Modeling the process of deodorization of cottonseed oil in a liquid-vapor-floating nozzle system

Xamdamov Anvar Maxmudovich
Naziraliyeva Nigora Jo'ramirza qizi

There is a high growth in global demand for consumer oils, including soybean, palm, sunflower, rapeseed, and cottonseed oils. In order to increase the production of deodorized oil, a number of measures are currently being implemented in our republic to improve vegetable oil production technologies, comprehensively process oil-bearing vegetable raw materials, and re-equip oil and fat enterprises with modern technologies and high-tech efficient equipment. The development strategy of the new Uzbekistan sets such tasks as "implementing the food industry development program to increase the volume of food products to 7.4 million tons by 2026, and the assortment of food products from 898 to 1,100..." Accordingly, scientific research aimed at improving the deodorization process using nozzles based on a computer model is of urgent importance in increasing the efficiency of producing high-quality vegetable oil.

In order to further accelerate the ongoing work, Resolution No. PF-36 dated February 16, 2024, "Additional Measures to Ensure Food Safety", was updated and several additional resolutions and regulations were established.

Based on these resolutions and regulations, as a result of measures taken in recent years to develop the food industry in the republic, attract investment funds to the sector, and support export activities, the volume of food production has exceeded 6.1 billion US dollars and their annual export volume has exceeded 510 million US dollars.

Also, over the past three years, the production of 75 types of import-substituting food industry products worth 289.9 million US dollars has been ensured, and the volume of imports has decreased by 7.4%. The share of the food industry in the republic's industry has increased from 14 percent to 16.6 percent.

Cottonseed oil deodorization is an important step aimed at separating free fatty acids, aldehydes, ketones, peroxides and odorous volatile compounds, which significantly affect the physicochemical composition of the oil. In traditional deodorizers, the uneven distribution of steam, low heat transfer efficiency and high energy consumption require process improvements. Therefore, the use of spherical wooden nozzles floating with a steam flow accelerates the technological and hydrodynamic process. The study of the hydrodynamic characteristics of the cottonseed oil deodorization process with the participation of spherical wooden nozzles serves to optimize and increase the efficiency of the process based on theoretical modeling. In modeling the process of deodorization of cottonseed oil in a liquid-vapor-floating nozzle system, the process involving floating wooden nozzles was divided into elementary processes based on a systematic analysis and their mathematical expressions were formulated. The input and output parameters of each separated elementary process (hierarchy level) were determined.

