Mechanization of the process of drying fruits and vegetables through the introduction of microwave drying unit UMS-2-10 in agricultural and food enterprises

E V Voronov¹,², E A Shamin¹, V A Bocharov¹, O B Terekhova², L G Shashkarov³, G A Larionov³, P V Zaitsev³ and N K Kirillov³

¹Nizhny Novgorod Engineering and Economic University, Knyaginino, Russia
²Nizhny Novgorod State Agricultural Academy, Nizhny Novgorod, Russia
³Chuvash State Agricultural Academy, Cheboksary, Russia

E-mail: e_voronov@list.ru

Abstract. The article describes the installation of microwave drying UMS-2-10, its use in agricultural enterprises. Installation of combined drying (microwave and convective heating). The installation was developed by the research and production Association "Gamma" in Nizhny Novgorod. The principle of operation is based on the use of microwave energy in combination with the circulation of "warm" air. It is established that when choosing a drying unit for the food industry, it is necessary to keep in mind that the scientifically justified choice of the design of the dryer intended for drying specific types of plant substrates containing biologically active substances is more dependent on the structural properties and biological composition of the plant raw materials used in production. Drying plant UMS-2-10 installation provides for the use of microwave, convective and combined methods of heating the feedstock; characterized by small size and ease of operation; has optimal performance, focused on the orders of commercial enterprises, and not on the formation of large batches of finished products, the implementation of which may be in doubt; characterized by high maintainability, low cost and tariffs for delivery, and installation of the dryer.

1. Introduction

The results of the analysis of patent data of leading foreign firms (USA, UK, Germany, France, Finland, Canada, Sweden, Japan, etc.) show scientific and technological progress in the food and processing industries is carried out in two main areas: improvement of food production on the basis of traditional principles and radical change of production processes on the basis of the latest achievements of science and technology [1, 2].

Drying technologies are undergoing significant changes. Short-term drying processes using gentle modes for maximum preservation of physiologically valuable substances for the body - vitamins, dissolved carbohydrates, mineral substances and quick removal of moisture to increase shelf life - are becoming increasingly common. More and more importance is attached to fast food and therefore find their place in the human diet of the new century dried foods that are restored in a matter of minutes [3].

2. Materials and methods

The research was carried out at the Nizhny Novgorod State Agricultural Academy.
The technological processes of drying samples of carrots, beets and onions using convection heating, microwave (heating in the electric field of microwave) heating and heating at the same time combining the effects on the product of convection of warm air and electric microwave energy were chosen as the objects of research.

The combined drying unit (microwave and convective heating) was used in the studies. The installation was developed by the research and production Association "Gamma" in Nizhny Novgorod.

3. Results and discussion

The principle of operation is based on the use of microwave energy in combination with the circulation of "warm" air.

The microwave drying unit has three modes: microwave, combined, combining microwave and electric processing methods and traditional electric heating.

Microwave processing in the installation is carried out by the method of volumetric heating, in which the field energy generated by magnetrons is converted into heat throughout the volume of the processed product. The air and product containers do not heat up because of the flow microwave field, without absorption.

The unit performs all the functions of microwave drying in the combined mode. In addition, in the operating mode, the warm air coming from the tubular electric heaters, with the help of a fan, is evenly distributed throughout the volume, carrying out additional surface drying of the product.

Under the conditions of convection (traditional electric heating), the heating of products is carried out with warm air coming from heating elements using a fan, microwave generators (magnetrons) are disabled in this mode. It is used not only for the main convective drying but also to remove moisture from the surface of the product after extracting it from the inside using microwave energy.

![Diagram of microwave drying unit](image)

1 – drying (resonator) chamber; 2 – microwave generator unit; 3 – ventilator; 4 – power supply; 5 – heater; 6 – control panel

**Figure 1.** Installation of microwave drying UMS-2-10.
The installation consists of the following components (figure 1): drying (resonator) chamber with a door; three blocks of microwave generators that convert AC power into microwave power; fans, which removes moisture from the drying chamber; three power supplies that convert the mains voltage to the type required for the operation of magnetrons; heater, which is heated air entering the chamber from the bottom by means of a fan; remote control.

The speed of movement of the material in the dryer can vary by changing the angle of inclination of the springs, the amplitude, and frequency of oscillations, as well as the speed of the gaseous coolant, supplied to the sublattice of the dryer. Dryers of this type are produced both by the domestic industry and by some foreign companies. The grid area is 0.5...10 m, and the specific removal of moisture from the surface unit 30...70 kg/m².

The door of the drying chamber with rubber seals, which are wearing a metal braid, fits snugly to the chamber and thus provides ideal protection against leakage of microwave energy. To control the tightness of the door to the drying chamber, a limit switch is installed between the case and the door. When the door is not tightly closed, the limit switch blocks the inclusion of microwave generators—which ensures the safety of the installation.

