Технічні науки

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EXPERIMENTAL RESEARCH OF THE PHYSICAL MODEL OF THE PROCESS OF DRYING FRUIT AND VEGETABLE RAW MATERIALS USING A THERMOELECTRIC HEAT PUMP

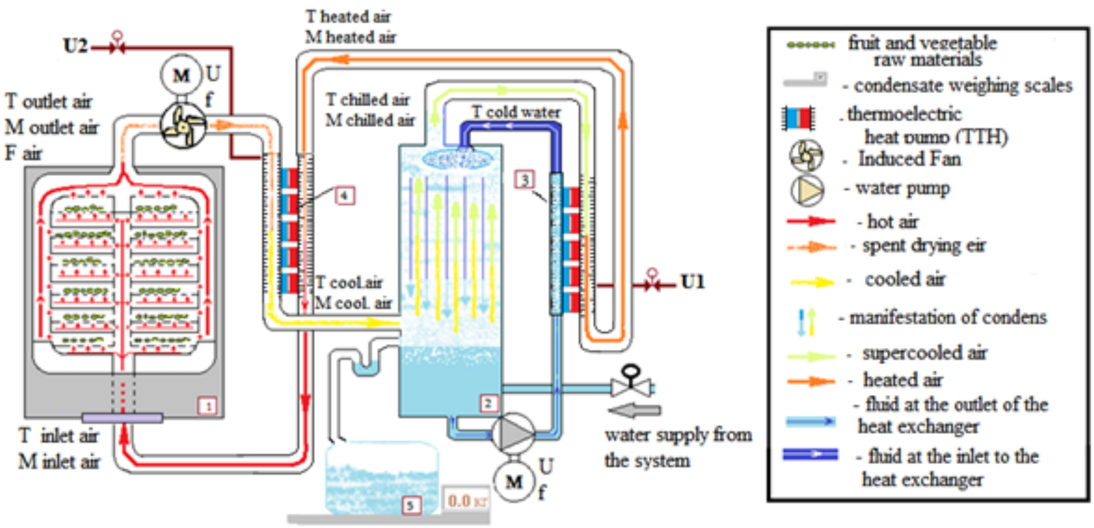
Summary. *The optimal drying mode is created with minimal heat and energy consumption and maximum preservation of nutritional properties. Therefore, the issue of process automation is increasingly important for modern enterprises. A review of existing developments reveals significant shortcomings. The Department of Process Automation and Robotics Systems has developed a new approach to automating one of the product drying processes, namely condensation drying of fruit and vegetable raw materials using thermoelectric heat pumps.*

That is why condensing drying using thermoelectric heat pumps will help to reduce energy consumption by implementing energy-efficient modes in the drying process, in particular, by improving the control system.

This article discusses the implementation and feasibility of using the physical model as an experimental setup to obtain the necessary data for further implementation in the construction of a simulation model of condensation drying with thermoelectric heat pumps, for automation and energy-efficient process control.

Key words: *physical model, condensing chamber, thermoelectric heat pump, energy efficiency, transient process.*

Introduction. This drying process is carried out by convective moisture removal from the product [1]. When loading the initial product into the chamber, it is placed on trays with a mesh surface. The chamber has trays with a mesh surface on which the product is loaded. Below, under the trays, there is a fan that supplies the heated dry drying agent to the annular perforated air channel located around the periphery of the drying chamber, and from it to the gaps between the trays with the product. In the center of the dryer, a perforated pipe passes through the trays, allowing the moisture-saturated drying agent to exit the chamber and be cooled by an air-to-air thermoelectric heat pump. There it is cooled to almost dew point temperature, at which its relative humidity is 95-98%. The cooled drying agent then enters the condenser where it is supercooled below the dew point to form condensate, where it flows to the collector, while its absolute humidity decreases. From the condenser outlet, the supercooled drying agent with a relative humidity of 100% enters the inlet of the water-to-air heat pump, where it is heated by 10-20 *C, and its relative humidity is reduced to 50-70%. From the outlet of the water-to-air heat pump, the heated drying agent enters the inlet of the air-to-air heat pump, where it is heated by another 10-20 *C and its relative humidity is reduced to 15-30%, which corresponds to the set parameters at the inlet of the dryer chamber [2,3]. Figure 1. shows the technological scheme of the drying station, which shows the main structural elements.



