CONVECTIVE DRYING TECHNOLOGY IN AN INERT GAS ENVIRONMENT

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https://doi.org/10.5281/zenodo.19348185

Introduction

Vegetable raw materials, including root vegetables, have a colloidal, capillary-porous structure, containing fragments of high-molecular carbohydrates, proteins, lipids, vitamins, macro- and microelements. Preparing vegetables for drying and the traditional dehydration process itself can lead to a significant loss of biologically active substances [1].

In this regard, the task of improving the method of drying vegetables with maximum preservation of the physiologically valuable substances of the original raw materials is very urgent [2].

Convective drying is the most common method for dehydrating vegetable raw materials to extend their shelf life. Traditional convective drying involves transferring heat to the raw material using hot air [3,4]. This transfer of thermal energy releases moisture from the raw material, which is then carried away by the drying agent. By summarizing literature data and experimental studies on the thermal diffusivity of vegetables, S.A. Ilyina was able to determine the thermal diffusivity coefficients for a range of vegetables [5].

Various methods for dehydrating raw materials of plant and animal origin are described in the technical literature [3, 6–8]. In a pilot-scale experiment, we developed a method for drying vegetable raw materials, providing a theoretical justification and experimental confirmation of the feasibility of pre-blanching and treatment with a low-frequency electromagnetic field (LFEMF) to transfer moisture from the core to the surface. The essence of this method is the use of resonant frequencies to maximize the redistribution of moisture from the core to the surface, followed by drying the product in a microwave oven.

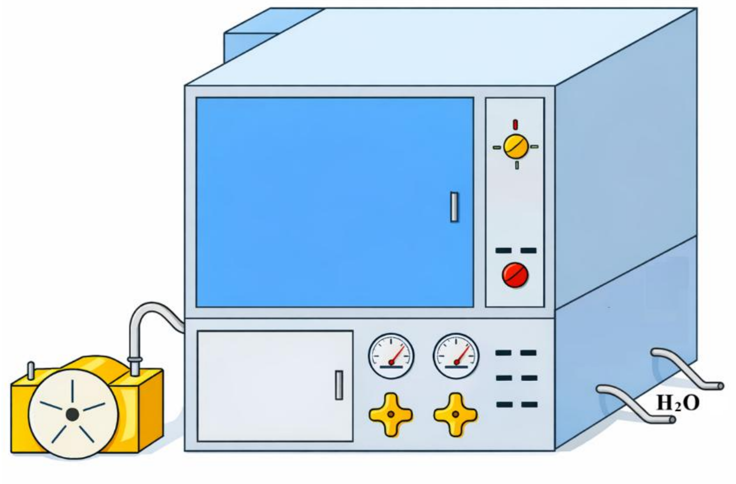

Fig. 1. External appearance of a vacuum microwave dryer [5]

A device for removing moisture from a product through the synergistic use of vacuum and electromagnetic processing is described [1, 4]. Multicomponent dry product formulations with balanced amino acid compositions are proposed. The technology for producing dried and shelf-stable dry products has been improved.

Convective drying of raw materials in a fluidized bed is highly effective. However, existing convective drying systems have high specific energy consumption, reaching 3.0 kWh/kg. This can lead to product overheating and deterioration of quality due to the oxidation of the raw material's biologically active substances by atmospheric oxygen.

The vegetable drying process can be intensified by using an inert gas as a drying agent.

The aim of the work was to develop a technology for gentle drying of vegetables and root crops in a dryer with intensive energy supply in an inert gas environment.

Object and methods of research

To carry out research on improving the technology of drying vegetables, we proposed a multi-level drying unit using argon as a drying agent (Fig. 2).

