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# DIRECT AND INDIRECT MODELING IN AMARANTH BIOMASS PROCESSING

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## ABSTRACT

*The aim of the article is about theoretical facilities of process engineering which are rarely use, or in special cases not used at all, by the optimization techniques. Therefore I will consider the mathematical modeling application by the description of the processes which are used in the treatment of amaranth biomass into final products. In many kinds of processes running in the biopolymer industry is the exact mechanisms of the process not known, hence modeling of the existing operation need to be done on an experimental equipment. One of the main questions which are solved by the rationalizing measures is how the given model should be constructed, to what degree should be similar with the real machinery and how it influences it. The answer is in the modeling selection – direct or indirect.*

**Keywords:** modeling, amaranth, processing

## 1. INTRODUCTION

Amaranth is a pseudo-cereal cultivated for both its seeds. Both the leaves and seeds contain protein of an unusually high quality [1]. 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, 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. 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. MATHEMATICAL MODEL OF ANAEROBIC DECAY

The purpose of the article is to check out the an-aerobic 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:

$$\text{degradation} \rightarrow \text{hydrolysis} \rightarrow \text{acetolysis} \rightarrow \text{methanegenesis}$$

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:

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

$$\frac{dc_B}{d\tau} = k_1 c_A - k_2 c_B \qquad (2)$$

$$\frac{dc_c}{d\tau} = k_2 c_B - k_3 c_c \qquad (3)$$

$$\frac{dc_D}{d\tau} = k_3 c_C - k_4 c_D \qquad (4)$$

$$\frac{dc_E}{d\tau} = k_4 c_E \qquad (5)$$

$$\dot{C} = A \cdot C \qquad (6)$$

where $C_{A,B,C,D,E}$ are concentrations of particular compounds. Equation (6) is a vector differential equation with consecutive initial conditions:

$$\begin{bmatrix} c_A(0) \\ c_B(0) \\ c_C(0) \\ c_D(0) \\ c_E(0) \end{bmatrix} = \begin{bmatrix} c_{A0} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = C(0) = C_0 \qquad (7)$$

Consequently Laplace transformation is solved, which leads to these results:

$$c_A = c_{A0} e^{-k\tau} \qquad (8)$$

$$c_B = \frac{c_{A0} k_1}{k_1 - k_2} \left( e^{k_L \tau} - e^{-k_1 \tau} \right) \qquad (9)$$

$$c_C = c_{A0} k_1 k_2 \left[ \frac{e^{-k_1 \tau}}{(k_3 - k_1)(k_2 - k_1)} + \frac{e^{-k_2 \tau}}{(k_3 - k_2)(k_1 - k_2)} \right] \qquad (10)$$

$$c_D = k_3 k_2 k_1 c_{A0} \left[ \frac{e^{-k_4 \tau}}{(k_2 - k_4)(k_1 - k_4)(k_3 - k_4)} + \frac{e^{-k_2 \tau}}{(k_4 - k_2)(k_3 - k_2)(k_1 - k_2)} \right] + \left[ \frac{e^{-k_3 \tau}}{(k_4 - k_3)(k_2 - k_3)(k_1 - k_3)} + \frac{e^{-k_1 \tau}}{(k_4 - k_1)(k_3 - k_1)(k_2 - k_1)} \right] \qquad (11)$$

$$c_E = 1 + k_4 k_3 k_2 k_1 c_{A0} \left[ \frac{e^{-k_4 \tau}}{-k_4 (k_3 - k_4)(k_2 - k_4)(k_1 - k_4)} + \frac{e^{-k_3 \tau}}{-k_3 (k_4 - k_3)(k_2 - k_3)(k_1 - k_3)} \right] + \left[ \frac{e^{-k_2 \tau}}{-k_2 (k_4 - k_2)(k_3 - k_2)(k_1 - k_2)} + \frac{e^{-k_1 \tau}}{-k_1 (k_4 - k_1)(k_3 - k_1)(k_2 - k_1)} \right] \qquad (12)$$