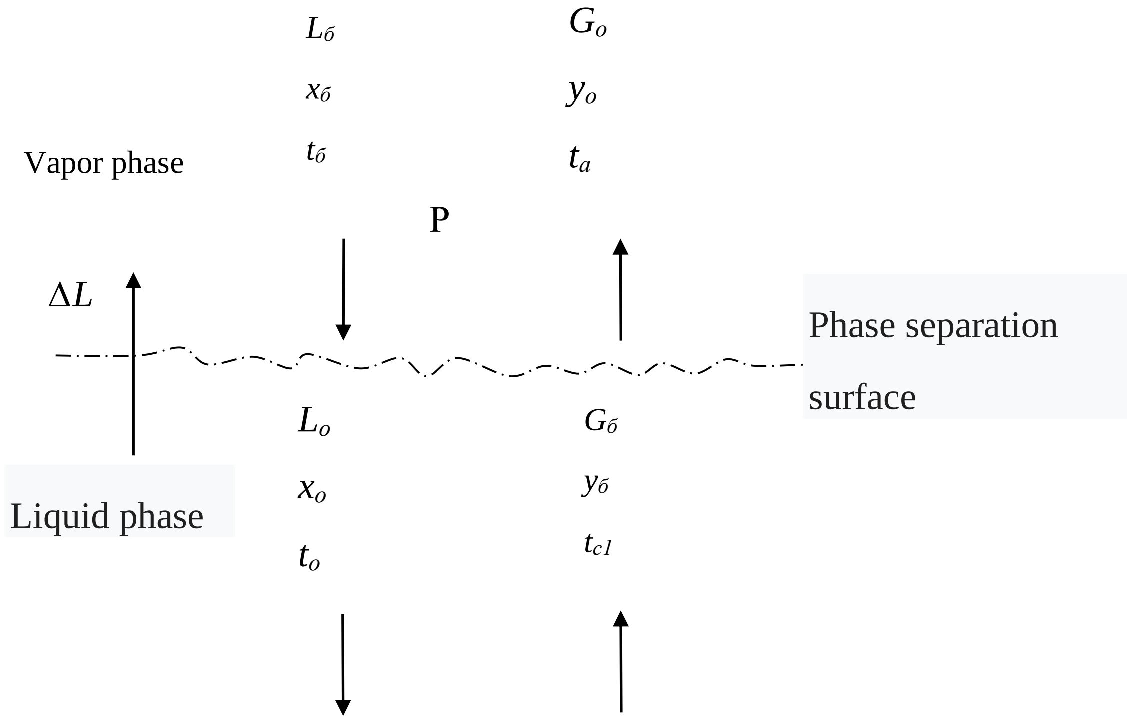

Figure 1. Scheme of the mechanism of heat and mass transfer through the phase separation surface in a liquid-vapor system

Stage input parameters: Lb - initial oil consumption; xb - concentration of volatile substances in the oil; tb - initial oil temperature; Gb - initial steam consumption; ts1 - water vapor temperature; yb - initial concentration of volatile substances in the water vapor; P - total pressure in the apparatus. Stage output parameters: Lo - final oil consumption; xo - concentration of volatile substances in the oil; to - final oil temperature; Go - final steam consumption; ta - temperature of the steam-gas mixture; yo - final concentration of volatile substances in the water vapor. A six-stage hierarchical structure of the process for the comprehensive analysis of the process of deodorization of vegetable oil using floating nozzles has been developed. The main heat and mass exchange processes are carried out in the quasi-layers of the working chamber, with the participation of floating nozzles, by the bubbling method.

Due to the complexity of the mechanism of the deodorization process and its implementation in a fundamentally new design of equipment, this system was initially sequentially decomposed into several simpler functional subsystems. In order to study the heat and mass transfer processes by combining the mathematical expressions of the elementary processes into a single system of equations, a mathematical model of the deodorization process taking place in the working chamber was developed:

$$\begin{cases} \dfrac{dx}{d\tau} = \dfrac{L_б x_б - L \cdot x - K_V V_L \left(x - x^*\right)}{V_L \rho_L} \\ L = L_б - \sum \Delta L \\ \Delta L = \dfrac{L_б \left(x_б - x\right)}{100 - x} \\ y = \dfrac{G_б y_б + \Delta L}{G} \\ G = G_б + \sum \Delta L \\ x^* = \dfrac{p}{\left(b_{11} t - b_{10}\right) \cdot 100} \\ p = \left(\left(\dfrac{G \cdot y}{M} \right) \Big/ \left(\sum \dfrac{G_i y_i}{M_i} \right) \right) P_{ум} \\ \dfrac{dt_м}{d\tau} = \dfrac{\left(G_{м1} c_{м1} t_{м1} - G_{м2} \dfrac{x_{м.б}}{x_{м.о}} c_{м2} t_{м2} - G_б i_б + \alpha F \left(t_{буг} - t_м\right) \right)}{V_L \rho_L c_L} \end{cases} \tag{1}$$

This model of the mass transfer process includes the mass transfer processes occurring on both sides of the boundary surface separating the interacting vapor and liquid phases, as well as the mass transfer processes that diffuse through this surface.

The MATLAB Simulink program was used to calculate the deodorization process model, and its computer model overview is shown in Figure 2 below.

