CONSTRUCTION OF A MATHEMATICAL MODEL OF THE DEODORIZATION PROCESS OF COTTONSEED OIL IN THE MATLAB PROGRAM

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***Abstract**. One of the powerful and versatile application software packages that provide solutions to typical mathematical problems arising in various fields of human activity is the MathWorks MATLAB package. Using mathematical modeling, any metabolic process can be described as a large system consisting of a number of subsystems, such as equilibrium, matter transfer, hydrodynamics, heat transfer, mass and energy balance. The article presents mathematical and computer models of the deodorization process of cottonseed oil, using a computer model to study the concentrations of volatile components in the liquid and vapor phases, as well as changes in their temperature over time.*

***Keywords**: deodorization process, mathematical model, computer model, floating nozzle,concentration.*

INTRODUCTION

One of the powerful and versatile application software packages that provide solutions to typical mathematical problems arising in various fields of human activity is the MathWorks MATLAB package. The range of mathematical analysis methods implemented in the MATLAB package is quite wide and covers numerical integration, interpolation and approximation of functions, linear algebra, solving nonlinear equations and systems of ordinary differential equations, equations of mathematical physics, optimization problems, logic and other methods. The MATLAB Package has well-developed interpretation capabilitiesdata from two- and three-dimensional arrays is supplied with a programming language that allows you to easily create proprietary applications. Users of the MATLAB package can expand their knowledge in the field of computer modeling, programming and visualization of results while working. [1].

The peculiarity of modern food technologies, which run at high speeds at high temperatures and pressures in multiphase systems, is that they are nonlinear, that there are many variable parameters that determine the course of processes, that the internal relationships between variables and their mutual influence on each other are very complex.

In addition, the process is influenced by external random disturbances, which are ignored when calculating chemical and food production processes and devices. As a result, the amount of data that we process in our calculations becomes quite large, and we are forced to reduce or adjust this volume, limiting the number of choices in order to exclude this low-impact data. This is achieved by studying the process on a model, understanding the phenomena of the process through simplified "equivalents" that reflect the desired directions[2].

Using mathematical modeling, any metabolic process can be described as a large system consisting of a number of subsystems, such as equilibrium, matter transfer, hydrodynamics, heat transfer, mass and energy balance. During the deodorization process, due to the evaporation of volatile components from the liquid composition, its amount in the liquid phase decreases, and the amount in the vapor phase increases. The composition of the liquid, which does not evaporate, will consist mainly of a volatile component - oil, which boils at high temperature. In order to reduce the boiling point of the oil during the process, taking into account the insolubility of the components of the mixture in water, high-temperature water vapor is introduced into its composition in an open manner as an additional component.

The supply of liquid and vapor phases in the column in opposite directions allows the formation of many quasi-products. Each quasi-apparatus will consist of floating nozzles, a liquid phase and a vapor phase. Wooden nozzles lead to a significant reduction in process time due to intensive mixing with open steam supplied from below the device[3].

The MATLAB package of the oil deodorization process must specify the initial values for analysis, including the initial concentration of the volatile component in the liquid phase, the initial concentration of the volatile component in the vapor phase, the flow rate of the liquid and vapor phases, and the process temperature.

A general computer model of the periodic oil deodorization process in the MATLAB package is presented below:

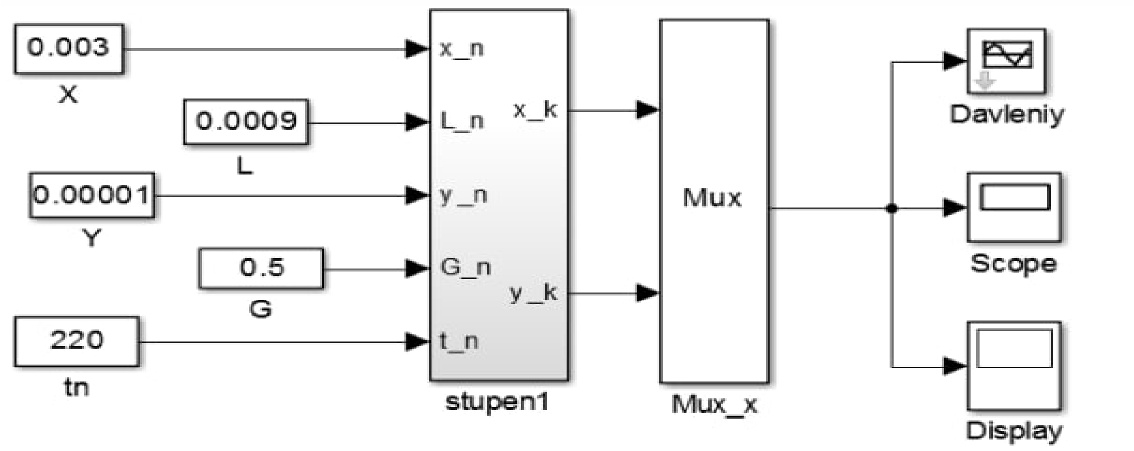

Figure 1. Overview of the general computer model of the periodic oil deodorization process in the MATLAB package.