In Figure 1: 1 - drying chamber; 2 - contact heat exchanger (CHE);

3 - TTN (air-water); 4 - TTN (air-air); 5 - condensate tank.

Fig. 1. Flow chart of the process of condensation drying of fruit and sheep raw materials using the heat exchanger

Based on the existing developments, discussions, and information on apple drying by convection, a physical model was designed, followed by research and experiments. Figure 2 shows a photo of a physical model of a condensation chamber for drying fruit and vegetable raw materials using a thermoelectric heat pump.

Fig. 2. Physical model of a condensation chamber for drying fruit and vegetable raw materials using a thermoelectric heat pump.

The main part. After connecting our physical model to the data logging and plotting the dryer parameters, it was decided to review the ability of our system to monitor and record transient data. The transients inside the chamber were checked without loading the product. Figure 3 shows transient plots taken from an empty physical condensing dryer using thermoelectric heat pumps.

After setting up our physical model according to the drying parameters: relative humidity of the inlet drying agent = 20% (M inlet) and temperature of the inlet drying agent = 60*C (T inlet) and air flow rate = 1.5 m/s (V), the drying process was simulated by condensing drying using thermoelectric heat pumps.

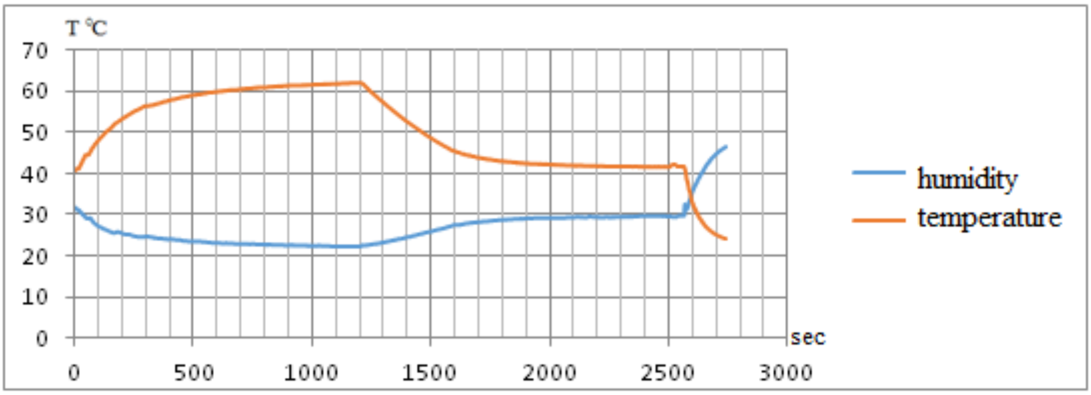


Fig. 3. Transients taken from an empty physical condensing dryer

After conducting the experiment, we can observe that the parameters at the output and input of the chamber remain unchanged and see from the graphs of transients that there is a direct proportional relationship between the parameters of temperature and relative moisture of the drying agent. This indicates that the system works accordingly, since no product is dried, in the process of condensation drying the air is recuperated, the temperature and humidity are equivalent to the parameters at the inlet and outlet, the amount of condensate taken is not variable.

The development of a new technology for the preparation of apple snacks makes it possible to obtain a product with a low calorie content and a balanced chemical composition. In order to establish the optimal specific load of the semi-finished product, the study showed that the optimal specific load on the dryer is 6-8 kg/m2 [4; 5].

Golden apples were chosen as the raw material for drying. This apple variety is characterized by high initial indicators, including sugar content and sugar-acid index. A particular advantage of these apples is their large fruit size, higher ratio of pulp to seed chamber compared to other varieties, and lower skin thickness. This minimizes waste, which is essential, especially on an industrial scale.

