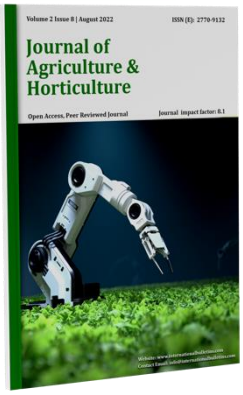

LOW TEMPERATURE DRYING OF FRUIT: MODERN METHODS OF SLOWING DEVELOPMENT OF MICROORGANISMS

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Abstract: This article analyzes modern methods of slowing down the development of microorganisms using low-temperature fruit drying technologies. The influence of lyophilization, vacuum and heat drying methods on microbiological safety was studied based on experimental studies. The relationship between drying temperature, humidity level and the amount of microflora was statistically analyzed. The results showed that low-temperature drying is an effective solution for extending the shelf life of fruit products and ensuring food safety.

Keywords: fruit drying, low-temperature technologies, microbial activity, food safety, lyophilization, vacuum drying, urbanization methods, microbiological analysis, humidity level, innovative storage methods.

Food safety is considered a global issue today. In particular, the high level of humidity in fruits and vegetables makes them an ideal environment for microorganisms, causing their rapid decomposition. This not only reduces the quality and size of the product, but also poses a threat to consumer health. Fungi, bacteria and yeasts contained in fruits can cause foodborne infections and toxicosis. Therefore, controlling their development has become an important aspect of food preservation.

Traditional high-temperature drying technologies, although they reduce the activity of microorganisms, lead to the loss of biological and sensory properties of fruits. In this process, vitamin C is broken down, color and odor change, and the amount of polyphenols decreases. Therefore, in recent years, more and more attention has been paid to low-temperature drying technologies. These technologies not only slow down the activity of microorganisms, but also allow preserving the nutritional and functional properties of fruits.

This article will analyze modern methods of preventing the development of microorganisms by drying fruits at low temperatures, as well as their microbiological and technological efficiency. A comparative study of drying methods substantiates innovative approaches to ensuring food safety.

In recent years, the importance of modern drying technologies in food storage has increased. In particular, low-temperature drying methods - lyophilization, vacuum drying and heat pump drying - are considered as effective solutions for ensuring the microbiological safety of fruits and vegetables.

The studies conducted by the authors [1] examined the effect of various drying methods on the composition of fruit microflora, the level of nutrient preservation and product quality. The study proved that the lyophilization method significantly reduces the number of microorganisms and has an advantage in preserving vitamins. The preservation of biologically active substances in low-temperature dried fruits and vegetables and their potential for the

production of functional drinks were analyzed [2]. In their study, low-temperature drying technologies not only ensure microbiological safety, but also give the product additional functional value.

During the meta-analysis, the effect of modern drying technologies on microorganisms was studied in detail. The results of the studies show that vacuum and lyophilization-drying methods for salmonella and E. coli significantly slow down or stop the growth of dangerous microorganisms such as aspergilli [3]. Analyzed the effect of low-temperature drying on the physicochemical composition of the product, in contrast to heat treatment during drying of food products. They substantiated the possibility of preserving the color of the product, the absence of loss of vitamin C and the preservation of polyphenols [4]. These analyses show that low-temperature drying not only protects fruits from the threat of microorganisms, but also preserves their biological value. Therefore, it becomes important to widely implement these technologies with scientifically based approaches in local conditions. Apples, strawberries and bananas, which have a high moisture content and are prone to rapid growth of microorganisms, were selected as objects of study. They were prepared in a new state as identical samples, observing special hygienic requirements.

The fruits are dried using the following low-temperature drying technologies:

- Lyophilization (sublimation drying): the fruits were frozen at -40 °C, then dried with steam under vacuum conditions. Drying time is 24 hours.

- Vacuum drying: drying at 40°C, 0.05 MPa pressure for 12 hours.

Heat pump drying: drying at 50°C for 10 hours. Energy consumption was in the range of 0.8-1.2 kW/h.

Fruits that were dried by conventional heating (8 hours at 70 °C) were also analyzed as a control group.

Microbiological analysis methods:

The number of microorganisms in the fruits before and after drying was determined and assessed based on the following methods:

- Culture method: - Colony forming units (CFU/g) were identified by incubation in Petri dishes at 37 °C for 24-48 hours.

-qPCR (real-time polymerase chain reaction): lyophilized samples contained

Salmonella spp. and Aspergillus spp. DNA of dangerous microorganisms such as was determined.

Physicochemical analyses:

- Moisture content: gravimetric method (drying at 105 °C for 3 hours).
- pH levels: Homogenized samples were measured in pH meters.
- Vitamin C content: 2,6-dichlorophenolindophenol was determined by titration.

Statistical analysis:

The obtained results were analyzed using SPSS 25.0. Each measurement was repeated 3 times. The mean values and standard deviations were calculated. Differences between results were assessed using the ANOVA test (α = 0.05 degrees).

