Results of experiments conducted in a helio water heating convective drying plant

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Abstract. This article describes the drying process in a solar heating system. Medicinal herbs were analyzed to analyze the process. Systematic analysis was studied to optimize the process. Analytical methods of mathematical modeling were considered and the optimal temperature was selected. Using experiments on the computer and the physical model, the correction of the computer model in terms of mass transfer coefficient and heat transfer coefficient was carried out.

1. Introduction

Chemical, food, pharmaceutical, machine-building production, which implements a certain complex production technology, is a specific chemical-technological system (CTS), which requires production management contributing to high productivity and low costs to ensure that the product of the required quality is obtained and to realize the maximum possible environmental safety of production [1,2].

Drying is an operation that removes free water and some of the bound water without affecting the chemical structure of the plant material. The goal of this process is to reduce weight and minimize the risks of many unwanted chemical changes [3]. Drying triggers a complex phenomenon of heat and mass transfer. Hence the variety of drying modes and models.

2. Materials and methods

In industry, to carry out the drying process of medicinal plants, mainly the natural method is used, convective, greenhouse, chamber dryers that operate using solar and electric energy of high temperature and have a number of significant disadvantages: large dimensions and metal consumption, complexity of maintenance and repair, large heat and energy costs, minimum preservation of biologically active substances in the composition of the final product, etc.

To carry out the research, an experimental helium-water-heating convective drying unit was made, which makes it possible to carry out the process of dehydration and fixing the optimal parameters of dried medicinal plants (Fig. 1.).

Figure 1 shows a laboratory solar water heating drying plant. It consists of a flat collector with a surface of 2 m², a drying chamber with a volume of 1.5 × 2.5 m and a centrifugal fan. Drying experiments were carried out in August and September 2019.
3. Analysis of the structure of the water heater dryer

On the basis of systems thinking, a solar water heating convective drying plant is analyzed. The use of the method of multistage analysis for a solar water heating drying installation allows considering the deep phenomena in it [4-6].

In the first hierarchical stage, a water-heating convective drying plant is considered in the form of a system with a material drying process.

In the second hierarchical stage, it is taken into account that the solar water heating convection drying plant consists of supply elements, heating agents - water, a working zone and zones for removing agents. Indicators are determined - the input and output parameters of each subsystem.

At the third hierarchical stage, the long working area of the solar water heating drying plant can be represented as multi-apparatus. A multi-stage system analysis considered the installation, which is divided into quasi-devices of 8 pallets. Indicators are determined - input and output parameters of each subsystem - quasi-apparatus.

In the fourth hierarchical level, each quasi-apparatus can be imagined that each pallet consists of quasi-apparatuses, quasi-apparatuses of the material heating pipe and air. Indicators are determined - the input and output parameters of each subsystem.

In the fifth hierarchical level, In turn, the material can be divided into elements - quasi-devices, these are pieces or particles. Each element - a quasi-apparatus (pieces or particles) consists of quasi-layers. Indicators are determined - the input and output parameters of each subsystem.

By means of experiments on a computer and physical model, the correction, consistency of the computer model with the correction for the mass transfer coefficient and the heat transfer coefficient was carried out [7-9].

In the laboratory drying installation, the coolant - water is supplied by heat-conducting pipes 7, which are heated from the collector 1. A pump 2 is installed at the top, with the help of which the water flow is regulated and lowered down. Further, this water moves up the rows, heating the inner chamber of the dryer. Heat transfer pipes 7 are attached to the frame of the drying chamber by means of special fasteners. Hot water is used as a heat agent. Removable trays 6 are placed in the water heating drying unit. The movement of hot water ensures a uniform flow of heat through the unit. The temperature is controlled by thermocouples 3. It can be adjusted if necessary. In order to maximize the

Figure 1. Schematic diagram of laboratory solar water heating plant: 1-solar collector; 2-circulation pump; 3-thermocouple; 4-control unit; 5-scales with digital display; 6-pallets; 7-pipelines; 8-raw material; 9-stand.
quality of the final product, the temperature is automatically maintained during the drying process using a thermostat located in the chamber.

The proposed design of the solar water heating convection unit allows intensifying the technological process of drying plant raw materials, in particular, ginger roots.

Fresh ginger roots were sorted out, the dirt was removed and the remaining dirt was cleared of other contaminants. They were cut into rings with a thickness of 0.5-0.6 mm and pre-dried in the shade in the open air for 1 - 2 hours to reduce the initial moisture content.

The input and output parameters of the elements at each stage of the hierarchy were determined, the interactions of the parameters of the selected system were determined, and a step-by-step multistage system analysis of drying was carried out.

Input parameters of the investigated object - helium-water heating convective installation: the mass of the material to be dried, the amount of moisture in it, temperature, mass transfer coefficient, density and heat capacity of the material; mass (consumption), density, heat capacity, air temperature, the amount of energy supplied to the device.

The output parameters also correspond to the mass of the material, the concentration of moisture in the composition, temperature, humidity, pressure, the amount of energy expended, etc.

| Table 1. The process of drying ginger root at 70 °C with a mass of 70 g. |
|------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|
| time, s          | Weight, g       | Temperature, \( \text{X}_{\text{exp}} \) °C | X_{acc}          | \( \Delta X \)  | \( \Delta X^2 \) |
| 0                | 70              | 70             | 70              | 70              | 0               | 0               |
| 5560             | 52.5            | 69             | 59.6            | 60              | -0.4            | 0.16            |
| 7800             | 47.8            | 69.6           | 52.6            | 54.5            | -1.85           | 3.42            |
| 10100            | 40.4            | 69.7           | 49.7            | 49.4            | 0.3             | 0.09            |
| 15000            | 34.4            | 69.9           | 41.1            | 39.3            | 1.8             | 3.24            |
| 19600            | 32.1            | 69.96          | 33              | 32.2            | 0.8             | 0.64            |
| 25000            | 28.2            | 69.98          | 25              | 26.1            | -1.1            | 1.21            |
| 30000            | 26.8            | 69.99          | 21              | 21.5            | -0.5            | 0.25            |
| 35000            | 25.9            | 69.99          | 18.8            | 18.7            | 0.1             | 0.01            |
| 42000            | 24.8            | 70             | 15.2            | 15.3            | -0.1            | 0.01            |

Mean square deviation:

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\sigma = \sqrt{\frac{\sum \Delta x^2}{n}} = 0.95
\] (1)
Figure 2. Diagram of the drying process of ginger root at 70 °C with a mass of 70 g.
(the red line is the result of the experiment, the black line is the graph of the change in humidity over time, calculated in the model).

The experiments were carried out on the basis of the initial data of the helium-water heating drying installation and the values of the change in material moisture, the temperature of the material, the mass of the material to be dried, the amount of water passing into the gas phase, the work performed by the energy for drying the material were obtained. They are in good agreement with the results obtained on the mathematical model (Fig. 2). On this basis, we can recommend a number of ways to optimize this installation and its use in the production of thermolabile drugs.

4. Conclusion
On the basis of systems thinking, a solar water heating convective drying plant is analyzed. A multi-stage system analysis divides the installation into quasi-devices - pallets (each pallet consists of quasi-devices), heating pipe, material, housing and air. The material is divided into pieces or into particles based on a quasi-apparatus. With the introduction of the initial data, experiments were carried out to establish changes in the moisture content of the material, the temperature of the material, the mass of the material to be dried, the amount of water passing into the gas phase, the work performed by energy to dry the material. They are in good agreement with the results obtained on the mathematical model. On this basis, it is possible to recommend the use of a solar water heating convection drying plant.

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