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MODERN DRYING TECHNOLOGIES OF MELON FRUIT AND THEIR EFFICIENCY

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ABSTRACT

This article studies modern technologies for drying melon fruit, including convective, vacuum, and infrared drying methods. The effectiveness of these methods and their impact on product quality are analyzed.

Keywords : *melon, modern drying, vacuum drying, infrared drying, technology, quality*

Relevance of the topic. Nowadays, deep processing of food products, preservation of their quality and extension of shelf life are one of the most important issues on a global scale. The growing population, the need to ensure food security, and the increasing demand for export-oriented products require the processing of agricultural products using modern technologies. Despite its high biological value, melon fruit is among the perishable products due to its high moisture content (85–90%). Therefore, its processing using modern drying technologies expands the possibilities of long-term storage, transportation, and export. Compared with traditional drying methods, modern drying technologies (convective, vacuum, and infrared drying) are distinguished by their high preservation of product quality, acceleration of the process, and compliance with hygienic requirements. At the same time, adapting these technologies to local conditions, assessing their economic efficiency, and developing optimal technological regimes are among the current scientific and practical problems.

In this context, it is important to conduct an in-depth study of melon processing processes based on modern drying methods, identify their advantages and disadvantages, and develop effective technological solutions.

Scientific research on modern drying technologies is aimed at developing highly efficient methods for processing melons and other fruit and vegetable products. The main focus in this direction is on maintaining product quality, increasing energy efficiency, and optimizing the drying process.

In the fundamental works created by AS Mujumdar, the drying process is explained as a complex physical process based on the laws of heat and mass transfer. His work "Handbook of Industrial Drying" covers in detail the kinetics of drying, diffusion processes, and the principles of operation of various drying devices, forming the theoretical basis of modern drying technologies [1].

P.Fellows (Food Processing Technology) has emphasized the importance of drying food products to ensure microbiological stability, reduce water activity, and extend shelf life. He believes that vacuum and low-temperature drying maximizes the nutritional value of the product[2].

Kudra and Mujumdar (Advanced Drying Technologies) compared traditional and modern drying methods and found that vacuum, infrared, and microwave drying were the most suitable technologies for heat-sensitive products. These methods are characterized by reducing product discoloration and increasing vitamin retention[3].

In the studies of Ratti (2001) and Doymaz (2014), the drying kinetics of fruit products were expressed using mathematical models. In their work, exponential and diffusion models of the drying process were developed, which made it possible to predict the drying time. This is of great importance in industrial production planning[4].

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Sharma, Chen, and Wu Lan (2009) studied solar-based hybrid drying systems and showed that they were highly energy efficient and hygienically superior to the traditional solar drying method[5].

Rizvi (Food Engineering Principles) and Maskan (2001) scientifically analyzed the color change, Maillard reactions, and caramelization processes during drying. These processes directly affect the appearance and consumer quality of the product[6].

In general, the analysis of scientific literature shows that modern drying technologies significantly improve product quality, but further research is needed on their cost-effectiveness and adaptation to local conditions. In particular, the development of optimal drying regimes for fruits with high moisture content, such as melons, remains a pressing scientific problem[7].

The object of the study was melon fruits and their processing using modern drying technologies. The following melon varieties grown mainly in Uzbekistan were studied in the study: "Gulobi", "Torpedo", "Mirzachul", as well as modern drying equipment and technological processes used for these varieties.

The subject of the study: a complex of physical, chemical and technological changes that occur during the processing of melon fruits using modern drying technologies. In particular, the following indicators were studied: duration and kinetics of the drying process; the effect of temperature and pressure on the moisture content of the product; the final moisture content of the dried product; organoleptic indicators such as color, taste and texture; the degree of preservation of nutritional value (sugar, vitamins); the effectiveness of various drying methods (convective, vacuum, infrared).

The study also compared and evaluated the impact of modern drying technologies on energy consumption, economic efficiency, and product quality.

In this study, a complex of experimental and comparative analysis methods was used to study the process of processing melon fruits using modern drying technologies. The research work was carried out in laboratory conditions. For the experiment, melon varieties grown in Uzbekistan with the same degree of ripeness were selected: “Gulobi”, “Torpedo”, “Mirzachul”. The raw materials were prepared in the following stages: visual sorting (separation of damaged fruits); washing and sanitary treatment; peeling; cutting into uniform sizes with a thickness of 5–8 mm.

The following modern drying methods were used in the study: Convective drying (with hot air flow): temperature: 50–65°C, air velocity: 1.5–2.5 m/s, drying environment: forced ventilation chamber. Vacuum drying: pressure: 6–10 kPa, temperature: 40–55°C. Infrared (IR) drying: radiation power: 0.5–1.2 kW/m², distance: 15–25 cm.

The following parameters were recorded regularly during the drying process: initial and final product moisture content (%); drying time (hours); mass loss (g); color and organoleptic changes; energy consumption (kWh). Moisture content was determined by a standard gravimetric method (drying method at 105°C).

During the study, drying processes of melon fruit based on convective, vacuum and infrared drying technologies were studied. Drying kinetics, final moisture content, time and quality indicators were evaluated for each method.

