UDK: 664.8.037.1

INVESTIGATION OF THE CHARACTERISTICS OF FRUIT PRESERVATION TECHNOLOGY IN AN IONIZED ENVIRONMENT

Matqosimov Muhammadsodiq Mahammadhoshim o‘g‘li
(PhD) Assistant, Energy Efficiency
Andijan State Technical Institute, Republic of Uzbekistan.
ORCID: 0009-0004-7849-8918
Abduhoshimov Muslimbek Abdulboqi o‘g‘li
ORCID:009-0000-9634-9634

Abstract: This article investigates the fundamental principles and technological processes of fruit preservation in an ionized environment and their effects on fruit quality and shelf life. Research shows that ionizing radiation significantly reduces microbial contamination, slows down the rotting process, and preserves the external appearance and beneficial properties of fruits. The article also analyzes the efficiency, energy-saving aspects, and environmental safety of storage in ionized conditions. The results obtained are of great importance for improving long-term fruit preservation technologies.

Keywords (in English): Ionization, fruit preservation, food safety, microflora, radiation technology, shelf life, environmental safety.

Introduction

Characteristics of Fruit Preservation Technology in an Ionized Environment.

The effect of an ionized air environment on fruit products is investigated. After being harvested from the parent tree, fruits continue to undergo biological processes. Nutrients within the fruit are gradually consumed, and water evaporates over time. As a result, the fruit deteriorates — losing its commercial appearance, flavor, and aroma. The slower the metabolic processes in the fruit, the better it can be preserved.

The main objective of long-term fruit preservation technology is to minimize the fruit’s respiration rate. Ionization of the surrounding air creates an ion layer on the surface of the fruit, which in turn slows down metabolic activity.

A significant portion of fruit mass consists of water — approximately 70–80%. Grapes, apples, and other fruits also contain essential nutrients such as sugars, organic acids, aromatic, and volatile compounds. During storage, for instance in apples, the carbohydrates gradually break down into simpler forms. Sugars undergo hydrolysis and transform into more soluble forms. As a result of ongoing physiological and biochemical processes, the nutrient content in fruits decreases over time.

Water vapor continuously evaporates from the surface of the apple. Additionally, water is consumed during the respiration process. These factors collectively reduce the fruit’s storage stability. In cases where the fruit surface is mechanically damaged, the protective skin is compromised, creating favorable conditions for the development of pathogenic microorganisms.

Air ions, when applied under cooling conditions or in a natural environment, contribute significantly to better preservation of fruits. These ions exert both direct and indirect effects on fruit quality.

The **direct effect** of air ions is characterized by the formation of an ion layer on the surface of the fruit, which influences the ion exchange processes associated with metabolism. This process helps retain moisture, nutrients, and aroma in the fruit more effectively.

The **indirect effect** of ionized air is associated with the suppression of fruit diseases and the inhibition of microbial growth.

The outcomes of fruit preservation are evaluated based on certain criteria after a predetermined storage period — including mass loss, waste quantity, and the proportion of marketable product.

When fruits are intended for long-term storage, their preservation depends on a complex set of factors, such as the microclimatic conditions, ionization regimes, the type and physiological state of the product, as well as the type and capacity of the packaging containers.

To study the process of fruit preservation in an ionized air environment, experiments were conducted on commonly cultivated late-season apple varieties (such as Semerenko) and the Toifi grape variety under the conditions of the Republic of Uzbekistan. Research was carried out in a storage facility located at the “Malek” farm, affiliated with the Farmers Association of the Sirdaryo district, Sirdaryo region. The fruits were stored in chambers of a fruit storage warehouse with a capacity of 50 tons.

Fruits, particularly apples, were stored over extended periods in different types of containers. The air in the storage facility was ionized under various regimes using both positive and negative ions. In the naturally ventilated storage environment, the air temperature ranged from t = 8 to 10°C, with relative humidity maintained at 75%. Ventilation was provided by opening doors and windows.

Parameters such as air temperature and humidity, electrode voltage, volumetric concentration of air ions, ionization device operation time, and duration of fruit exposure were regularly monitored. The concentration of air ions was measured using a САИ-ТГУ-66М-type air ion counter. In addition, the number of air ions was assessed based on the magnitude of discharge current. A correlation between the ionizer’s discharge current and air ion concentration was established, and the ion concentration was determined using a complete set of ionizer characteristics [8,9].

