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TEMPERATURE MODE OF VACUUM FREEZE DRYING

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ТЕМПЕРАТУРНЫЙ РЕЖИМ ВАКУУМНОЙ СУБЛИМАЦИОННОЙ СУШКИ

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ABSTRACT

The energy saving trend is reflected in all processing industries, including food production. In this regard, this article discusses the process of freeze-drying fruits at temperatures of moisture removal from -5 to -30 ° C, corresponding to the depth of vacuum in a laboratory dryer, as well as various modes of operation of the refrigerator and vacuum pump, in order to find the optimal mode of lyophilization. Prior to freeze-drying, fruits were cut into slices, then frozen under conditions of forced convection in the same chamber where sublimation occurs at a temperature of –30°C. C. The temperature at the final drying stage is 35–38 º C. The final moisture content of the dried fruits was 2–2.2%. Lowering the sublimation temperature from -5 to -30 º C leads to an increase in the drying time from 9 to 20 hours. It is noted that lowering the sublimation temperature from -5 to -30 º C leads to an increase in total energy consumption. At a sublimation temperature of –5 º C, the specific power consumption is 2–2.2 kWh/kg of removed moisture. When the sublimation temperature drops to –30 º C, this indicator increases to 3.8–4.2 kWh/kg of removed moisture. The ways of reducing the specific energy consumption for vacuum freeze drying by changing the mode are shown.

АННОТАЦИЯ

Тенденция энергосбережения отражает во всех перерабатывающих отраслях промышленности, включая пищевые производства. В связи с этим в данной статье рассматривается процесс сублимационной сушки фруктов при температурах удаления влаги от –5 до –30 о С, соответствующей глубине вакуума в лабораторном сушильном устройстве, а также различных режимах работы холодильной машины и вакуумного насоса, чтобы найти оптимальный режим леофилизации. До начала сублимационной сушки фрукты нарезали в виде ломтиков, затем замораживали в условиях вынужденной конвекции в той же камере где происходит сублимация при температуре –30 º С. По окончании этапа замораживания сушку осуществляли при различных температурах на этапе сублимации

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в диапазоне –5… –30 ° С. Температура на стадии досушки равна 35–38 ° С. Конечная влажность высушенных фруктов составила 2–2,2 %. Понижение температуры сублимации с –5 до –30 ° С приводит к увеличению длительности сушки с 9 до 20 ч. При этом отмечается, что понижение температуры сублимации с –5 до –30 ° С ведет к увеличению общих энергозатрат. При температуре сублимации –5 ° С удельный расход электроэнергии составляет 2–2,2 кВт·ч/кг удаленной влаги. При понижении температуры сублимации до –30 ° С этот показатель возрастает до 3,8–4,2 кВт·ч/кг удаленной влаги. Показаны пути снижения удельных энергозатрат на вакуумную сублимационную сушку посредством изменение режима.

Keywords: vacuum freeze drying, temperature conditions, energy consumption
Ключевые слова: вакуумная сублимационная сушка, температурные режимы, энергозатраты.

Introduction

Freeze drying is the removal of moisture from frozen materials by sublimation (sublimation) of ice, i.e., its direct transition to a vapor state, bypassing the liquid phase.

This process can be carried out in natural conditions. Some materials are freeze-dried outdoors during the winter frosts. However, the sublimation of ice at atmospheric pressure under natural conditions is very slow.

In industrial dryers, an increase in the intensity of ice sublimation is achieved, usually by reducing the pressure above the material. During the main dehydration, the material is in a frozen state, so the microstructure and properties of the material are preserved to the maximum extent [1]. Sublimation-dried products retain their original volume and easily absorb moisture during hydration; color, aroma, content of vitamins and other components change little. Properly packaged, they will not deteriorate when stored for a long time under normal storage conditions (at uncontrolled temperature and humidity).

Moisture in the vapor state can be removed from the product by phase transformations: a) liquid - steam (thermal drying) or b) solid phase - steam (freeze-drying).

The conditions for the implementation of each of these drying processes are visible from the phase equilibrium diagram for water in the coordinates of vapor pressure - temperature (Fig. 1).

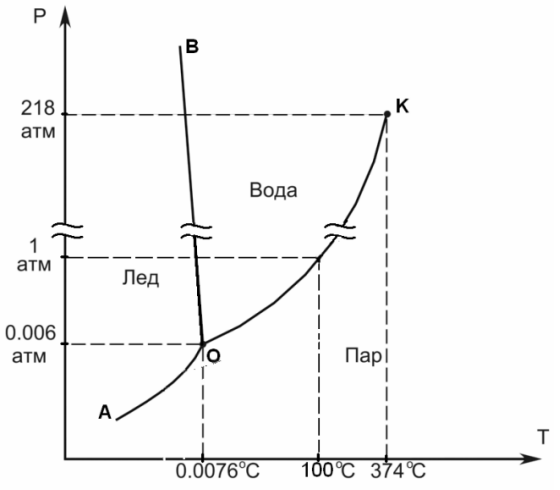

Figure 1. P-T water chart

AO - dependence of saturated vapor pressure over ice on temperature (sublimation temperature dependence on pressure) OK - dependence of saturated vapor pressure over liquid on temperature (boiling temperature dependence on pressure) OB - dependence of ice melting temperature on pressure O - triple point (three phases coexist : ice, water, steam) K - critical point (the distinction between gas and liquid disappears)Опыт и результаты

Quality is one of the main indicators of the effectiveness of the technological system. It is the result of an interconnected dynamic change in regime parameters and thermophysical properties of processing objects [2, 3]. The quality level of each specific product can be assessed based on dozens of local indicators.

