the first degree was contemplated. In this presumption the following system of differential equations will be applied:

$$\frac{dc_A}{d\tau} = -k_1 c_A \qquad (1)$$

$$\frac{dc_B}{d\tau} = k_1 c_A - k_2 c_B \tag{2}$$

$$\frac{dc_c}{d\tau} = k_2 c_B - k_3 c_c \tag{3}$$

$$\frac{dc_D}{d\tau} = k_3 c_C - k_4 c_D \tag{4}$$

$$\frac{dc_E}{d\tau} = k_4 c_E \tag{5}$$

where $C_{A,B,C,D,E}$ are concentrations of particular compounds. Consequently Laplace transformation is solved, which leads to these results:

$$c_A = c_{A0} e^{-k\tau} \tag{6}$$

$$c_B = \frac{c_{A0} k_1}{k_1 - k_2}\left(e^{k_L \tau} - e^{-k_1 \tau}\right) \tag{7}$$

$$c_C = c_{A0} k_1 k_2 \left[\frac{e^{-k_1\tau}}{(k_3 - k_1)(k_2 - k_1)} + \frac{e^{-k_2\tau}}{(k_3 - k_2)(k_1 - k_2)} + \frac{e^{-k_3\tau}}{(k_2 - k_3)(k_1 - k_3)}\right] \tag{8}$$

$$c_D = k_3 k_2 k_1 c_{A0}\left[\frac{e^{-k_4\tau}}{(k_2 - k_4)(k_1 - k_4)(k_3 - k_4)} + \frac{e^{-k_2\tau}}{(k_4 - k_2)(k_3 - k_2)(k_1 - k_2)}\right] + \\ + \left[\frac{e^{-k_3\tau}}{(k_4 - k_3)(k_2 - k_3)(k_1 - k_3)} + \frac{e^{-k_1\tau}}{(k_4 - k_1)(k_3 - k_1)(k_2 - k_1)}\right] \tag{9}$$

$$c_E = 1 + k_4 k_3 k_2 k_1 c_{A0}\left[\frac{e^{-k_4\tau}}{-k_4(k_3 - k_4)(k_2 - k_4)(k_1 - k_4)} + \frac{e^{-k_3\tau}}{-k_3(k_4 - k_3)(k_2 - k_3)(k_1 - k_3)}\right] + \\ + \left[\frac{e^{-k_2\tau}}{-k_2(k_4 - k_2)(k_3 - k_2)(k_1 - k_2)} + \frac{e^{-k_1\tau}}{-k_1(k_4 - k_1)(k_3 - k_1)(k_2 - k_1)}\right] \tag{10}$$

3. EXPERIMENTAL SET-UP

The mathematical model of anaerobic decay was verified by the help of experimental equipment which is shown in Figure 1. The reactor with a magnetic stirrer was filled with the mixture of anaerobic sludge and biomedium, then the substrate was added and saturated with water so the inlet of inert gas was dipped. The reactor was hermetically closed and aerated with nitrogen for 15 minutes, which provided oxygen expulsion from water liquor and performance of anaerobic conditions. Produced gas was collected and drained through the bubble flow meter to ambient air. The sensor was composed of a glass tube, which was encased in a chuck from organic glass. The inlet of gas measuring through a nozzle needle was fixed on the chuck and leads below the liquid level. The bubbles were formed by the low flow rates in the issue of the jet. The needle was placed to the gas inlet hence regular separation of commensurate bubbles. These were photoelectric detected by virtue of a photodiode and phototransistor and added to figures on the counter. The bubble flowmeter was volumetric gauged. The scaler was connected to a computer, where the process of the measurement was registered via program Control Web. The bioreactor was maintained with constant temperature 23°C and the content was stirred with 50 rpm.

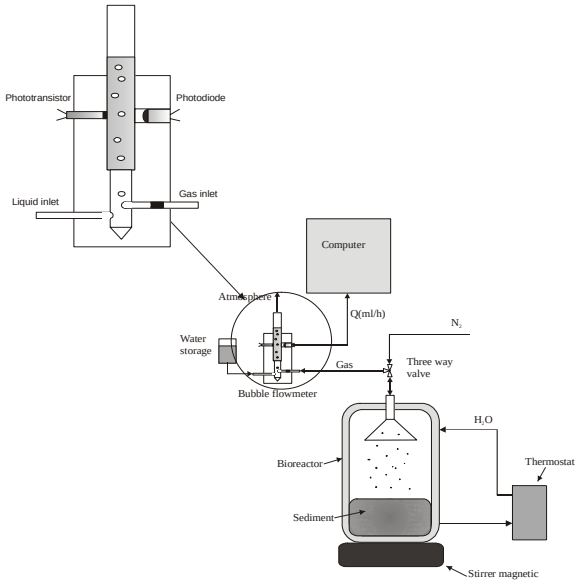

Figure 1. Scheme of the experiments for gas production monitoring

As can be seen, the decomposition of amaranth biomass grows with time. At the beginning the speed of methanogenesis is higher, then it slows down according to activity of the anaerobic methanogene bacteria. After the sludge is exhausted, the biogas production stops, as can be seen, in the last part of the curve – the stable state. This process takes several days.

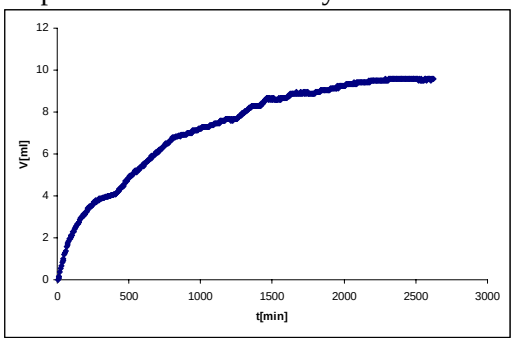

Figure 2. The time dependence of amaranth mass anaerobic decay

4. CONCLUSION

In this paper, the efficiency of anaerobic decay of sodium acetate and amaranth mass and its time behavior were measured using the photodiode and phototransistor. A constant momentary reaction speed during all the reactions, including amaranth mass, was proved with the same value. This fact shows that the speed of methanogenesis is probably the most important part of the reaction. Finally, the experiments verified that amaranth biomass is suitable for anaerobic decomposition and therefore to biogas production.

5. ACKNOWLEDGMENT

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