Influence of microwave pretreatments on the duration of freeze-drying of onions and beets

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Abstract. In the work, an overview of freeze-drying was made, as well as the use of pre-treatments with microwave waves. The change in temperature during freeze-drying of onion and beet samples with and without pre-treatment was experimentally studied. When processing the product with short-wave electromagnetic waves, it was noticed that the freeze-drying process without pre-treatment of the product was 5 hours longer than for dried samples with pre-treatment in the microwave range.

1 Introduction

The previous years of development of freeze-dried food preservation were the period of introduction of advanced drying technologies that ensure high quality products. At the same time, this period was a period of high energy intensity of production and irrational and inefficient use of new equipment.

At present, the main directions of development of freeze dryers are modern methods of accelerating the process, including methods of special processing of drying materials, methods of intensive heat transfer to the sublimation zone and removal of water vapor from the sublimation zone to increase the evaporation surface of sublimation apparatus and improve efficiency.

High process acceleration in drying liquid and pasty materials can be achieved when the thickness of the material is in the "thin layer", i.e., sublimation of ice, while the heat flux throughout the volume is constant and is at a high level. Preparation of liquid food products for drying, which improves the efficiency of sublimation technology. This is evidenced by the results of studies of freeze-drying of coffee, tea, and orange juices [1].

An important factor determining the intensity of the drying process is the heat spent on the sublimation of ice and the evaporation of water vapor. The efficiency of heat transfer largely depends on the methods of energy transfer. In turn, the correct choice of the mode

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and method of heat transfer is determined by the thermophysical, mass transfer and optical characteristics of the dried materials.

An analysis of the known methods of energy transfer during freeze drying showed that the most basic and common are the conductive and thermoradiation methods. The heat source can be a surface heated by a liquid heat exchanger or by electric current. The heat transfer efficiency is determined by the drying mode. In several works [2], instead of the conductive method, the method of thermoradiation energy transfer was used, which made it possible to speed up the process at all stages of drying thermoradiation energy. The specificity of this type of energy transfer is based on the thickness of the thermocouple current material and its ability to enter the sublimation zone.

The scientific work of foreign researchers has proved that the use of light irradiators, sources of short-wave radiation when drying several food products can achieve much better results. Currently, only various incandescent lamps with a heating temperature of 2000-3000°C can be used as such illuminators. Scientific papers [3] present theoretical and experimental results of the study of the mechanism of light energy transfer. It is shown that the high-frequency part of the radiation spectrum has the most polarizing effect on dielectric materials.

The use of high-temperature irradiators significantly accelerates heat and mass transfer in the vapor-air environment surrounding the drying material, compared with drying on heated shelves. In addition, radiation penetrates the material and accelerates the passage of vapor particles through the pores of the material to its surface.

The use of microwave electromagnetic oscillations in the sublimation process can significantly speed up the process since the internal heat source introduced into the material moves behind the sublimation zone. Research on the use of electromagnetic waves in the sublimation of ice.

Freezing products before freeze drying is one of the initial operations that speeds up the drying process and positively affects the quality of the dried product. The presence of unfrozen moisture in the cured product may cause foaming during the sublimation process and its exit from the tray, which will adversely affect the quality of the dried product. Such cases can also occur when the temperature of the product in the sublimation zone rises to the melting point of crystalline moisture.

Freeze drying of foodstuffs should be used mainly when drying samples with important quality characteristics and in cases where other drying methods cannot be used. Freeze drying combines freezing and vacuum drying, which allows preserving the nutritional value, chemical composition, and structure of products [4].

In world practice, products with a high yield of biological and nutritional value are dried by sublimation. These products include mushrooms - champignons, shrimp, fruits, nettles, fruit and vegetable juices, purees and more. However, convection or other freeze-drying methods are also used to dry certain heat-labile foods that lose vitamins, taste, odor or colour. Among freeze-dried vegetables, it was decided to choose onions and beets as objects of study due to high demand in world markets [5-7].

Below you can find a brief description of onions and beets, as well as information about their uses.

2 Objects and Methods

For the experiment, onion varieties were selected. Onion variety “Banko” is a mid-season variety, the color of dry tops is yellow-brown, bulb heads are large, round, diameter 7-10 cm, fleshy white inner bark, average weight 140-150 g, dry matter content 9-10%, yield 80-100 t/ha. Ripening period 130-135 days [8]. This onion variety is widely used in the canning industry.
And also, beet varieties "Bordeaux" were chosen - the leaves are dark green, the leaves are large, the rhizome is round, the bark and pulp are dark red, 15–18 cm long, 12–14 cm in diameter, juicy and sweet. It weighs 160 g and has a yield of 40-45 tons per hectare. Recyclable and disease resistant.