For example, when drying fruit, the temperature of the material must not exceed the maximum permissible temperature. Higher temperatures are not beneficial for some food products. As noted by Vega-Galvez et al. [6] and Turhan et al. [7], it is advisable to use a temperature not exceeding 70 °C for drying. Based on this, we can note that the temperature of the drying agent at the inlet to the chamber should be at 60 °C for the optimal drying process of apple crisps.

After setting up our physical model according to the drying parameters: relative humidity of the inlet drying agent = 10% (M inlet) and temperature of the inlet drying agent = 60*C (T inlet) and air flow rate = 1.5 m/s (V), the drying process was carried out by means of condensation drying using thermoelectric heat pumps. The results of the experiment are shown in Figure 4 - a graph of the transient parameters of the drying agent at the outlet of the physical model of the chamber loaded with apple slices. Figure 5 shows the graphs of intermediate parameters such as the temperature of cold water supplied to the contact heat exchanger and the temperature of the cooled drying agent at the outlet of the contact heat exchanger.

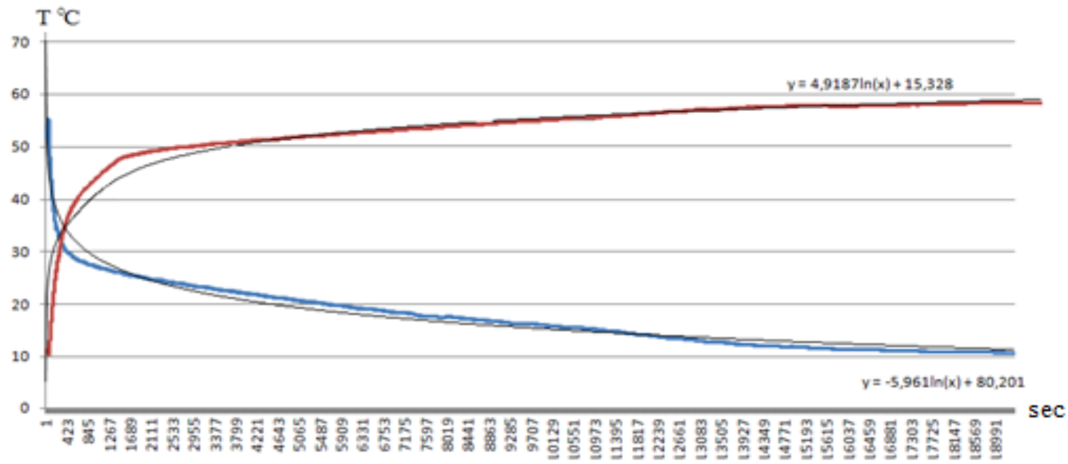


Fig. 4. Graph of transient parameters of the drying agent at the output of the physical model of the chamber loaded with apple slices

