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OPTIMIZATION OF DRYING OF FRUIT AND VEGETABLE PRODUCTS

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Annotation: Drying is one of the most ancient and widely used methods for preserving fruits and vegetables. The process reduces water activity, which inhibits microbial growth and enzymatic activity, ensuring extended shelf life. However, optimizing the drying process is crucial to preserve the nutritional value, color, texture, and flavor of the products while minimizing energy consumption and operational costs. **.** It is known that the drying process is one of the main links in reducing the costs of long-term storage and transportation of fruits and vegetables grown in agriculture. Accordingly, a systematic analysis of the process of drying fruits and vegetables was carried out in the research work, and the laws of interphase exchange in the capillary pore structure of the product during the heat-metabolism process, humidity and temperature changes in the layers of the product were studied. Based on research, a 6-level hierarchical structure was developed taking into account the generality of chemical, physic-chemical, biophysical, and metabolic processes This article delves into the principles of drying, factors affecting its efficiency, techniques for optimization, and advances in drying technologies for fruits and vegetables. The drying of fruit and vegetable products is a crucial process for preserving nutritional value, extending shelf life, and enhancing marketability.

Keywords: system, object, element, drying, heat and mass transfer, system analysis, drying apparatus, instantaneous pressure relief, analysis, method, process, mathematical model.

Introduction. Optimizing the drying process for fruits and vegetables is essential for producing high-quality, shelf-stable products efficiently. Advances in pre-treatment methods, drying technologies, and process control systems have significantly improved drying outcomes. However, ongoing research and innovation are needed to address energy consumption and sustainability challenges. By leveraging modern technologies and techniques, the drying industry can meet the growing demand for high-quality dried fruits and vegetables while minimizing its environmental footprint. However, traditional sun drying methods are inefficient, often resulting in significant losses due to spoilage, inconsistent quality, and low throughput. The optimization of drying processes is therefore essential for ensuring food security, minimizing waste, and maximizing economic benefits. Systematic analysis is one of the main methods of in-depth research of thermal and metabolic processes carried out in equipment and devices in chemical and food industry technology. The essence of systematic analysis, its structure, the principles of adequate resolution of any problems and issues in heat and metabolic processes, academician V.V. It is reflected in the research conducted by Kafarov [1]. Based on a systematic analysis, research aimed at solving the problems of modeling, management and design of chemical technology processes is presented by the authors in the research works on the modeling of biotechnological processes in the food industry [1,2,3].

Setting the problem and problem to be solved. The strategy of a systematic approach to drying technology includes the following steps in the construction of mathematical models of heat and metabolic processes:

- qualitative analysis of the drying process;

- synthesis of mathematical models of the drying process;

- checking the compatibility (adequacy) of mathematical models and determining the influence limits of the parameters affecting the object.

The drying process analyzed in the system is divided into functional subsystems with a certain integrity and appropriateness - the correct analysis of the material and energy relationship of the system elements during their interaction with each other and with the external environment, and creates a basis for solving existing issues. The hierarchical structure developed on this basis allows to identify different levels of detail that occur during the drying process.

In accordance with the above and the general principle of system analysis, we consider each apparatus and its process as an independent system and determine the following hierarchical structures of the main processes most necessary for the drying system.

Drying is the process of removing moisture from a product by the application of heat. The main objectives of drying fruits and vegetables are to prevent spoilage and reduce weight and volume, making storage and transportation easier. The process can be broken down into three main stages:

1. **Initial Heating:** The product absorbs heat, raising its temperature to the wet-bulb temperature of the drying environment.

2. **Constant Rate Period:** Water evaporates from the surface of the product at a constant rate. This stage is energy-intensive and largely dependent on external conditions such as air velocity and temperature.

3. **Falling Rate Period:** Internal moisture migrates to the surface, slowing the drying rate. This phase is influenced by the product's internal structure and composition.

Analysis of the experiment and obtained results. On the basis of research, a 6-level hierarchical structure was developed, taking into account the generality of chemical, physic-chemical, biophysical, and metabolic processes.

It is known that the number of hierarchical levels of each system determines the complexity of the system. Accordingly, this study is dedicated to the qualitative analysis of the processes occurring in the subsystems of the hierarchical structure developed for the drying process. In this context, the process belonging to each hierarchical level is described by input and output parameters that describe the behavior of the system in its subsystem. An effective method of drying fruits and vegetables will be developed, and research and development activities aimed at producing quality dried products will be carried out.

To study the drying process at the system, hardware and element level, the development of a systematic approach methodology makes it possible to obtain goal-oriented results. A multi-level hierarchical structure was developed for the purpose of learning.

Processes of the first stage of the hierarchy. At this stage of the hierarchy, a systematic analysis of the processes at the molecular level was carried out, and the changes of the liquid, gas system, protein and vitamins in the product during the drying process were analyzed.