Each microwave generator unit includes magnetron, waveguide, fan, and high-voltage local transformer.

The power supply includes a single-phase power transformer, a high-voltage diode rectifier, and a voltage regulator.

The structure of the heater includes three tubular electric heaters and exhaust system.

On the control panel there are power buttons: ventilation chamber, heating and anode voltage of magnetrons, exhaust systems and tubular electric heaters; time relay; the switch of the control device for measuring the currents of magnetrons; microammeter; warning lights; Handles "Regulation of the anode current of magnetrons" toggle switch mode selection; lamp alarm magnetrons [4].

Rational design of the dryer can be selected only for a specific product or a small group of materials with similar physical and chemical characteristics.

Selecting the rational structures of the dryer was guided by the following requirements:
- providing high-quality indicators of the finished product (swelling, digestibility, preservation of attractive organoleptic characteristics, etc.);
- the minimum specific consumption of heat, steam, air, and electricity referred to 1 kg of evaporated moisture or 1 ton of finished product;
- the intensity of the process, ensuring the minimum overall dimensions of the installation, removal of moisture from 1 m² of the capacity of the device or from 1 m² of the production area;
- the possibility of maximum automation and mechanization of the drying process.

In all cases, it is necessary to carefully study the influence of the main parameters of the drying agent and the characteristics of the material on the dewatering process, namely: the possibility of using a higher temperature, air flow rate, its relative humidity, oscillating modes, combined methods of heat supply and drying methods, as well as pre-technological preparation of raw materials. At the same time, however, we should not forget about the chemical composition of the finished product (the safety of a group of vitamins, provitamins, proteins, sugars, etc.).

When choosing a drying unit for the food industry, it should be borne in mind that the scientifically justified choice of the design of the dryer intended for drying specific types of plant substrates containing biologically active substances is more dependent on the structural properties and biological composition of the plant raw materials used in production [5].

At the enterprises of vegetable-drying production, mainly convection drying lines are used using belt dryers, spray dryers (for drying juices and purees), tunnel dryers, cabinet boilers with boiling and vibratory boiling layer and lines using single-roll and double roll dryers. They are designed for drying a large volume of raw materials under specified conditions and uninterrupted supply of raw materials [6].
Currently, the use of large production capacities is inefficient, as there is a shortage of agricultural products, the constancy of supply of raw materials for enterprises is broken and vegetable drying plants are not fully loaded.

In such a situation, small enterprises with small-sized equipment designed for small batches of raw materials come to the first place. Installation dryers small performance gives a significant economic effect.

As a result of the analysis of literary sources as an installation for scientific research, the choice is made on the drying plant UMS-2-10, guided by the following:

- the installation provides for the possibility of using the microwave, convective and combined methods of heating the feedstock;
- small dimensions of the installation and ease of use;
- optimal performance focused on the orders of commercial enterprises, and not on the formation of large batches of finished products, the implementation of which may be in doubt;
- high maintainability, low cost, and tariffs for delivery and installation of the dryer.

Justification of parameters and modes of drying

The temperature of the drying agent – air – is one of the main factors affecting the drying process. Experiments on drying, in which the relative humidity and air velocity were maintained constant, and only the temperature changed, it was found that at the beginning of drying, the increase in air temperature increases the speed of the process to a lesser extent than at a subsequent stage. when the thermal effects. associated with evaporation, can be neglected and the temperature of the material becomes close to the air temperature.

However, as the air temperature increases, heat losses increase, which are most significant at the final stage of drying the material with low humidity.

Relative humidity is the second important factor affecting the drying rate. In the case of constant temperature and air flow rate, the decrease in the drying rate at the first stage is directly proportional to the increase in the relative humidity of the air. Following this, the dependence of the process speed on the relative humidity decreases, and in the final section increases again.

The air flow rate at a constant drying rate section also affects the drying rate of the material (at a constant temperature and relative humidity). This effect is significant mainly at an air flow rate of less than 5 m/s. Further increase in the air flow rate has no significant effect on the drying rate of the material in the first section. The increase in the air flow rate after reaching this value is also limited by the fact that the jet begins to "tear" small pieces of the dried material from the drying surface. At the drying area of the material with low humidity, the air flow rate does not have a significant effect on the drying rate. In this area, it makes little sense to set the airspeed above 1 m/s.

The atmospheric phenomenon also affects the drying rate. Lowering the barometric pressure has a significant impact on the drying rate only at the first stage.

Grinding the material greatly reduces the drying time. This is the secret of the success of spray drying, which, if the material is well crushed and the particle size does not exceed a few microns, occurs in a few seconds.