On fig. Figure 2 shows the calculated dependence of the change in the quality level Δ of dry material at different dehumidification temperatures. From fig. 2 it follows that the quality of the product will be the higher, the lower its temperature during drying, and, consequently, the rate of decomposition determined by this temperature, as well as the shorter the residence time of the product at this temperature. This is a general, fundamental regularity based on generally accepted relationships of changes in the properties of thermolabile biological objects under various temperature effects on them [4–7].

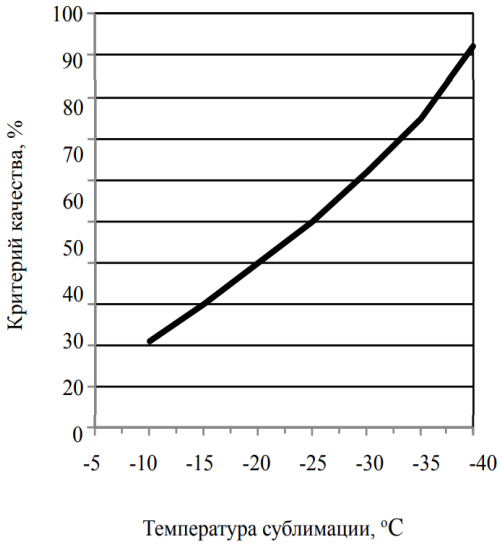

Figure 2. Calculated dependence of the complex quality index (as a percentage of the maximum level) on the temperature of the "ice-steam" phase transition

However, for practical use, specific numerical values obtained in relation to dryers used in industrial production are of interest. The paper presents the results on changes in regime parameters, energy consumption and the quality of the dried material, obtained using a sublimation unit. This plant is of periodic operation, with conductive heat supply and a capacity of up to 3 kg of raw material/drying cycle. The general view of the installation is shown in fig. 3.

Figure 3. schematic diagram and real view of the installation

1-chamber, 2-control panel, 3-chamber temperature sensor, 4-feed temperature sensor, 5-cover and sight glass, 6-vacuum release valve, 7-vacuum pump, 8-expressor valve, 9-compressor , 10-condenser, 11-heater, 12-evaporator

The computer control system of the plant allows to automatically maintain the set pressure in the drying chamber by gradually turning on two vacuum pumps of different capacities and opening/closing the vacuum valves on the suction line. The set temperature of the desublimator is provided by the operation of the refrigeration machine in the start-stop mode and the corresponding setting of the expansion valve. The objects of drying were apples, pears. Prior to freeze-drying, fruits were cut into slices, then frozen under conditions of forced convection in the same chamber where sublimation occurs at a temperature of –30°C. C. The temperature at the final drying stage is 35–38 o C. The total duration of the process and the duration of the sublimation stage were recorded by the change in temperature in the layer of dried raw materials. Another reliable sign of the completion of the entire drying cycle was the cessation of pressure increase in the chamber when the vacuum valves on the suction line were closed. The total duration of the drying cycle varied within 9–20 h. The final moisture content of the dried samples was 2–2.2%.

Conclusions

The results obtained allow us to draw important conclusions for industrial production.

1. Drying at lower and lower sublimation temperatures leads to an increase in total energy consumption. For example, at a sublimation temperature of –5 o C, the specific power consumption is 2–2.2 kWh/kg of removed moisture. When the sublimation temperature drops to –30 o C, this indicator increases to 3.7–4.2 kWh/kg of removed moisture. Numerical values are obtained on the basis of real measurements of consumed electricity in a laboratory stand.

2. In the practice of industrial production of sublimated products from vegetable raw materials, the rational range of sublimation temperatures is considered to be the temperature range corresponding to the inflection on the curve of dependence of the proportion of frozen moisture on temperature. In our example, this temperature range is from -9 to -16 o C. In this area, the crystallization of free moisture and moisture with low

binding energy ends, and the solidification of moisture with high binding energy begins, the amount of which in most plant origin products is not large.

3. An increase in the duration of drying leads to a proportional decrease in the amount of finished dry products per unit of time.

4. When creating large-scale industrial production of freeze-dried products with a wide range of processed raw materials, it is advisable to immediately provide for the use of several types of drying devices.

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