The advantages of this stage are determined by the issues of maintaining the quality indicators of the product, choosing optimal technological modes, equal distribution of the pressure acting on the entire volume of the product, and speeding up the process based on the low-temperature drying mode.

Factors that negatively affect the technological process include: - protein denaturation at high temperature, loss of vitamins contained in the product, formation of a thin layer on the surface of the product being dried, which greatly affects the release of moisture from the inner layer, resulting in the entire volume of the product according to which moisture is not released at a uniform rate.

Processes of the second stage of the hierarchy. At this stage of the hierarchical structure, we consider the processes occurring in the molecules of the particle. The second stage of the drying process, that is, the movement of liquid droplets in the product as a result of the effects of pressure generation and instantaneous discharge in the drying chamber over a certain time unit, is considered, as is the change in volume due to the transition of liquid droplets at the molecular level in the capillary pore structure of the product from one phase to another.

Product mass in the drying chamber:

$m_{local} = \rho_{local} \cdot V_{local}$(1)

where - ρ_{local}product density in the drying chamber, kg/m ^{3}; V_{local}- product volume, m ^{3}.

In turn, the volume of the vapor-liquid mixture released from the product is equal to:

$$V_{water+steam} = V_{steam} \cdot V_{liquid\ drop} + V_{part.} \quad (2)$$

where V_{steam}- is the volume of the gas phase that is separated from the product; $V_{liquid\ drop}$- is the volume of the separated liquid droplets; V_{part}- is the partial volume of air.

The third stage of the hierarchy processes. At this stage of the hierarchy, processes occurring in the liquid and gas phases are analyzed. The input parameters of the stage: P_0 - initial pressure inside the product pretreatment device, MPa; t_0 - humid air temperature, ^{0}C; φ-relative humidity of humid air humidity; output parameters: τ_p- duration of instantaneous pressure action, min; t_2 - is the temperature in the drying chamber, ^{0} C; D is the diffusion coefficient, m ^{2} /c. Improving the efficiency of the drying process is achieved by changing the parameters, and by developing differential equations to study the process of material exchange occurring within the elements [2,5].

The amount of heat released from the liquid phase of the product is determined by the following equation:

$Q_{s.f.} = m_{local} \cdot s_{local}(t_1 - t_2)$(3)

where m_{local}- mass of the product; s_{local}- heat capacity; $t_1 - t_2$- initial and final temperatures of the product.

The processes of the fourth stage of the hierarchy. The processes characterizing the change in moisture content of the quasi-layers of the product being dried under the influence of the pressure and temperature created in the chamber are considered. The structural element of this level is the quasi-layer of the product and the liquid droplets and gas phase that are released from the quasi-layer of the product per unit of time. During the drying process, the wet product begins to take an equilibrium state due to the influence of the environment , therefore, the temperature and moisture content of the product change over time and can be expressed as a function of the coordinate :

$T = f(x, y, z, t) \qquad W^0 = f(x, y, z, t)$(5)

If we consider moist air at the minimum value of pressure R and temperature T as a binary mixture of ideal gases - dry air and water vapor, then according to Dalton's law we write the following [Dalton's book]:

$$P = P_{q.h} + P_p(6)$$

where: P -pressure of the vapor-gas mixture; $P_{q.h}$ -partial pressure of dry air; P_p -partial pressure of water vapor.

For an ideal gas in the free and saturated states, the Mendeleev -Clayperon equation is :

$$P_p = P_p \cdot M_p / RT(7)$$

where: M_p- mass of 1Mol of steam, kg; R -gas constant.

The components of the gas mixture (dry air and steam) that are released during the drying process have the same volume as the entire mixture:

$$\rho_{q.h} = \frac{m_{q.h}}{V} \qquad \rho_p = \frac{m_p}{V} \qquad (8)$$

where: $m_{q.h}$, m_p–mass of dry air and water vapor in humid air, kg; V- volume of humid air equal to the volume of dry air or the volume of vapor, m [3] .

The laws of operation of this system are expressed by the following input parameters: $t_0 \div t_n$ initial temperature in the product layers, ^{0} C; $W_0 \div W_n$ -initial humidity, %; P_0 -pressure, MPa and output parameters: P_1-pressure in the drying chamber, MPa; τ_p-pressure duration, min; W_k-final humidity in the product layers, %; τ_s-drying time, min; W_m-equilibrium humidity of the product, %. Effective organization of the drying process is achieved by selecting optimal values of the influencing parameters.

The fifth stage of the hierarchy processes. At this stage of the hierarchy, the processes characterizing the drying kinetics over the entire volume of the product are analyzed. The change in moisture content in the product at each stage of the proposed combination drying method is analyzed and the threshold values of the influencing factors are determined.