The level access options include:

x_n-concentration of the light component in the liquid falling from the upper stage;

L_n-flow rate of liquid falling from the upper stage;

y_n is the concentration of the light component in the steam coming out of the lower stage.

G_n-the flow rate of steam coming out of the lower stage;

t_n is the temperature of the liquid falling from the upper stage;

The parameters of the exit from the step are as follows:

x_k-the concentration of the light component in the liquid falling from this step to the lower step;

y_k is the concentration of the light component in the steam rising from this stage to the upper stage.

Input parameter values for conducting experiments on a computer model:

- the initial concentration of volatile components in the oil $x_n = 0.003$;
- the initial concentration of volatile components in the Gas $Y_N = 0.00001$;
- the initial flow rate in the gas phase is 0.5 kg/sec;
- initial temperature in the oil phase TN = 220 ^oC;

- initial microconsumption in the oil phase -0.0009 kg/sec;

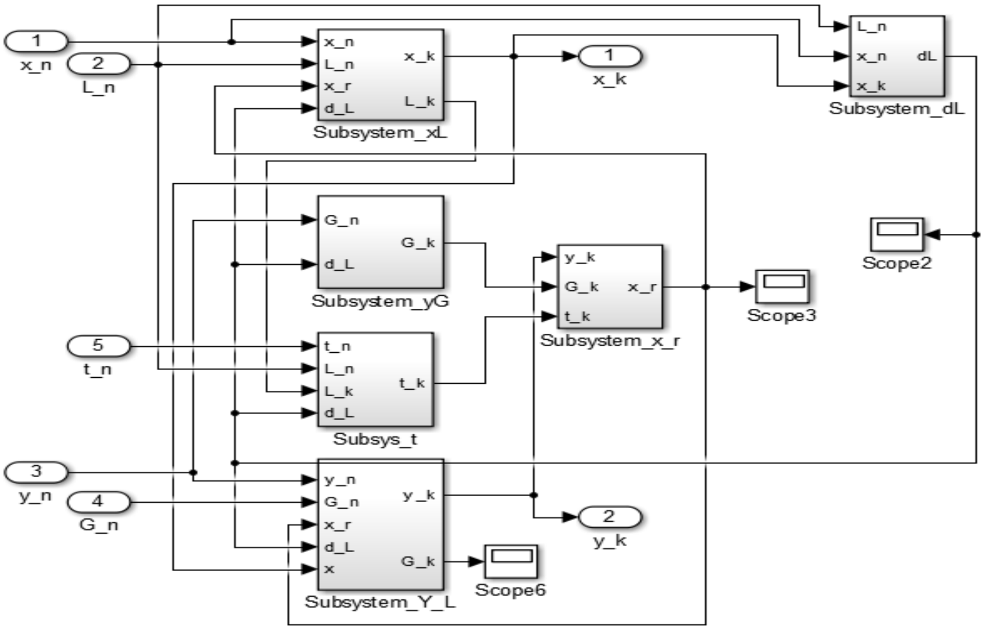

Figure 2. Computer model of quasi-hardware processes of the second stage of the oil deodorization facility

A mathematical expression and a computer model of changes in the concentration of volatile components of the quasi-composition processes of the oil phase at the third stage of the oil deodorization facility.

$$\frac{dx}{d\tau} = \frac{L_б x_б - L \cdot x - K_V V_L \left(x - x^*\right)}{V_L \rho_L} \qquad (1)$$

L_b and L are the flow rate of the liquid phase at the initial and considered time, kg/sec; Kv is the transfer coefficient of the substance in the liquid phase; V_l is the volume flow rate of the liquid phase (constant contact surface), kg/sec; P_l is the density of the liquid phase, kg/m3; x_b and x are the flow rate of the component in the liquid phase of the initial and observed concentration, %; x* is the equilibrium concentration of the Volatile component, %.

A mathematical expression and a computer model of the quasi-equipment process of the gas flow phase at the third stage of the oil deodorization facility.

$$G_o = G_б + \sum \Delta L \qquad (2)$$

Gb is the consumption of the vapor phase, kg/s; ΔL is the consumption of common components separated from the oil in the vapor state, kg/s.

Mathematical expression and computer model of temperature changes in the deodorization processes of the oil phase.

$$\frac{dt_o}{d\tau} = \left(L_б\, c_l\, t_б - L_o c_l\, t_o - \Delta L\, i_б\right)\big/ V_L \rho_L c_L \qquad (3)$$

where i_b is the enthalpy of steam, kJ/kg; C_l is the heat capacity of the oil, kJ/(kg).0C), TB and k are the initial and final temperature of the oil entering and leaving the device, 0C.