## 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 con-tent was stirred with 50 rpm.

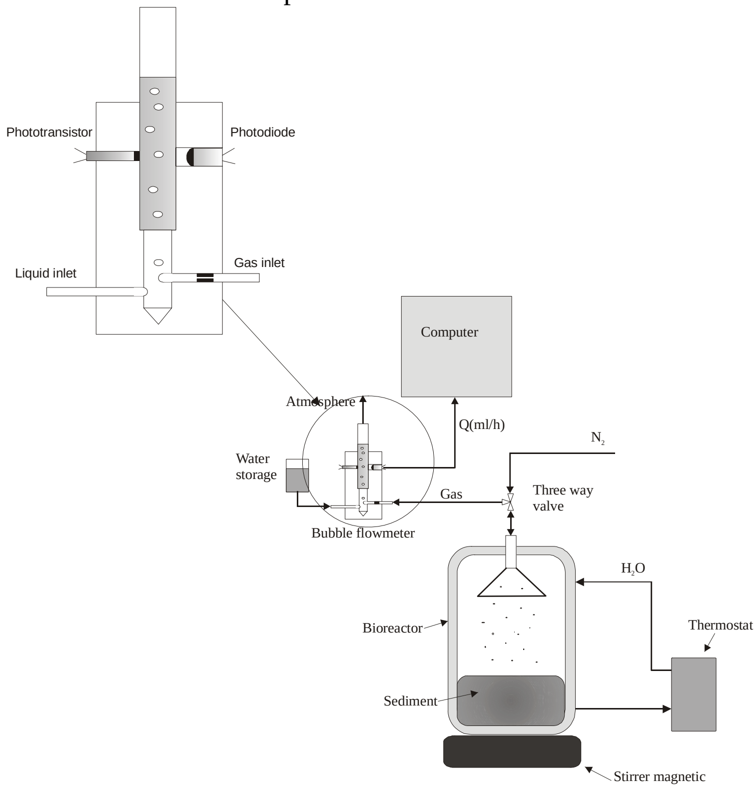


*Figure 1. Scheme of the experiments for gas productions monitoring*

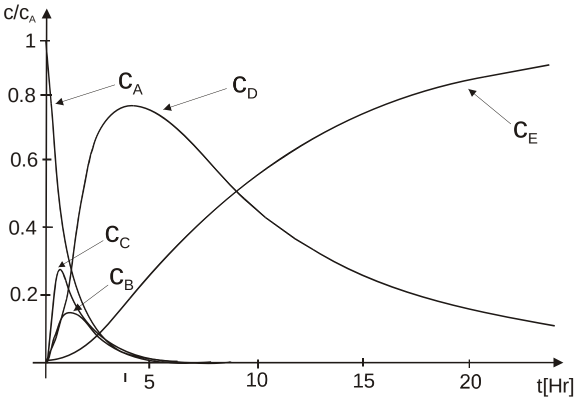


*Figure 2. Time dependence of initial substance, intermediate product and product concentration by the four-level model, where constants were chosen as k1= 1, k2= 2, k3 = 3, k4 = 0.5*

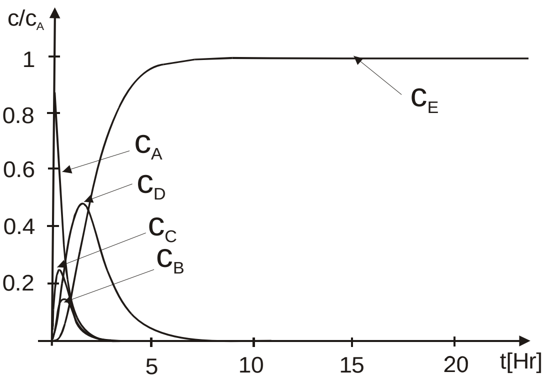


*Figure 3. Time dependence of initial substance, intermediate product and product concentration by the four-level model, where constants were chosen as k1= 1, k2= 2, k3 = 3, k4 =0.1*

In the mathematical model in Figure 2, which was designed in computer program Mathematica 4, the time dependence of concentration by the four-level model can be seen. Methanogenesis (the last step of anaerobic decay) represents the curve $c_E$. It was proved as the slowliest part of the decomposition. Therefore the speed of methanogenesis is the most important part of the reaction.

As can be seen in the graph below (Fig.4), the decomposition of amaranth biomass grows with time. At the beginning the speed of methanogenesis is higher, than it slows down according to activity of the anaerobic methanogene bacteria. After the sludge is exhausted, the biogas production stops. This process takes several days usually.

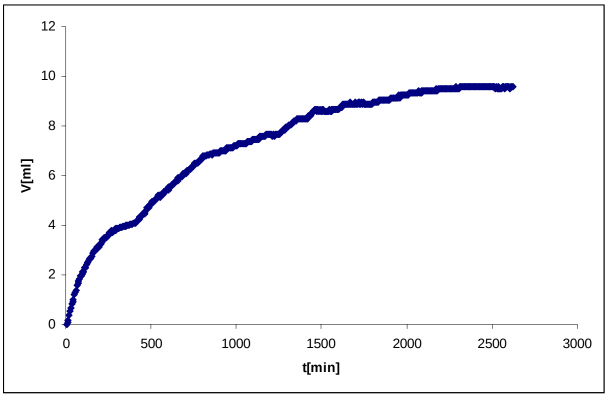


*Figure 4. The time dependence of amaranth mass anaerobic decay*

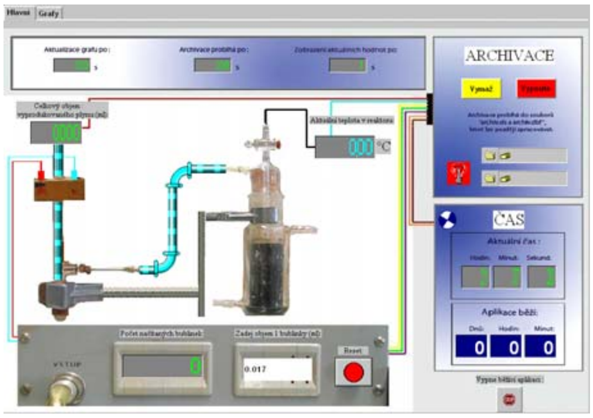


*Figure 5. Visualization of the decay in Control Web (Panel 1)*

### 3.1. Visualization in computer environment Control Web

On the ground of the requirement of more sophisticate equipment for archiving of the anaerobic decay process, we connected the bubble flow-meter through the measuring technological card with PC, where the whole process was visualized by the medium of computer environment Control Web. This program is a czech product produced by Moravské pristroje, s.r.o.

While the application processing composed for Windows 98/NT, which visualizes the measured data from the bubble flow meter and ensures its reset, was important to register the particular scanned places. The program was divided into two parts, so-called panels, each one is compounded of instruments, which enable the data logging [4]. Switching between both panels runs through the marks, which are placed in upper-left corner of the running application. The main panel – the true scanning of measured values - is shown in figure 5. To these values rank the sensing of arising gas bubbles amount and its recount to the volume of generated biogas, then scanning of temperature magnitude (meaning inside the reactor).

## 4. CONCLUSION

In this paper, the efficiency of anaerobic decay of amaranth mass and its time behavior were measured using the photodiode and phototransistor. The visualization was made in computer program Control Web due to connection through the technological card and PC. A constant momentary reaction speed during all the reactions, was proved with the same value. This fact shows that the speed of methanogenesis is 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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