Preliminary preparation of drying rooms by mechanical and thermal effects, after which the raw materials are subjected to sublimation drying. The properties and compositional properties of food materials determine the way they are prepared for drying [9-11].

In laboratory experiments, the processing of electromagnetic waves was carried out in standard microwave ovens. Samples are subjected to short-term heat treatment (2-3 minutes), samples are removed from excess moisture on filter paper and incubated for 5-7 minutes at room temperature. Then the samples - onions and beets, are first sorted, washed, and cleaned. Then the onion is cut into cubes 6x6x6 mm and the beetroot 8x8x8 mm, placed in trays at a ratio of 6-8 kg/m², and the test samples are placed in a refrigerator at a temperature of -25°C. The frozen vegetable samples are then dried in a freeze dryer under high vacuum (10–15 Pa) [12-13].

3 Results and Discussion

In the technology of freeze drying, the processing of the product in the waves of the electromagnetic range is carried out before the process of freezing. That is, products at room temperature are processed briefly, 2-3 minutes by waves in the electromagnetic range, and then placed in a refrigerator or directly into a freeze-drying equipment for freezing. When processing the product with short-wave electromagnetic waves, the temperature can rise to 110-120°C. The change in the temperature of samples obtained during pre-treatment and freeze-drying of onion samples taken in the microwave range was studied (Fig. 1–2). In this case, when samples are placed in the drying chamber, special thermal sensors are attached to them, and it is possible to control the temperature during the entire drying process. This process allows you to select temperature modes to speed up the process while displaying the actual temperature in the product.

![Temperature change during freeze-drying of onions with and without pretreatment](https://doi.org/10.1051/bioconf/20236608002)

**Fig. 1.** Change in temperature during freeze-drying of onions with and without pretreatment.

In the selected onion samples, during the freeze-drying process, the temperature of the onion samples was reduced to -250°C for 8 hours, then the temperature was gradually increased to 350°C, and the process was continued until 10% of residual moisture remained.
In onion samples, the freeze-drying process is preceded by pre-treatment of the product in the microwave range, which dries faster than pre-treated dried samples. This is because onion samples lose up to 25-30% moisture during the pretreatment of the product in the microwave range.

In the selected onion samples, the temperature of the onion samples was reduced up to -25°C for 8 hours in the process of freeze drying, and then the temperature gradually increased to 35°C, and the process continued until 10% residual moisture remained (Fig. 1). In onion samples, it was observed that the freeze-drying process without product pre-treatment was 5 hours longer than dried samples with microwave pre-treatment. This is due to the loss of moisture by onion samples from 25 to 30% during pre-treatment of the product in the microwave range.

Similarly, in beet samples, a change in the temperature of the samples was observed during pre-treatment and freeze-drying of the product in the microwave range. In the process of freeze drying, the temperature of beet samples was reduced to -25°C for 8 hours, then the temperature was gradually increased to 35°C and the process was continued to a residual moisture content of 10% (Fig. 2).

In the beet samples, it was noted that the samples dried out 6 hours earlier than the samples dried by the traditional freeze-drying method, since during the primary processing of the product in the microwave range, they lost up to 25-27% moisture during freeze-drying. At the initial stage of the drying process, the temperature in the drying chamber is 0-50°C. The pressure in the chamber during the drying process is 10-15 Pa. The kinetics of the drying process was analysed by changing the weight values of the product every 3 hours. The samples were dried to a residual moisture content of 10%.

During sublimation drying of onion and beet samples, pre-treatment of the product in the microwave range reduces the drying time by 20-25%.

The development of mechanisms for short-term processing to reduce the drying period of agricultural products is of great importance today for obtaining high quality products. Studies have shown that the use of microwaves as a short-term treatment in the drying process is highly effective.

Fig. 2. Change in temperature at freeze-drying beet samples with and without pretreatment.
4 Conclusion

The results showed that a short-term treatment should be carried out after the washing process before the freezing process. In this case, as a rule, in the technology of freeze drying, the objects to be dried are pre-treated before the freezing process. Especially when it comes to the heat treatment of the product. At the same time, the freeze-drying time is significantly reduced compared to the traditional method of primary processing of products in the electromagnetic range.

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