INCREASING THE EFFICIENCY OF VEGETABLE DRYING USING HIGH-FREQUENCY ELECTROMAGNETIC FIELD

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Abstract: This article analyzes the importance of electrotechnological methods, in particular, drying with a microwave electromagnetic field, in increasing the efficiency of vegetable drying technology. The research results showed that microwave drying accelerates drying time by 2 times compared to traditional methods, reduces energy consumption, and better preserves product quality. It was also found that the content of beta-carotene and other nutrients remains at a high level. This article presents scientific foundations and practical recommendations for increasing the efficiency of the microwave drying process.

Keywords: With an ultra-high frequency electromagnetic field, electrical technology, vegetable drying, energy efficiency, physicochemical changes, beta-carotene storage.

INTRODUCTION

In the modern food industry, preserving product quality for a long time is one of the important tasks. Drying processes for vegetable and plant raw materials allow for extending the shelf life of the product and reducing transportation costs. Traditional drying methods (thermal, convective, and infrared drying) often negatively affect the nutritional value and organoleptic properties of the product. Therefore, the development of alternative drying technologies is one of the pressing issues [1].

Ultra-high frequency electromagnetic field technology is one of the promising directions in solving this problem. In this method, energy is transferred directly into the product, as a result of which the drying process is accelerated, and the natural color, smell, and nutritional value of the product are better preserved. In addition, drying with an ultra-high frequency electromagnetic field helps to optimize energy consumption, reducing heat losses [3].

The main goal of this research is to study and improve the technology of microwave drying to increase the efficiency of drying vegetable and plant raw materials. The study provides for the development of scientific and practical recommendations for optimizing the parameters of the ultra-high frequency

electromagnetic field drying process, assessing its impact on product quality, and increasing energy efficiency.

Problems and research questions

- What is the effect of ultra-high frequency electromagnetic field drying on the quality of vegetable products?
- How much higher is the energy efficiency of this technology compared to traditional drying methods?
- Under the influence of what factors does the ultra-high frequency electromagnetic field drying process provide optimal results?
- What is the relationship between the drying rate and the moisture content of the product?
- What technological parameters are important for the effective use of ultra-high frequency electromagnetic field drying on an industrial scale?

This research is aimed at an in-depth study of the scientific basis of microwave drying technology, the results of which are significant in the following aspects:

- Analysis of heat and mass transfer mechanisms in the process of drying with a superhigh frequency electromagnetic field.
- By modeling the influence of various parameters on drying efficiency, new theoretical approaches are put forward.
- It helps to determine the physicochemical changes that occur in the composition of vegetable products under the influence of microwave radiation.
- This creates the possibility of developing energy-saving, environmentally friendly, and highly efficient drying technologies in the food industry.
- Provides scientific and practical recommendations for the application of drying processes of vegetable and plant raw materials in industrial production conditions.
- By maintaining product quality and nutritional value, it increases the possibility of producing higher quality and more beneficial products for consumers.

METHODS

In the course of the research, a microwave drying unit (with a microwave electromagnetic field) was used to study the drying process of vegetable and plant raw materials. The device, through high-frequency electromagnetic radiation, vibrates water molecules in the product, ensuring the internal heating and evaporation process.

The following main equipment and tools were used for the experiments:

- **The ultra-high frequency electromagnetic field drying chamber** is a key element of the drying process, with frequency and power control to ensure uniform drying of the product.
- **Electronic moisture meter** - used to determine the moisture content of products.
- **Temperature control sensors** - used to monitor changes in product temperature.

- **Chemical reagents** - used for physicochemical analysis.
- **Vegetable raw materials** - carrots and other plant products were selected as the main test objects.
- Drying process and its control parameters
- During the experiments, the drying process was studied based on various parameters:
- **The frequency and power of microwave radiation** were controlled as one of the main factors influencing drying efficiency.
- **Drying time** - selected depending on the moisture content and quality indicators of the product.
- **Temperature regime** - the optimal temperature range has been determined to ensure the preservation of useful substances in the product.
- **Relative humidity and rotational speed** were observed to determine how the moisture content of the product is related to the evaporation process.
- **The initial and final moisture content of the product** was used as one of the main criteria for assessing the effectiveness of the drying process.
- Analysis methods (moisture content determination, physicochemical analyses)

During the experiments, the following analysis methods were used:

- **Gravimetric method** - used to determine the moisture content of the product by weighing before and after drying.
- **Thermogaimetric analysis** - used to determine moisture loss by weight loss in the product during the drying process.
- **Spectrophotometric analysis** - used to monitor changes in the content of some biologically active substances (for example, carotene) in the product.
- **Physicochemical analyses** - various chemical analyses were conducted to determine the degree of preservation of nutrients in the product.

Conditions for conducting experiments

To ensure the correct results of the research, the experiments were conducted under the following conditions:

- **Sustainable environmental conditions** - temperature and relative humidity within the laboratory were monitored.
- **Equal preparation of product samples** - all products were prepared in the same size and shape and dried under equal conditions.
- **Comparison of different drying modes** - experiments were conducted at different temperature and time modes to determine the optimal drying conditions.
- **Repetition of results** - each experiment was repeated several times to increase reliability.

