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Research of Mathematical Model of Statistics of the Steaming Process of Tomato Paste

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ABSTRACT: In this article, we studied the process of single-stage evaporation of tomato paste in an evaporator and built a mathematical model of the static process of concentration.

KEY WORDS: tomato product, evaporation, concentration, tomato paste, heat process.

I.INTRODUCTION

In recent years, the level of technical equipment of the food industry has increased significantly. One of the most important sectors of the food industry is the processing of fruits and vegetables. Tomato is the most important vegetable canning crop. Its fruits contain a significant amount of carotene, vitamin C, sugars and acids; they have good taste. In our country, tomato products account for up to 25% of the production of canned fruits and vegetables. Many types of canned fish are produced in tomato sauce.

The following types of tomato products with a dry matter content are produced: tomato juice - at least 4.5%, tomato puree - 12, 15 and 20%, tomato paste - 25, 30, 35, 40%, as well as tomato sauces. High-yielding varieties with a maximum solids content are most suitable as raw materials; the yield of finished products depends on the latter. It is important that when wiping the amount of waste (wipes) is small. For this, the fruits must be quite ripe, red, with a low fiber content, without coarse and green patches. The time from removal of the fetus to processing should be minimal (no more than 48 hours), otherwise a significant part of the dry matter will be expended in respiration and the yield of tomato products will decrease.

However, further progress in this direction is inconceivable without a detailed and in-depth study of the processes and apparatuses of food technology based on the methodological principles of system analysis, widely relying on the method of mathematical modeling.

The mathematical model of the process, being a system of mathematical descriptions of its elements that make up the process itself, should reflect the essence of the phenomena occurring in the object. For a mathematical model, a simulation algorithm must be specified. The model should be considered in the aggregate of its three aspects - semantic, analytical and computational in combination with modern means of calculation. Methods of mathematical modeling in a relatively short period of time allow, under conditions of relatively low material costs, to investigate various options for the hardware design of the process, study its basic laws and open up reserves of intensification [1, 27].

Thermal processes occupy a large place in the production of tomato products, in particular, the heat exchange process of concentration is the main technological method for the production of tomato paste.

An important role is played by a systematic approach to the problem being solved, which dictates the need to establish causal relationships that characterize the course of the process. In this regard, it is advisable to consider and analyze the phenomena and effects of the concentration process in all structural elements of the apparatus. Such an analysis implies the identification of the hierarchical meaning of the process (as a typical physical and chemical system). When analyzing and synthesizing various variants of technological installations for concentrating the extract, it is necessary to have the equation of static, which is part of the mathematical model of the process.

When compiling a mathematical model of the process of concentration of tomato paste, the physicochemical characteristics of the interacting phases, design features and operating modes of the apparatus are taken into account and certain assumptions are made.

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The methodology for compiling a mathematical model of the process of evaporation of tomato paste includes the following research steps: selecting an object, studying it, substantiating the structural diagram of the object, compiling a mathematical description of the phenomenon, obtaining a mathematical model of the process, choosing methods for solving the mathematical model of the object, and evaluating the accuracy of calculations based on the proposed mathematical models of the evaporation process.

For the optimal structural design of the process of concentrating tomato products in vertically tubular apparatuses, it is of great interest to study the nature of the distribution of parameters along the height of the boiling pipes of evaporators.

As the determining parameters of the process of evaporation of tomato paste, its concentration and boiling point are taken. The study of the distribution of these process parameters along the height of the boiler tubes is carried out by compiling a mathematical model of the static process of its concentration.

When compiling a mathematical model of the statics of the evaporation process, the main step is to study the features of the processes that occur inside the boiler pipes.

To obtain a mathematical description of the process inside the heating pipes, we select their elementary height sections with the initial j-1 and final j their boundaries. Composing the heat balance for this case, we obtain

$$Q_{экс_{j-1}} + Q_{пр_{j-1}} + Q_{гп} = Q_{экс_j} + Q_{пр_j} \qquad (1)$$

где$Q_{экс_{j-1}} = G_{j-1}C_{j-1}t_{j-1}$ - heat input with concentrated to io product;

$Q_{пр_{j-1}} = G_{пр_{j-1}} i_{j-1}$ - heat input by solvent vapor;

$Q_{гп} = K\Delta\Gamma(t_{кн} - t_{j-1})$ - heat input from heating steam through heat transfer through the walls of the boiling pipes;

$Q_{экс_j} = G_j C_j t_j$ -heat removal with concentrated tomato product;

$Q_{пр_j} = G_{пр_j} i_j$ - heat removal by solvent vapor

$G = G_0 \frac{a_0}{a}$; $G_{пр} = G_0(1 - \frac{a_0}{a})$ -current expenses of tomato product and solvent vapor;

$\Delta F = \pi d_{вн} n \Delta h$ -heating surface of elementary sections.