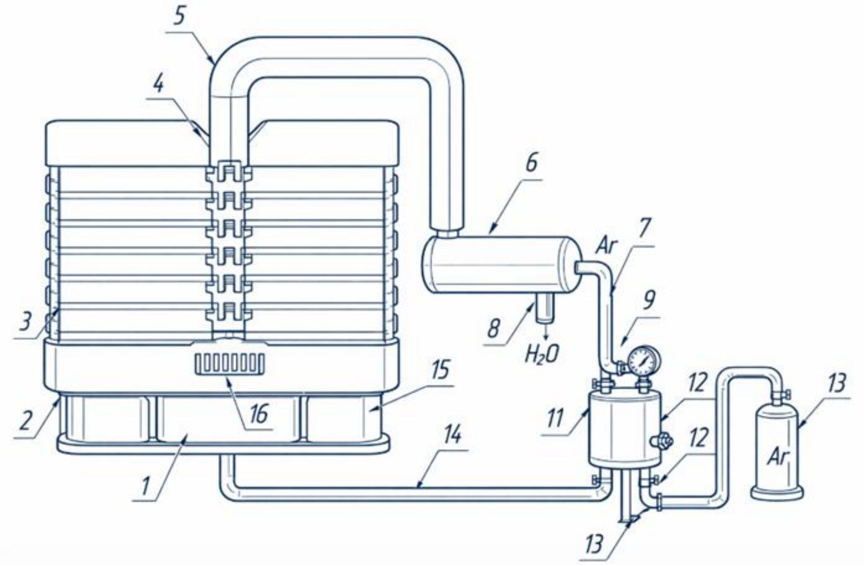

Fig. 2. Drying plant for root crops

1 – argon supply cavity; 2 – product tray; 3 – dryer compartment walls; 4 – exhaust pipes for exhaust gas; 5 – hood; 6 – condenser; 7 – argon pipe; 8 – water pipe; 9, 12 – solenoid valves; 10, 11 – removable adsorption filters; 13 – argon cylinder; 14 – suction manifold; 15 – main platform with built-in fan heater 16, which pumps and heats argon

Warm gas, with a temperature set between 35 and 65°C using a thermostat, is supplied from below, not through the entire volume of raw materials loaded into the trays, but into each tray individually, from the edges to the center.

To determine the quality and safety of vegetable raw materials and dried products, standard methods for testing organoleptic, physical, and biochemical properties were used.

The safety of raw materials and finished products was determined instrumentally and assessed based on the content of microbiological indicators and toxic elements.

Measurements were conducted using rotatable central composite designs of a full factorial experiment. Statistical processing of the experimental results was performed using Microsoft Excel.

The reproducibility of the experiments was assessed using Cochran's G test (Gp), the adequacy of the regression equations was assessed using Fisher's test (Fp), and the regression coefficient was assessed using Student's t test (t3).

The selection of root vegetables for the production of dried products is theoretically substantiated, and the qualitative and quantitative composition of the new food products is presented.

Drying conditions for sliced raw materials were established within the range of 35 to 65°C. Drying of pre-prepared raw materials is fast and efficient, consuming 250–300 W/h of electricity.

The chemical composition of long-life dried products largely depends on the quality of the starting materials.

Carrot roots and sugar beets were used in the research. The frost- and drought-resistant Jerusalem artichoke variety "Dieteticheskу," with a high inulin content, was also used.

To prevent the roots from browning, they are blanched in steam for 1–2 minutes before drying.

Table 1 shows the chemical composition of the roots.

Table 1. Chemical composition of the raw materials selected for research

Type of raw material	Content , %						Average weight, g.
	Moisture	Protein Nx6,25	Fat	Sugar	Витамин С мг%	Ash	
Carrots	88	1,3	0,1	6,8	5,0	1,0	120
Sugar beets	86	1,2	0,1	8,6	10,0	1,0	550
Jerusalem artichokes	79	2,1	0,1	12,7	6,0	1,8	90

After analyzing the obtained data presented in Table 1, it can be concluded that the selected raw materials have a relatively high moisture content of 79–88% and contain carbohydrates and vitamin C, which are lacking in animal-based raw materials.

Pre-prepared root vegetables were cut into 4 mm thick slices and placed in drying trays. Drying was carried out at a temperature of 45°C. Changes in dry matter and total sugars were monitored during the drying process.

The water content of the root vegetable samples indicates that the product is dried to the specified moisture content values, which meet the standard requirements, within 3.0–3.5 hours.

The chemical composition of dried root crops is presented in Table 2.

Table 2. Chemical composition of root crops dried in an inert gas environment

Dried root vegetables	Content , %					
	Moisture	Protein Nx6,25	Fat	pectin substances	vit. C	total carbohydrates
Carrots	14,0±0,11	11,0±0,12	1,4±0,11	4,9±0,13	10,2±0,12	53,49±0,16
Sugar beets	14,0±0,11	5,5±0,12	0,3±0,11	8,6±0,13	9,8±0,12	61,12±0,16
Jerusalem artichokes	14,0±0,11	8,5±0,12	2,2±0,11	6,7±0,13	12,4±0,12	53,09±0,16

The research results confirm that sugar losses are observed during drying (over 3.5 hours), which is associated with melanoidin formation and caramelization reactions. In samples of dried Jerusalem artichoke root slices, the highest sugar concentration is observed after 3.5 hours of drying, reaching 26.5–26.7%. After analyzing the vitamin content of the dried product, it was found that vitamin losses largely depend on temperature and process conditions (convective drying in air or inert gas).

A study of the quantitative changes in vitamin composition based on the data obtained in Table 3 suggests that vitamins are better preserved when drying in an inert gas dryer, and less so when drying in a hot air environment. Therefore, high temperatures are unacceptable for preserving vitamins, making it advisable to use low temperatures for the creation of specialized food products with specific requirements.

Conclusion. The practical significance of the research conducted lies in the development of recommendations for the use of convective drying technologies for root vegetables.

The design of the root vegetable drying unit has been improved, allowing for the simultaneous drying of various raw materials.

Efficient drying conditions for root vegetable slices have been established: a process temperature of 35–65°C and a drying time of 3.5 hours

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