Mathematical expressions and computer models of partial pressure changes and equilibrium concentrations of quasi-contact processes in the oil phase at the third stage of the oil deodorization facility

$$p = \left(\left(\frac{G \cdot y}{M} \right) \Big/ \left(\sum \frac{G_i y_i}{M_i} \right) \right) P_{ум} \quad (4)$$

$$x^* = \frac{p}{(b_{11}t - b_{10}) \cdot 100} \quad (5)$$

Y - is the concentration of the volatile component in the vapor phase, kmol/kg; G is the vapor phase flow rate, kg/s; P_{um} is the total pressure of the mixture, kPa.

To determine the equilibrium concentration of volatile components (fatty acids, ketones, etc.) in oil, it is necessary to know its partial pressure. According to Dalton's law, the total vapor pressure is equal to the sum of the partial vapor pressures of the components on the surface of the solution:

$$Pum = P_{ек} + P_{сб} + P_{мой} \quad (6)$$

P, Rsb and moi are the partial pressures of the volatile component, water vapor and oil, respectively, kPa.

To determine the amount of a volatile component in a mixture, the following recommended dependence can be used:

$$m_i = \left(\frac{x_i}{M_i} \right) \Big/ \left(\frac{x_1}{M_1} + \frac{x_2}{M_2} + \frac{x_3}{M_3} + \frac{1 - x_1 + x_2 + x_3}{M_4} \right) \quad (7)$$

M_1, M_2, M_3 and M_4 – molecular weights of volatile components and cottonseed oil, kg/kmol; x_1, x_2 and X_3-concentrations (mass fractions) of volatile components in oil,%.

Mathematical expression and computer model of changes in the concentration of volatile components of gas-phase quasi-contact processes at the third stage of the oil deodorization facility

$$\frac{dy}{d\tau} = \frac{G_б y_б - G_o y_o + K_V V_L (x - x^*)}{V_L \rho_L} \quad (8)$$

The amount of volatile components evaporating from the liquid phase can be determined as follows:

$$\Delta L = \frac{L_б (x_б - x)}{100 - x} \quad (9)$$

The degree of use of open water vapor in the deodorization process is characterized by the saturation coefficient of secondary steam:

$$\varphi = P_{ек} \Big/ P_{ек.мув.} \quad (10)$$

where R_{vk} is the actual partial vapor pressure of fatty acids on the oil surface, kPa; Rvc.muv. is the partial vapor pressure of fatty acids in equilibrium with the solution, kPa.

In the process of deodorization with open water vapor, the vapor phase can be considered as an ideal gas. The concentration of molecules of each component is proportional to their partial pressure. We can express this state as:

$$\frac{N_{ек}}{N_{сб}} = \frac{P_{ек}}{P_{сб}} \quad ёки \quad \frac{G_{ек}}{G_{сб}} = \frac{M_{ек}}{M_{сб}} \frac{P_{ек}}{P_{сб}}, \quad (11)$$

where N_{vk}, R_{vk}, G_{vk} and M_{vk} are the quantity, partial pressure, flow rate and molecular weight of vapor molecules of the volatile component, respectively; Nsb , Rsb, Gsb and Msb are the quantity, partial pressure, flow rate and molecular weight of molecules of open water vapor, respectively.

An overview of the mathematical model representing the change in the concentration and temperature of volatile components in the liquid and vapor phases during the deodorization of cottonseed oil is presented in the system of equations (12).

$$
\begin{cases}
\dfrac{dx}{d\tau} = \dfrac{L_б x_б - L \cdot x - K_V V_L \left(x - x^*\right)}{V_L \rho_L} \\
G_o = G_б + \sum \Delta L \\
\dfrac{dt_o}{d\tau} = (L_б\, c_l\, t_б - L_o c_l\, t_o - \Delta L\, i_б))/V_L \rho_L c_L \\
p = \left(\left(\dfrac{G \cdot y}{M}\right) \Big/ \left(\sum \dfrac{G_i y_i}{M_i}\right)\right) P_{ум} \\
x^* = \dfrac{p}{(b_{11} t - b_{10}) \cdot 100} \\
\dfrac{dy}{d\tau} = \dfrac{G_б y_б - G_o y_o + K_V V_L \left(x - x^*\right)}{V_L \rho_L} \\
\Delta L = \dfrac{L_б (x_б - x)}{100 - x}
\end{cases} \qquad (12)
$$

To perform computational work using a computer model formulated on the basis of a mathematical model, invariant values of technological parameters were adopted within the following limits.