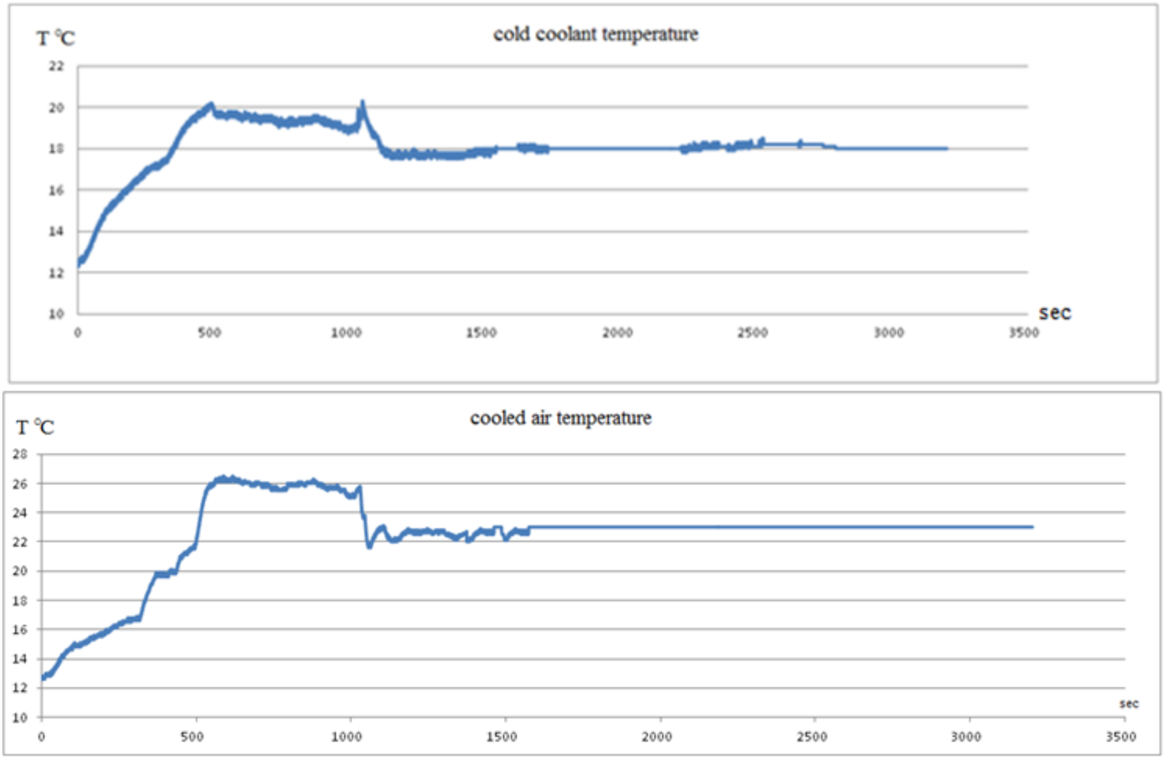


Fig. 5. Graphs of intermediate parameters such as the temperature of the cold water supplied to the contact heat exchanger and the temperature of the cooled drying agent at the outlet of the contact heat exchanger

After conducting an experiment with drying apple slices with a slice thickness of 5-7 mm during a drying time of about 6 hours, we can see that the finished product retains its nutritional value and is ready for storage. Since the condensation stopped accumulating and, accordingly, the output parameters of the drying agent became equal to the input parameters, it was decided to stop the drying process.

For the technological process of apple drying, the control channel has the property of self-leveling. An increase in the control action (u1), the current through the thermoelectric converter of the air-to-water heat pump, will reduce the temperature of the cold water - which, in turn, will reduce the temperature of the drying agent at the outlet of the condenser. An increase in the control action (u2), the current through the air-to-air thermoelectric converter, will increase the temperature and decrease the relative humidity of the drying agent at the inlet to the drying chamber and, conversely, will decrease the temperature and increase the relative humidity of the drying agent at the outlet to the condenser. Active experiments can only be conducted with channels whose input variables are available for targeted change. These are, first of all, control actions.

The next step is to build graphs of the static properties of the raw material drying process using thermoelectric heat pumps in accordance with changes in other dryer parameters. The graphs are shown in figures 6-11.