Input parameters of influencing factors: P_0 - air pressure supplied by the compressor in the working chamber, MPa; φ-relative humidity %; W_0 -initial moisture content of the product, %; F-contact surface of the product, m^2 , t_0 -product temperature, δ-product thickness, mm. Output parameters: P_{um} - total pressure in the working chamber, MPa; $W_{(\tau)}$ – change in product moisture content per unit of time, %, D-diffusion coefficient, m^2/c, τ_s–drying time, min.

Acceleration of the drying process is achieved by creating a pressure at a threshold value of 0.2-0.8 MPa during the initial processing of the product and using the method of instantaneously releasing it.

the melting temperature T of a substance and pressure according to the Clausius-Clapeyron equation as follows:

$$\frac{dT_{melting}}{dP} = \frac{mT_{steam}}{r_{steam}}\left(\frac{1}{\rho_s} - \frac{1}{\rho_q}\right), (9)$$

where: m is the mass of the solid phase, kg; ρ_s is the density of the liquid, kg/m [3] ; ρ_q is the density of the solid phase, kg/m [3] .

This equation allows us to calculate the heat of fusion of a substance in relation to the pressure generated. In addition, by determining the relationship between r vapor and T vapor, we can calculate the heat of fusion of a liquid . and the difference in heat capacity of the solid phase can be calculated. During the drying process of capillary - porous materials, phase change occurs within the capillaries . The evaporation temperature of the liquid contained in the product depends on the pressure and is described as follows [1,2,3,5] :

$$\frac{dT_{melting}}{dP} = \frac{T_{steam}}{\nu \cdot r_{steam}}\left(V_{gas} - V_s\right), (10)$$

where: r_{steam} - heat of vaporization 1mol J/kg; V_{gas} - volume of the gas phase; V_s - volume of the liquid phase.

The selection of technological modes that allow maintaining the quality indicators of the product, including ensuring an even distribution of the applied pressure throughout the entire volume of the product, and studies on accelerating the drying process by using a low-temperature regime, determine the advantages of the stage.

Sixth stage processes of the hierarchy. At this stage of the hierarchical structure, the drying process was studied at the level of the apparatus and elements, and the totality of phenomena was analyzed. The processes occurring at the scale of the drying apparatus can be described by the following input parameters: P_0 - air pressure supplied by the compressor in the working chamber, MPa; φ-relative humidity %; W_0 - initial moisture content of the product,%; F-contact surface of the product, m^2 , t_0 -product temperature, δ-product thickness, mm. Output parameters: P_{um} - total pressure in the working chamber, MPa; $W_{(\tau)}$ – change in product moisture content per unit of time, %, D-diffusion coefficient, m^2/c, τ_s–drying time, min. Improving the efficiency of the drying process is achieved by determining the optimal limit values of the influencing parameters and using a two-stage drying method.

Conclusion. In this research work, an analysis and a hierarchical structure of the drying process of fruits and vegetables with a capillary-porous structure were developed, a semantic analysis of phenomena and elementary processes, and a qualitative analysis of mathematical descriptions were carried out to develop a mathematical model. This allows for a rational mathematical description of elementary processes, combining them into separate subsystems within a hierarchical structure. This creates a basis for solving the problems of mathematical modeling of the drying process in hierarchical stages.

References:

Кафаров В.В., Глебов М.Б. Математическое моделирование основных процессов химических производств. -М.: Высшая школа. 1991. -400 с.

Артиков А.А., Джураев Х.Ф., Баракаев Б.Н. Системное мышление, анализ и нахождение оптимальных решений (на примерах инженерной технологии). Издательство «Дурдона». Бухара. 2019. 185с.

Mujumdar, A. S. (2014). Principles, Classification, and Selection of Dryers. In Handbook of Industrial Drying.

Гинзбург А.С. Основы теории и техники сушки пищевых продуктов. -М.: Пищевая промышленность. 1973 . –528 с.

Rustamov E.S., Artikov A., Djurayev X. F System thinking in analysis of device for removing moisture from the material by instantaneous pressure release. // Technical science and innovation. Tashkent, 2021. №4, pp 308-312.

Лыков М.В..Михайлов Ю.А. Теория тепло- и массопереноса. –М.: Госэнергоиздат. 1963. -536с.

Arun, S., & Sagar, V. R. (2014). Effect of drying methods on nutritional composition of fruits and vegetables. Journal of Food Science and Technology, 51(6), 1076-1082.

Vega-Gálvez, A., et al. (2012). Effect of drying method on quality of dried vegetables. Food Chemistry, 134(1), 632-639.

Rustamov E.S., Djuraev Kh.F.,Gafurov K.Kh. Kinetics of fruit crops drying with instant pressure release. // The American Journal of Engineering and Technology. USA, 2020. Volume 02 Issue 10. pp 45-54.

Rustamov E.S., Djuraev Kh.F.,Gafurov K.Kh. Research of the process of apricot fruit drying with instant pressure release. // International Journal For Innovative Engineering and Management Research. USA, 2021. Volume 10, Issue 03, pp 219-226.