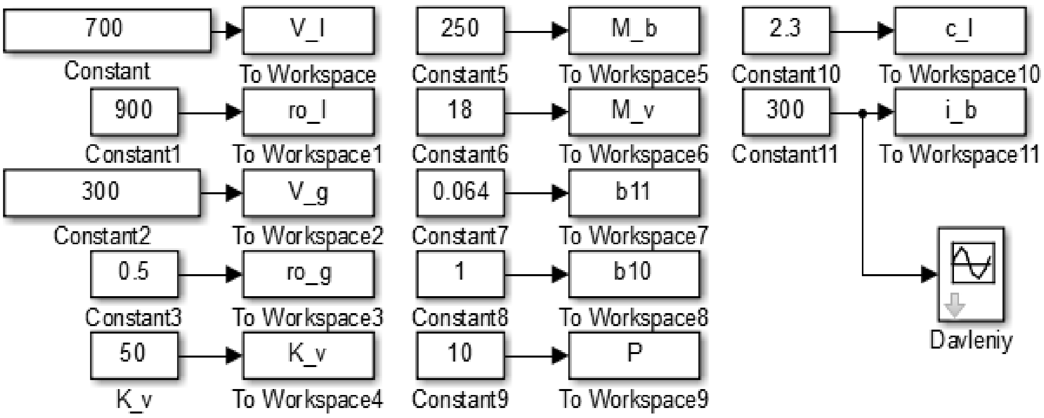

Figure 3. Unchangeable values of technological parameters of the periodic deodorization process

Also, during the deodorization process, the parameters change, including volatile components have an initial concentration in oil X_n=0.003, volatile components have an initial concentration in Gas y_n=0.00001, volatile components have an initial temperature in oil TN=220 ^{0} C, the initial temperature in the gas phase TN=220+10 ^{0} C, the initial the temperature in the oil phase TN = 220 ^{0} C, the oil and the mass transfer coefficient between the gas phase were assumed to be K = 0.5.

Let's consider the change in the concentration of volatile components in the oil and gas phases of the oil deodorization object over time.

The green (1) curve on the graph shows that the vapor phase is enriched with volatile components, and the red (2) curve represents a decrease in the content of volatile components in the oil due to the transition to the vapor phase.

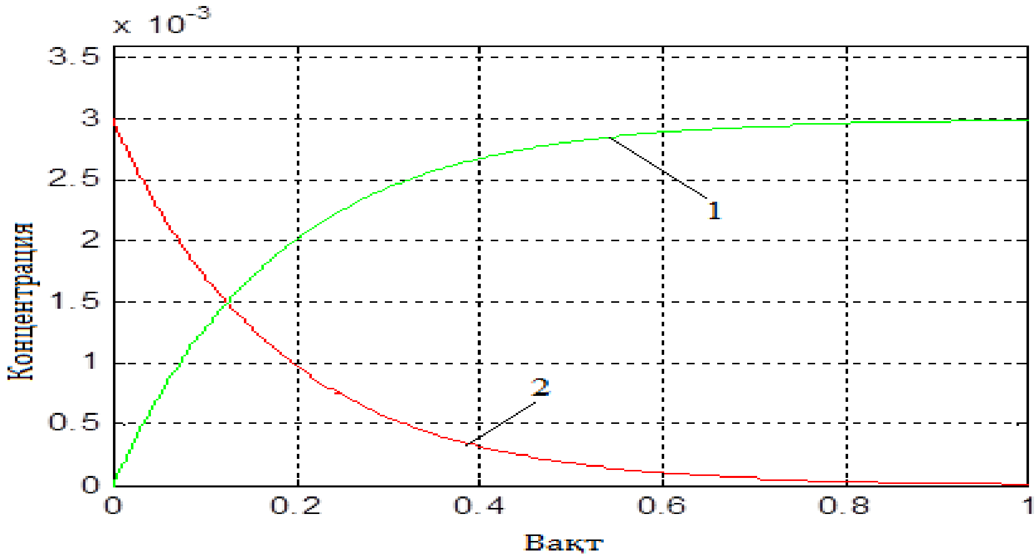

Figure 4. Graph of changes in the concentration of volatile components in oil over time in the vapor phase (curve 1) and the liquid phase (curve 2)

CONCLUSION

Food industry modern knowledge about processes and devices is difficult to imagine without mathematical and computer modeling. The essence of this technique is to study the initial object, that is, the process of deodorization of cottonseed oil, by replacing its mathematical model, and later, by implementing computational algorithms on a computer, the process model by changing various technological parameters at will. This way of thinking, designing, and designing combines many advantages, both practical and theoretical. Working with the model, rather than with the object itself, it is possible to conduct a relatively quick and cost-free study of its properties and (mostly theoretical) states in desired fantastic situations. Conducting experiments on a computer model of the deodorization process allows you to fully and deeply study even those issues that cannot be solved only by theoretical methods.

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