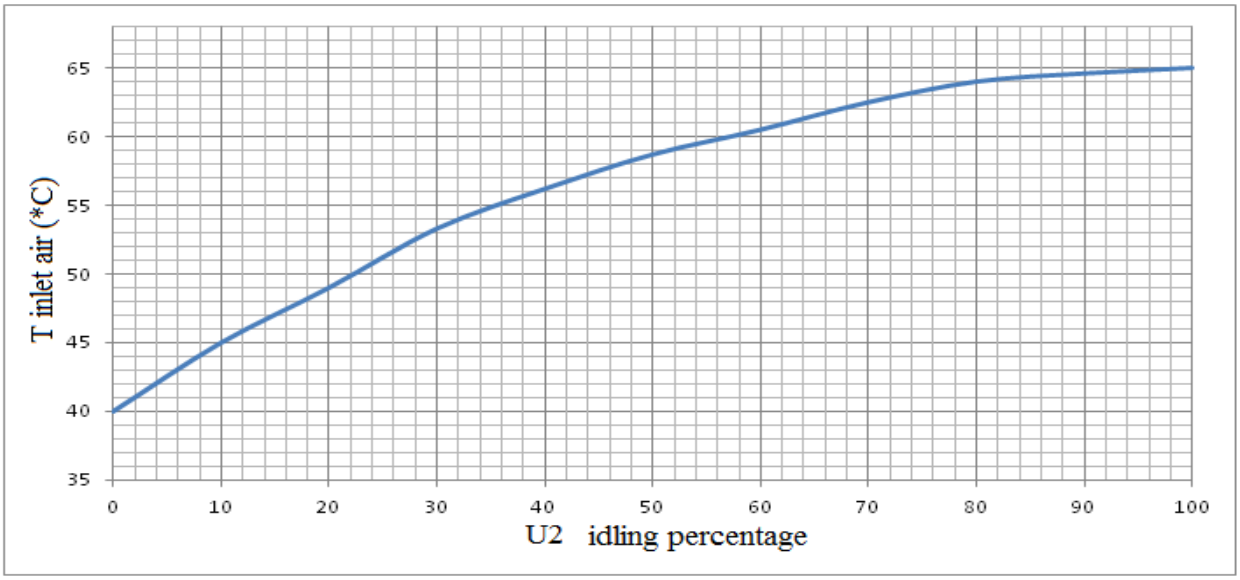


Fig. 6. Change of inlet air temperature by control action change ration u2

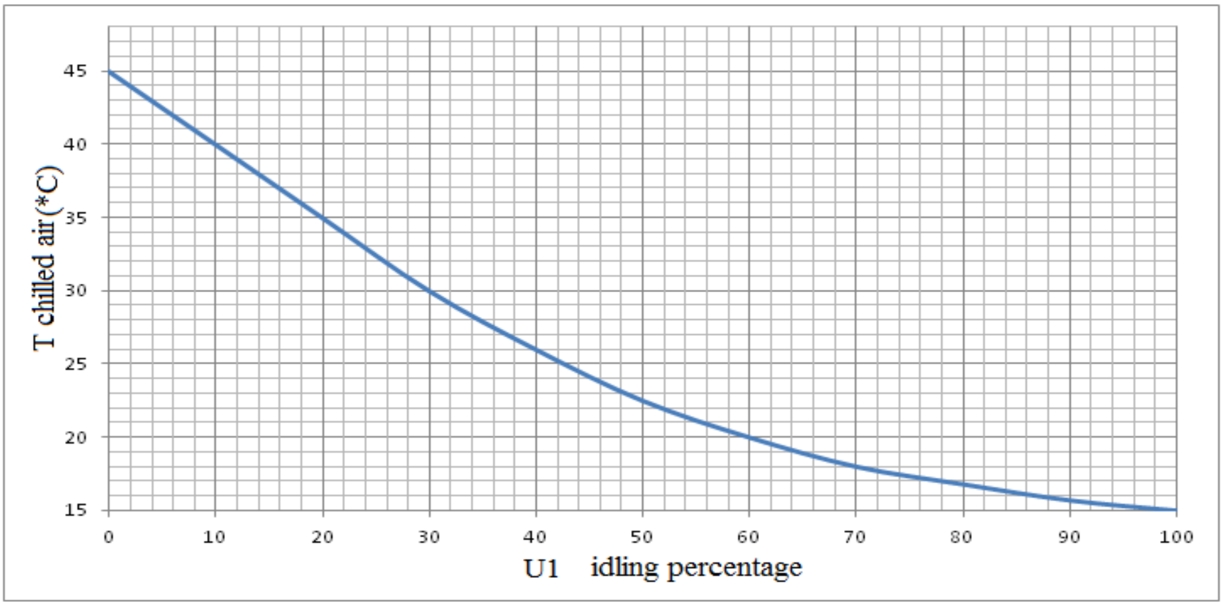


Fig. 7. Change of chilled air temperature by control action change ration u1