The thermal balance of the elementary section in expanded form takes the following form;

$$G_{j-1}C_{j-1}t_{j-1} + G_{пр_{j-1}} t_{j-1} + K\Delta F\left(t_{кн} - t_{j-1}\right) = G_j C_j t_j + G_{пр_j} i_j = 0 \qquad (2)$$

After substituting the values of the structural and technological parameters of the process, we have:

$$G_0 \frac{a_0}{a_{j-1}} C_{j-1}t_{j-1} + G_0\left(1 - \frac{a_0}{a_{j-1}}\right) i_{j-1} + K\pi d_{вн}\, n\Delta h x\left(t_{кн} - t_{j-1}\right) - G_0 \frac{a_0}{a_j} C_j t_j - G_0\left(1 - -\frac{a_0}{a_j}\right) i_j = 0 \qquad (3)$$

After a series of mathematical transformations, we arrive at the following equation:

$$G_0 a_0 \left(\frac{i_j - C_j t_j}{a_j} - \frac{i_{j-1} - C_{j-1}t_{j-1}}{a_{j-1}} + \frac{i_j - i_{j-1}}{a_0}\right) = K\pi d_{вн} \Delta h\left(t_{кн} - t_{j-1}\right) \qquad (4)$$

Dividing both sides of the equation by Δh, we obtain:

$$G_0 a_0 \frac{1}{\Delta h}\left[\left(\frac{i_j - C_j t_j}{a_j} - \frac{i_{j-1} - C_{j-1}t_{j-1}}{a_{j-1}}\right) + \frac{i_j - i_{j-1}}{a_0}\right] = K\pi d_{вн} n\left(t_{кн} - t_{j-1}\right) \qquad (5)$$

Bearing in mind that

$$a_j = a_{j-1} + \Delta a \;\; и \;\; i_j = i_{j-1} + \Delta i$$

we can write:

$$G_0 \frac{a_0}{\Delta h}\left(\frac{\Delta i + \Delta(ct)}{\Delta a} + \frac{\Delta i}{a_0}\right) = K\pi d_{вн} n\left(t_{кн} - t_{j-1}\right)$$

$$G_0 a_0 \frac{\Delta}{\Delta h}\left(\frac{i - ct}{a} - \frac{i}{a_0}\right) = K\pi d_{вн} n\left(t_{кн} - t_{j-1}\right) \qquad (6)$$

Passing from increments to differentials, we obtain

$$G_0 a_0 \frac{d}{dh}\left(\frac{i - ct}{a} - \frac{i}{a_0}\right) = K\pi d_{вн} n\left(t_{кн} - t\right) \qquad (7)$$

Equation (7) characterizes the changes in the process parameters along the height of the boiling pipes of the evaporators at their given design and technological parameters.

The boiling temperature of tomato paste t_ex depends on its concentration and pressure P in the apparatus and is determined by the obtained regression equation by the formula:

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$t_{кип} = f(a, P)$ (8)

The enthalpy of vapor in aqueous solutions depends on the boiling point and is determined by the formula:

$i = 2482 + 1.97t \ \frac{кДж}{кг}$ (9)

The heat capacity of tomato paste C is determined by the formula of the regression equation

$$C = b_0 + b_1CB + b_2t + b_3CBt + b_4CB^2 + b_5t^2;$$

depending on its concentration and temperature.

$C = f(a, t)$ (10)

The heat transfer coefficient is determined by the formula

K=(2464-26,6) (11)

To determine the condensation temperature of the heating steam t_kn at its pressure P_ (g.k) we use the equation

$t_{кн} = 86 + 0.15P_{г.к}$ (12)

Combining the above equations (8.12) into a system, we obtain the following mathematical model of the statics of the evaporation process in vertically tubular apparatuses with distributed parameters

$$G_0 a_0 \frac{d}{dh}\left(\frac{i - ct}{a} - \frac{i}{a_0}\right) = K\pi d_{вн} n(t_{кн} - t);$$
$$t_{кип} = \frac{B_0 + b_1CB - 0.014P^2}{b_3(b_4 - b_5CB - b_6CB^2)};$$
$$i = 2482 + 1.97t$$
$$C = b_0 + b_1CB + b_2t + b_3CBt + b_4CB^2 + b_5t^2;$$
$$t_{кн} = 86 + 0.15P_{г.к}$$
$$K = (2464 - 26{,}6)\ CB$$

This model of the process makes it possible to study and analyze the process of concentration of tomato paste in the boiler pipes, as well as to reveal the nature of the distribution of their parameters along the height of the boiler pipes. Thanks to this, it becomes possible to design devices with optimal design parameters, as well as identify the disadvantages of the existing designs of evaporator plants.

The optimal value of the main structural parameter of the evaporators of their heating surface can be calculated by formulating the optimization problem and imposing restrictions on the technological parameters.

One of the calculation options is to take as a criterion for optimality the specific productivity of the apparatus, which determines its optimal heating surface.

One of the calculation options is to take as a criterion for optimality the specific productivity of the apparatus, which determines its optimal heating surface. Given technological G_0, a_0, t_0 and structural n, d_BH parameters, the required working height of the apparatus heating pipes (h) is detected.

The statics of the process of concentration of tomato paste according to its mathematical model (7) is studied using a computer according to the following algorithm:

The numerical values of the parameters are set: the pipe diameter d_BH, their number n, concentration, temperature and flow rate of tomato juice entering the apparatus - G_0, 〖CB〗 _0 and t_0; heating steam pressure in the casing of the apparatus P_ (g.k) and K.

From equation (12), characterizing the pressure of water vapor in the heating chamber P_ (g.k) of the apparatus, the condensation temperature of the heating steam t_kn.

The concentration increment Δa of the product is set, keeping in mind

$\Delta a_{.} = a_j - a_{j-1}$.

From the regression equation (8) obtained from experimental data, the boiling point of the product is determined. From equation (11), the heat transfer coefficient is determined.

SubstitutingValue, $t_{экс}$the enthalpy of solvent vapor is determined in equation (9).

Substituting the values of the parameters a and t in equation (10) determines the value of the specific heat of product C.

Substituting the numerical values of the parameters t_kn, t, i and C into equation (7), the concentration and temperature in this pipe section are calculated.

For given values of P and K, the calculation is repeated from paragraph 3 to paragraph 7, followed by verification of the condition:

a = 40% и $t = 85^0C$.

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The calculation is carried out to the optimum concentration of the product at a given pressure providing the optimal processing mode of tomato products.

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