Table 1

Drying duration and final moisture content of melon fruit in different drying methods

Drying method	Temperature mode	Drying time	Final moisture (%)
Convective	55–65°C	10–12 hours	14–16
Vacuum	40–55°C	6–8 hours	11–13
Infrared (IR)	50–60°C	4–6 hours	12–14

According to the analysis results, the convective drying method lasted the longest (10–12 hours). In this method, heat is transferred only from the outer surface to the inside, so the moisture release is slow. The final moisture content is 14–16%, which is a relatively high indicator. This means that the moisture bound inside the product has not been completely removed (Table 1). Due to the low pressure in vacuum conditions, the boiling point of water decreases. Therefore, moisture is removed faster and the final moisture content is one of the lowest (11–13%). This has a positive effect on the long-term storage of the product. The infrared method was the fastest (4–6 hours) drying technology. IR radiation penetrates deep into the product and quickly evaporates internal moisture. The final moisture content is 12–14%, which is slightly higher than vacuum, but lower than convective. The experiment found that the fastest was infrared (4–6 hours), the driest product was vacuum (11–13%), and the slowest was convective (10–12 hours) (Table 1).

Table 2

Energy consumption and efficiency of drying methods

Drying method	Energy consumption (kWh/kg)	Efficiency (%)	Evaluation
Convective	1.8	70	Average
Vacuum	2.3	85	High
Infrared (IR)	1.5	90	Highest

Research results 1.8 kWh / kg energy expense average is considered , but heat losses many what happened for with efficiency 70% the most low indicator . In this method, a large part of the energy is released into the environment. Vacuum drying has one of the highest energy consumptions of 2.3 kWh/kg. This is due to the additional energy required for vacuum pumps and maintaining low pressure. However, due to the high quality of the product, the efficiency reached 85%. Infrared drying consumed the least energy (1.5 kWh/kg) and showed the highest efficiency (90%). This is because the energy is directed directly to the product and heat losses are minimal. In the experiment, it was found that: the most economical: infrared, the most expensive: vacuum, the most inefficient: convective (Table 1).

Table 3

Quality indicators of dried melon products (organoleptic evaluation)

Drying method	Color (point)	Taste (score)	Smell (score)	General quality
Convective	3	4	4	Good
Vacuum	5	5	5	Excellent
Infrared (IR)	4	4	4	Good+

Ready dried melon to the point of being organoleptic grade when given convective in a way dried melon of the scum color 3 points – product a little long , long heat effect result . Taste and smell are 4 points, relatively well preserved, but there is a slight difference from the natural state. The average indicator of melon varieties dried by the vacuum method gave the highest result. Since there were no oxidation processes at low temperatures, the color was preserved naturally (5 points). Taste and smell are also maximum (5 points), since volatile aromatic substances were not lost. As a result of rapid drying with infrared (color 4, taste 4, smell 4), the quality was well preserved, but due to high-intensity radiation, the color and aroma partially changed. Therefore, all indicators are 4 points (Table 93). From Table 3 it can be seen that the highest quality: vacuum, moderately high: infrared, satisfactory: convective drying.

The results of the general analysis showed that among the drying methods, the fastest drying method is infrared, the highest quality product is vacuum drying, and the cheapest and simplest method is convective drying. When choosing a drying technology, product quality, energy consumption, and economic efficiency should be comprehensively evaluated.

In this study, the technological, energy and quality indicators of the drying process of melon fruit based on modern drying technologies - convective, vacuum and infrared (IR) methods - were comprehensively studied. Based on the results obtained, the differences between these methods were analyzed in depth, and the specific advantages and limitations of each technology were identified.

According to the results of the study, the highest rate of drying was recorded for infrared drying (4–6 hours), which significantly speeds up the process due to the direct transfer of heat to the inner layers of the product. Vacuum drying, although it has a relatively moderate duration, was distinguished by the best preservation of biologically active substances and natural properties of the product, since it is carried out at low temperatures. Convective drying, despite being a technologically simple and widely used method, was characterized by a long process duration and high heat loss.

In terms of energy efficiency, infrared drying was rated as the most economical method (90%), while vacuum drying, while providing high quality, required additional technical equipment and more energy to create a vacuum. While the convective method had relatively low energy consumption, the overall efficiency was the lowest.

The results of organoleptic evaluation showed that the product prepared by vacuum drying was of the highest quality. In it, the color, taste and aroma indicators were preserved almost close to their natural state. In infrared drying, the quality of the product was maintained at a good level, but some changes were observed in some indicators due to the intensive heat effect. In convective drying, a slight darkening of the color of the product and a decrease in quality indicators were noted as a result of prolonged heat exposure.

The general analysis shows that each of the modern drying technologies should be used depending on certain goals and conditions. If the main goal is to maintain the maximum quality of the product - vacuum drying, process speed and energy efficiency are important - infrared drying is the most optimal option. Convective drying, on the other hand, is convenient for small production and simple conditions due to its low cost.

At the same time, it is determined that in the future, through the combination of these technologies (hybrid drying systems), it is possible to implement both high-quality, energy-efficient and fast drying processes. This will be of significant scientific and practical importance in the industrial processing of melon products and the production of export-oriented products.

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