The study examined the effect of four different drying technologies (lyophilization, vacuum drying, heat pump drying, and conventional thermal drying) on the number of microorganisms on fruits. The results are presented in the table below:

Table 1

Number of microorganisms by drying methods

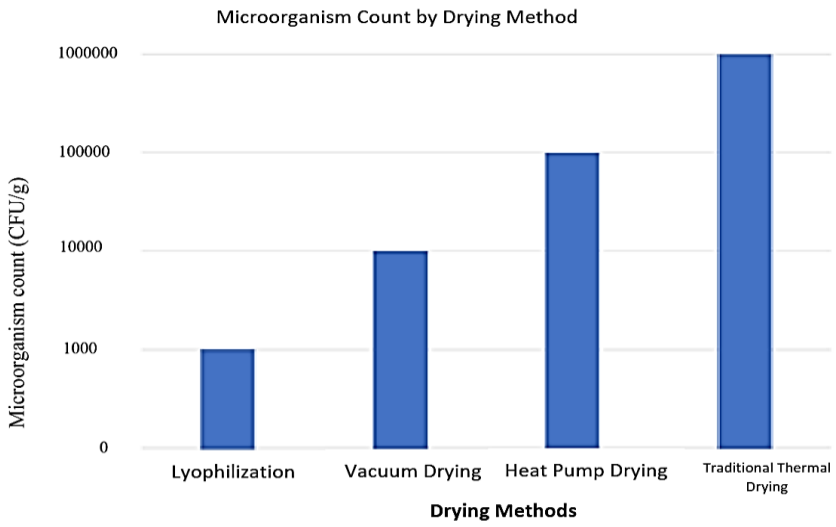
№	Drying method	temperature (°C)	drying time (hour)	number of microorganisms (CFU/g)
1	lyophilization	-40	24	1 000,0
2	vacuum drying	40	12	10 000,0
3	heat pump drying	50	10	100 000,0
4	conventional heat drying	70	8	1 000 000,0

As can be seen from the table above:

- Freeze drying (-40°C, 24 hours) was the most effective method, reducing the microorganism count to 103 CFU/g.

-Vacuum drying (40°C, 12 hours) resulted in a microorganism count of about 104 CFU/g.

- On the other hand, heat pump drying 105 resulted in a count of 10 5 CFU/g.Conventional drying (70°C, 8 hours) was relatively ineffective in reducing the microorganism count6 and was maintained at 10 6 (CFU/g)



Graph 1. Number of microorganisms by drying methods.

In the graph above, drying methods and the number of microorganism's mda are presented in logarithm M. Graphical analysis shows that as the drying temperature decreased, the number of microorganisms decreased. In particular, the combination of low temperature + vacuum conditions ensured the highest level of microbiological safety. In addition, physicochemical analysis showed that:

The moisture content with the lyophilization method was about 4-6%, which dramatically increased the shelf life of fruits.

In terms of preserving vitamin C, the lyophilization method also prevailed (preservation of about 85%), with vacuum drying this figure was 70%, and with traditional drying - only 40%.

No significant changes in pH were observed, indicating the chemical stability of the product.

The results show that low-temperature drying technologies, especially lyophilization, serve to significantly reduce the number of microorganisms on fruits. The number of microorganisms obtained as a result of lyophilization was about 103 CFU/g on the log10 scale, which is quite low compared to other methods. This method not only ensures microbiological safety, but also allows maintaining such sensory properties of the product as nutrition, taste, color, and smell at a high level.

However, the main disadvantage of the lyophilization technology is high-energy consumption, a long process and the need for expensive equipment. Therefore, the widespread introduction of this technology in small manufacturing enterprises may be associated with certain economic limitations.

As an alternative, vacuum drying is relatively cheaper and provides a balance between high efficiency and moderate costs. Drying with a heat pump is also considered an optimal technology for small-scale production.

The results of this study showed that low-temperature fruit drying technologies significantly slow down the development of microorganisms and increase the microbiological safety of products. In particular, the lyophilization (freeze-drying) method allows preserving such sensory properties of the product as nutrition, taste, and color, while most effectively reducing the activity of microflora. On the other hand, vacuum drying and heat pump drying are viable alternatives in terms of energy consumption, time and cost.

In the study, it was observed that freeze-drying method reduced the microorganism count on fruits to 103 CFU/g. This extends the shelf life of the product and ensures the delivery of quality food to users. However, high maintenance costs and energy consumption may limit the implementation of this technology on a commercial scale.

Based on the results, the following practical recommendations can be made:

- The use of low-temperature drying technologies should be expanded to ensure food safety;

- The development and application of energy-efficient drying equipment suitable for local conditions is recommended;

- Microbiological analysis and quality monitoring should be continuously carried out on dried products;

- Technological and financial support mechanisms should be developed for small and medium-sized producers.

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