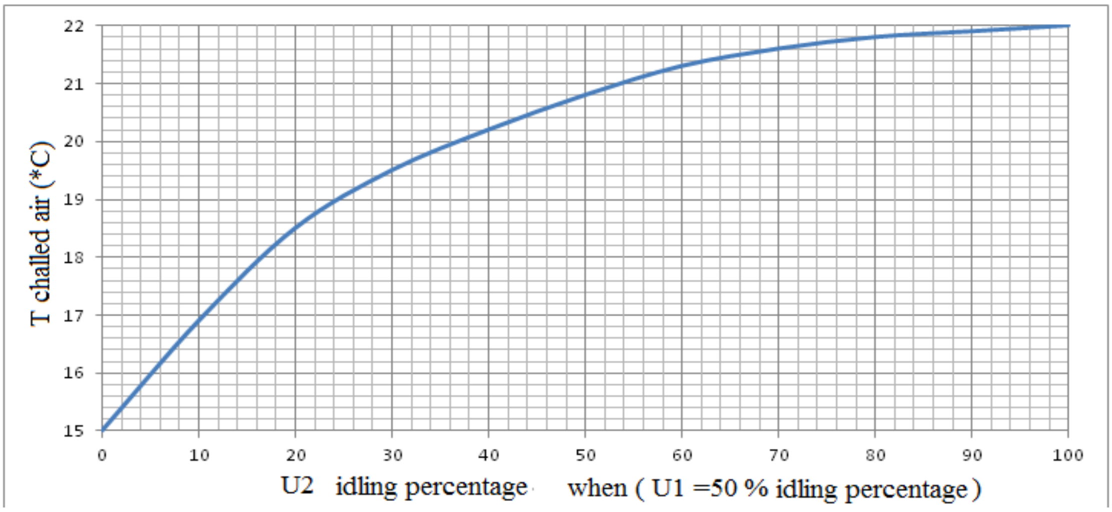


Fig. 8. Change of chilled air temperature by control action change ration u2 when u1=50% indling

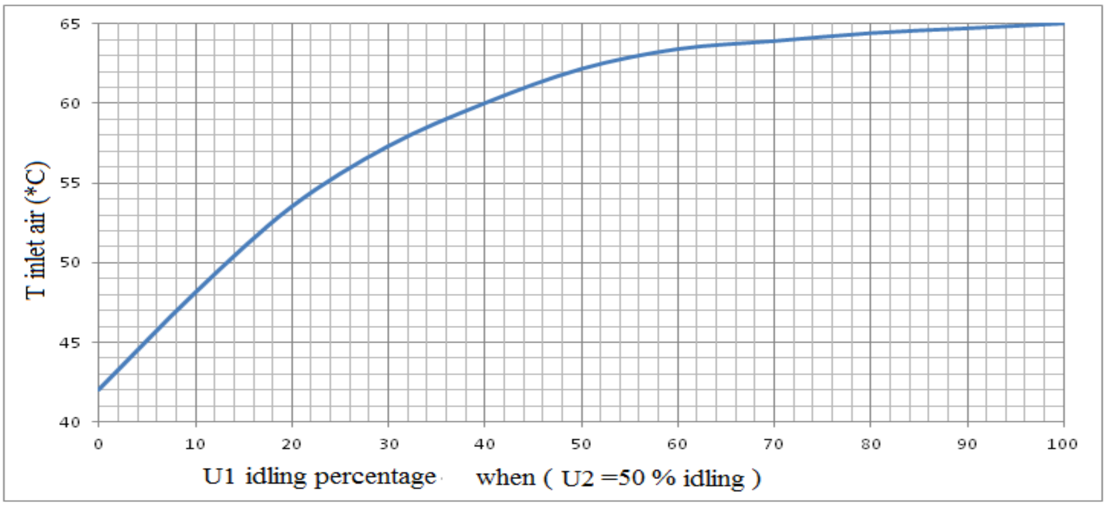


Fig. 9. Change of chilled air temperature by control action change ration u1 when u2=50% indling