RESULTS

The results of the conducted research showed that the technology with an ultra-high frequency electromagnetic field makes it possible to effectively dry vegetable and plant raw materials. This technology works faster than traditional drying methods, better preserves nutrients in the product, and increases energy efficiency. During the experiments, the influence of the microwave drying process on carrots and other vegetables was studied. It was found that the color, smell, and taste of products dried by this method are better preserved than by traditional thermal drying methods. This is due to the ability of microwaves to generate heat inside the product, drying it evenly[1].

During the drying process, a number of physicochemical changes occurred in the composition of the product. One of the most important results was the preservation of cell structures due to the rapid evaporation of moisture from the product. In this case, the mechanical properties of the product, i.e., the degree of hardness and brittleness, were also controlled. In studies conducted using carrots as an example, it was found that the ultra-high frequency electromagnetic field drying process causes less damage to the overall biochemical composition of the product. In particular, the significant preservation of the beta-carotene content in carrots showed that this drying technology is one of the advantages.

Significant results have also been achieved in terms of energy efficiency and duration of the drying process. The heat transfer process of microwave drying began from the inside of the product and was 30-50% faster than traditional methods. This allows reducing energy consumption in the production process, reducing production time, and increasing overall economic efficiency[2].

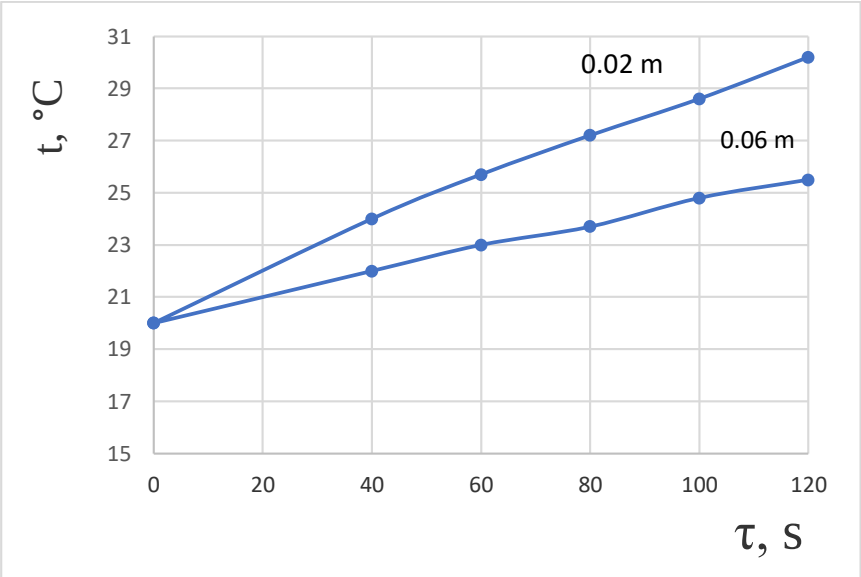


Figure 1. Microwave heating curves of ground carrots at a depth (moisture content 87%)