The thickness of the material loading layer, or specific loading (in kg/m2), significantly affects the rate of drying. The loading weight of sliced vegetables is usually 10...15 kg/m2. in drying plants with a good organization of the process much attention is paid to the uniformity of the material loading. In particular, each pallet (baking tray) of the chamber dryer must be loaded with the same amount of material. In belt dryers, uniform material loading is ensured by special equipment. The increase in the thickness of the load reduces the speed of drying, mostly on the first initial part of the drying. As a result of the shrinkage of the material as it dries, the loading layer is more easily penetrated by the air flow, and its thickness decreases. Thus, the initial decrease in the drying rate when drying a thick layer stops as the material is dehydrated. This phenomenon makes it possible to install a lower speed of the lower tapes than the upper ones on the belt dryers. Material loading greatly affects the performance of the equipment, and its optimal value is established empirically.
All these laws are entirely fulfilled only in that case, if the material crushed into particles of the same size is spread out on a pallet in thin uniform layers and the whole is permeated by a stream of warm air. However, most of the established rules and laws applied to other methods of drying [7].

The optimal drying mode should provide a product of standard quality with high technical and economic indicators. When justifying and choosing the drying mode, it is necessary to proceed from the technological properties of the material that changes during the drying process, that is, it is necessary to choose such operating parameters (temperature, humidity, airspeed, etc.), the impact of which on certain characteristics of the material would provide its best technological properties.

When choosing the mode, it is necessary to take into account the thermal stability of the product, its biological nature and structural and mechanical properties, on which the warping of the samples and the formation of cracks depend.

In order to avoid warping and cracking it is necessary to strive for the most uniform drying over the cross-section of the sample. The maximum permissible moisture gradient is experimentally determined for each product [8].

The quality of dried vegetables is directly influenced by preparatory technological operations: a form of cutting, type and time of pre-heat treatment.

Vegetables in preparation for drying cut into pieces of different sizes and shapes: columns, circles, segments, chips, blocks, and records. The shape and size of the pieces has a great influence on the drying speed, and therefore on the performance of the drying plant. With a decrease in the thickness of the product pieces, the duration of dehydration is reduced and the recovery time of the dried product during its cooking is accelerated.

If the products are cut into small pieces, surface hardening occurs to a lesser extent [8].

Intensification of the drying process improves the quality of the dried product and reduces the loss of vitamins and other valuable nutrients. However, the thickness of the piece can be reduced to a certain value (2 mm for vegetables), as cutting into thinner pieces leads to the formation of a large number of crumbs.

Preference is given to dried vegetables, sliced in the form of cubes, plates, and chips, since such a product has a large bulk mass, evenly mixed in soup mixes, well dosed in soft packaging on machines and has a more attractive appearance in the finished dish.

The content of trifle in the cut raw material should not exceed 5...8%. The increased content of the crumb worsens the drying conditions and leads to unnecessary losses, as this reduces the yield of the standard dried product and increases the consumption of raw materials.

Uneven cutting across the width and thickness, the presence of agglomerated or incompletely cut particles is also unacceptable, as the correct drying mode is disturbed, the product is unevenly dehydrated, resulting in the expenditure of additional labor for sorting and finishing the large pieces leaving the dryer with high humidity. The surface of the cut should be flat, smooth. In this case, the cells of raw materials are destroyed less and the loss of vitamin C is also much less [9].

Currently, there are conflicting opinions among scientists and specialists in the field of drying vegetables about the advisability of using pre-heat treatment before drying raw materials [10].

On the one hand, steam or water blanching is considered to be a necessary condition for the preservation of color, taste, smell, vitamin activity, acceleration of recovery, as well as, mainly, the destruction of oxidative enzymes – oxidases and the prevention of hydrolysis or oxidation of lipids in order to prevent loss of the level of quality of products in the process of dehydration and especially subsequent storage. On the other hand, numerous studies show that blanching is not particularly necessary [11].

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When blanching sugar, gelatinized starch, and gelling pectin penetrate into the intercellular space and clog pores, thereby making it difficult to remove moisture during subsequent drying. Also, in the process of pre-heat treatment, there are significant losses of coloring substances, which adversely affects the commercial properties of finished products [13].
Blanching reduces the activity of vitamin-destroying enzymes and preserves the taste, but vitamin losses can reach 30% [14].

As studies show, if combined heating is used, blanching is not particularly necessary. Volumetric and deep microwave heating at the first stage of drying creates a sufficiently high temperature (70...80°C) inside the product particles. This temperature gives blanchardi effect. As the drying rate decreases, both the temperature inside the product and it dries to a characteristic drying crust.

4. Conclusion
Based on the analysis of literary sources, the following conclusions can be drawn:

1. Among the modern methods of drying, combined methods are increasingly important, which combine different forms of heating the product during drying.
2. In the development of new designs of drying units, the development of small-size chamber dryers, in which a combination of two or more drying methods is possible, comes to the fore.
3. The quality of dried products largely depends on the preparation of raw materials for drying, in which it is necessary to take into account the types of raw materials and the purpose of the finished product.

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