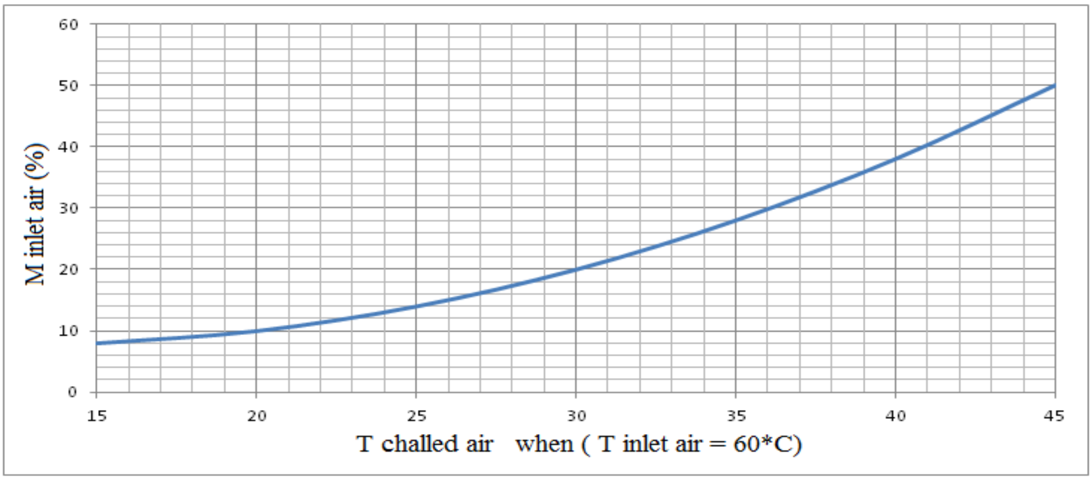


Fig. 10. Change in the relative humidity of the inlet air relative to the change in the chilled air temperature at the outlet from the contact utilize

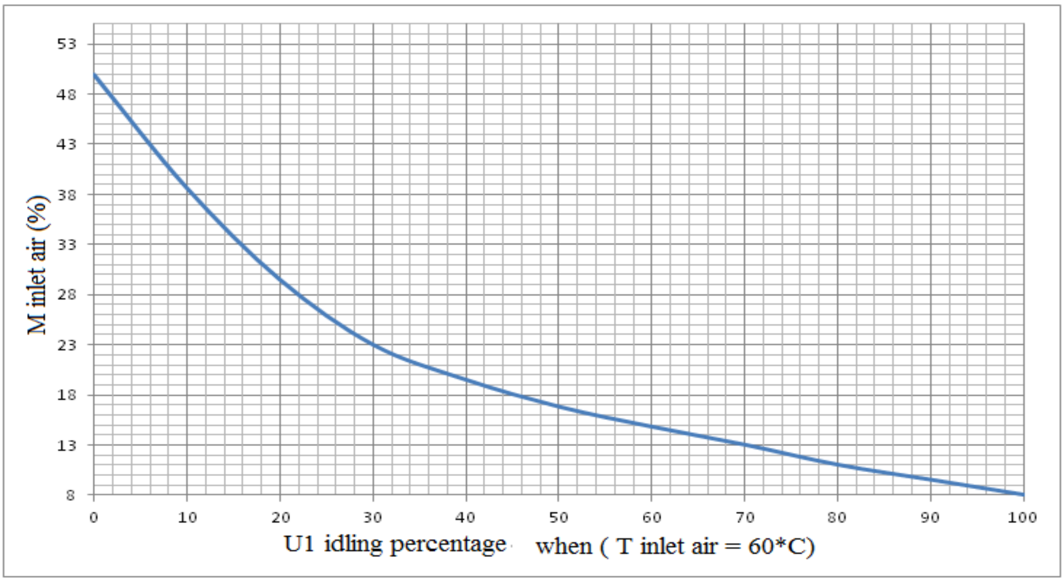


Fig. 11. Change in the relative humidity of the inlet air by control action change ration u1

Conclusion. Experimental studies have shown that the physical model works correctly, which allows us to understand and analyze the transient characteristics that occur during the drying process and which will need to be further developed. This article demonstrates the ability of this setup in its implementation and further research to automate the energy-efficient control system of the condensation chamber for drying fruit and vegetable raw materials using thermoelectric heat pumps.

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