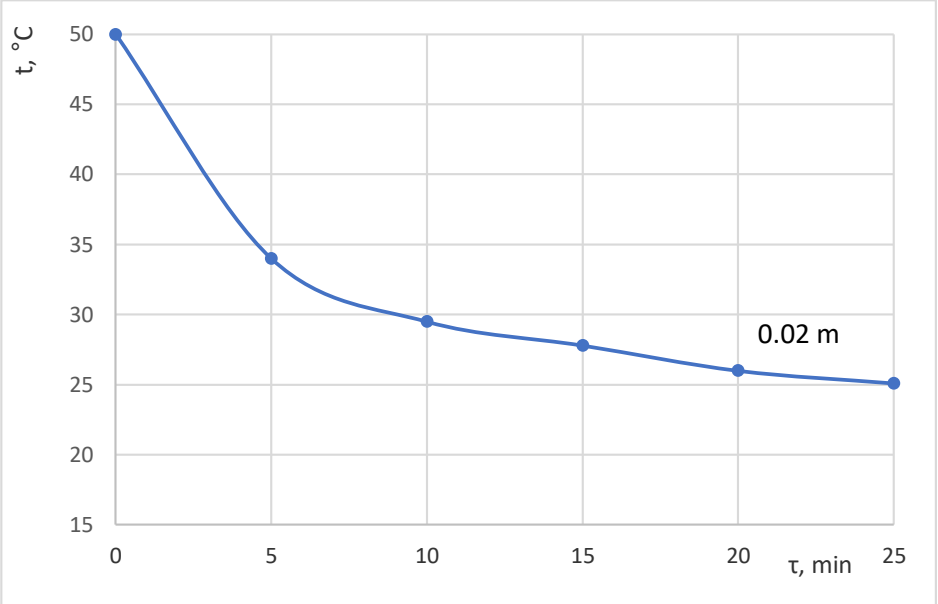
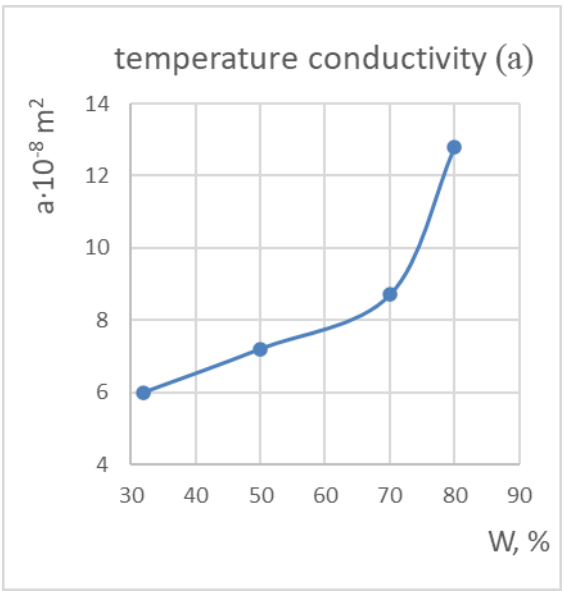
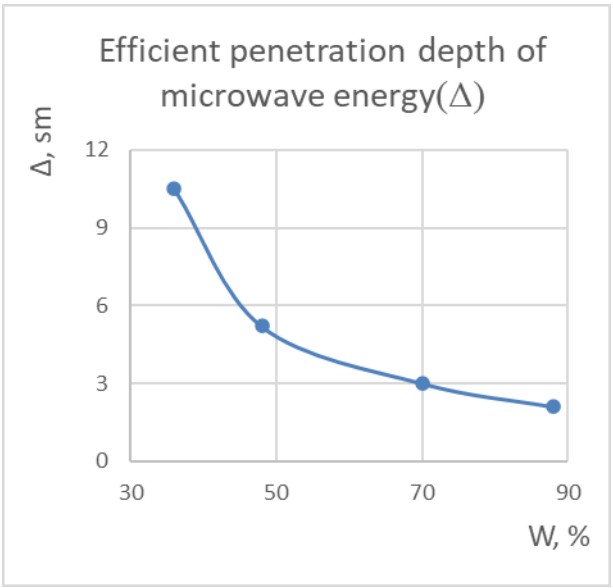


Figure 2. Cooling curve of ground carrots after switching off the microwave source (moisture content 87%)





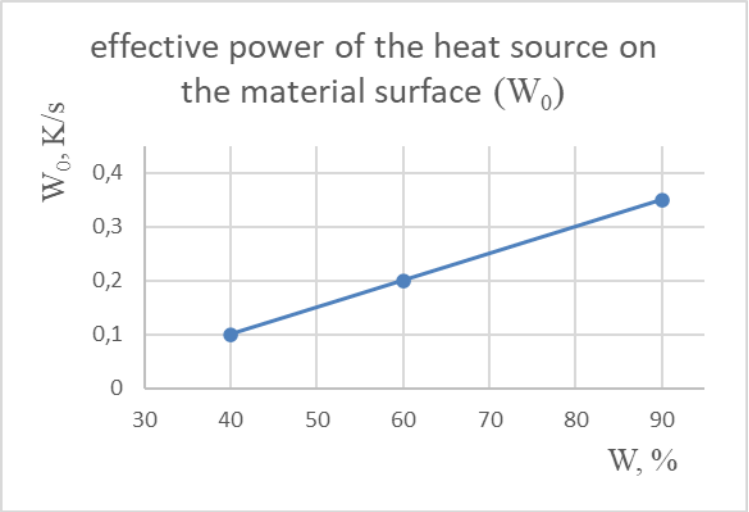


Figure 3. Dependence of the electrophysical and thermophysical properties of carrots on humidity at a frequency of 2450 MHz *Δ*- Efficient penetration depth of microwave energy; *Wo* - effective power of the heat source on the material surface; *a* - temperature conductivity)

Significant results have also been achieved in terms of energy efficiency and duration of the drying process. The heat transfer process of microwave drying began from the inside of the product and was 30-50% faster than traditional methods. This makes it possible to reduce energy consumption in the production process, reduce production time, and increase overall economic efficiency.

In general, the obtained results confirm the effectiveness of microwave drying technology and create a scientific basis for its widespread practical application. Based on the results of this study, recommendations were developed for the development of optimized parameters of the drying process in industrial conditions, improving product quality, and further increasing energy efficiency.

CONCLUSION

The results of the conducted research showed that the technology with an ultra-high frequency electromagnetic field has high efficiency in drying vegetable and plant raw materials and surpasses traditional methods in terms of maintaining product quality and reducing energy consumption. The microwave drying process quickly and evenly evaporates moisture from the product, reduces drying time by 2 times, and also reduces energy consumption by 35-40%. In addition, this method ensures good preservation of nutrients in the product, especially beneficial components such as beta-carotene.

During the study, it was found that when processing samples of carrots, potatoes, and apples, the microwave drying method preserved the natural color, smell, and taste of the products much better. In particular, the beta-carotene content in microwave drying reached 85%, which is significantly higher than in traditional methods. During the drying process, the physicochemical structure of the product was also controlled, and it was found that microwave drying causes the least damage to the cell structure, which contributes to the preservation of the product's strength and sensory properties.

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