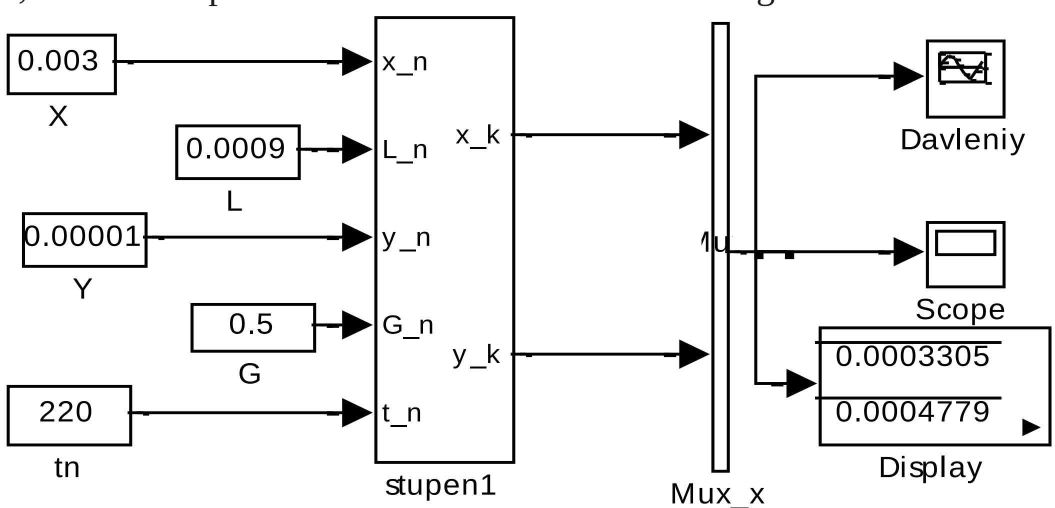

Figure 2. Computer model of the oil deodorization process

The following constant values were introduced to study the computer model: V_l - liquid volume; ro_l - liquid density; V_g - vapor phase volume; ro_g - vapor phase density; M_b - average molecular mass of fatty acids; M_v - molecular mass of water vapor; b11 - constant coefficient; b10 - constant coefficient; c_l - heat capacity of the liquid; i_b - water vapor enthalpy P - total pressure in the apparatus; K_v - volumetric mass transfer coefficient.

In a computer model of the cottonseed oil deodorization process using floating nozzles, the time-dependent changes in the concentrations of volatile components in the vapor and liquid phases of the oil layer were studied (Figure 3).

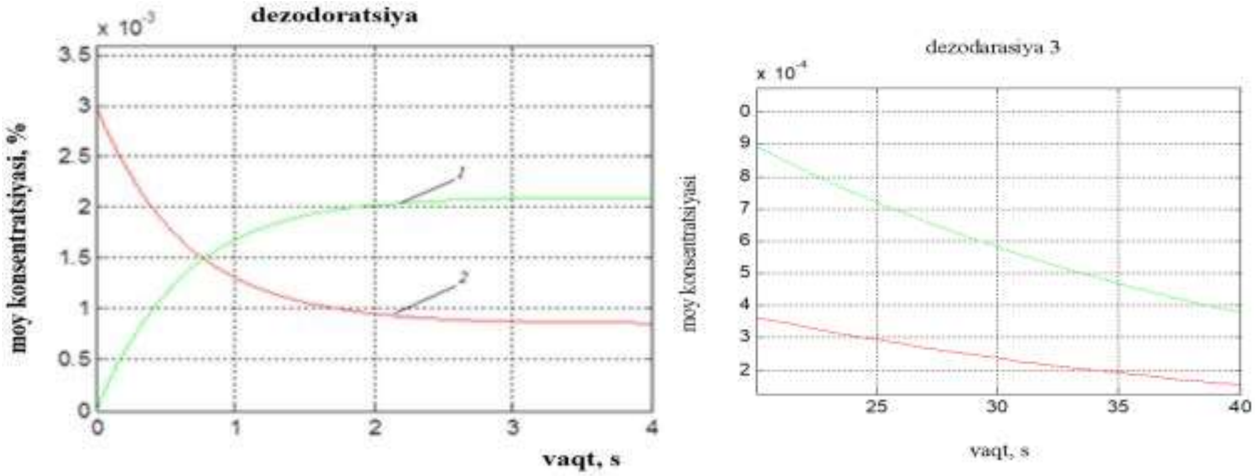

Figure 3. Time-dependent changes in the concentration of volatile components in the vapor 1 and oil 2 phases in an oil deodorization facility

Figure 3 shows that in the initial period of the deodorization process involving floating nozzles, the concentration of volatile components in the vapor phase increases over time, while the concentration of volatile components in the liquid phase decreases.

Summary

This process is aimed at removing volatile substances that give off unpleasant odors and tastes from cottonseed oil and involves modeling mass and heat transfer between the liquid (oil) and vapor (water vapor) phases. Mathematical models are based on differential equations. Modelingthe deodorization process in a liquid-vapor-floating nozzle system based on accurate mass transfer, equilibrium and hydrodynamic parameters allows for process optimization, a sharp reduction in steam and energy consumption, and increased product quality. This approach is currently being successfully used in the most advanced refineries in the world and is expected to become more widespread in the future.