Figure 1 illustrates the technological scheme of a needle-type ionizer operating in combination with a ventilation system.

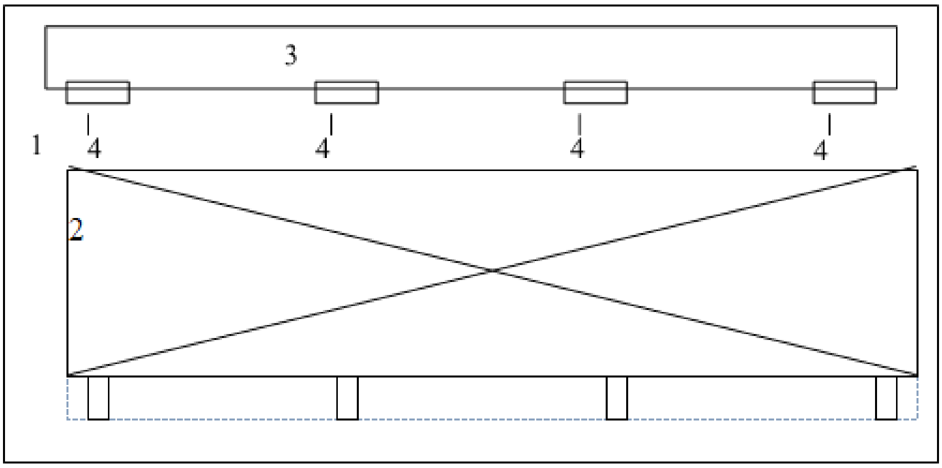

Figure 1. Technological scheme of a needle-type ionizer operating in combination with a ventilation system:

The system consists of the following components: 1.Storage chamber, 2. Stored products, 3. Ventilation and cooling system, Electroionization device.

In the experiments, a corona-discharge air ionization device was employed.

MAIN PART

Prior to placing the products into storage, the chamber was pre-ionized for 6 hours with an ion concentration of 5×10^{13} ions/m³. During storage, air ionization was carried out using both positive and negative ions at a concentration of 10^{12} ions/m³ for intervals of 2, 4, and 6 hours.

Apples and grapes were stored in wooden crates. The apples were hand-picked, sorted, pre-cooled, and then placed into the storage chamber. The products were stored in a cold storage room maintained at 0°C and 90% relative humidity. The fruit storage facility was equipped with a 50-ton capacity cooling system, and the fruits were also stored in a 10-ton capacity chamber with a naturally regulated microclimate.

The ion concentration levels and treatment durations were determined based on preliminary experimental studies, ensuring the complete elimination of pathogenic microorganisms without adversely affecting product quality. During apple storage, the most common contaminant is mold fungi [10]. In the course of the study, the effect of air ions on the viability of the fungus Penicillium glaucum (Ps.gl), commonly found on apples, was investigated. The findings provided valuable data for determining the parameters of electro-technological treatment.

For the experiments, a separate 0.5 m^3 chamber was designated within the fruit storage facility. Petri dishes containing Ps.gl cultures were placed inside these chambers and subjected to various ion concentrations and exposure durations. It is known that ion concentrations ranging from 10^3 to 10^{11} ions/m^3 can stimulate the biological activity of living organisms. However, higher concentrations may inhibit or completely suppress metabolic processes.

Air ions were applied at concentrations ranging from 0.5×10^{12} to 10^{13} ions/m^3. Similar trials were conducted using apples intentionally infected with Ps.gl fungi. The apples were first washed in cold water, then inoculated with the fungus and placed into the storage chambers. The air temperature was maintained at 0°C with 90% relative humidity. Infected apples were stored under varying environmental conditions for 20 days, and the resulting data were analyzed..

SOLUTIONS

1. As the concentration of air ions increases, the growth of microorganisms is significantly inhibited.
2. To achieve a noticeable antimicrobial effect, the volumetric concentration of air ions must reach at least 10^{12} ions/m^3. For complete elimination of microorganisms, air ion treatment should be applied once a week for a duration of 1.5 to 2 hours (see Figure 2).

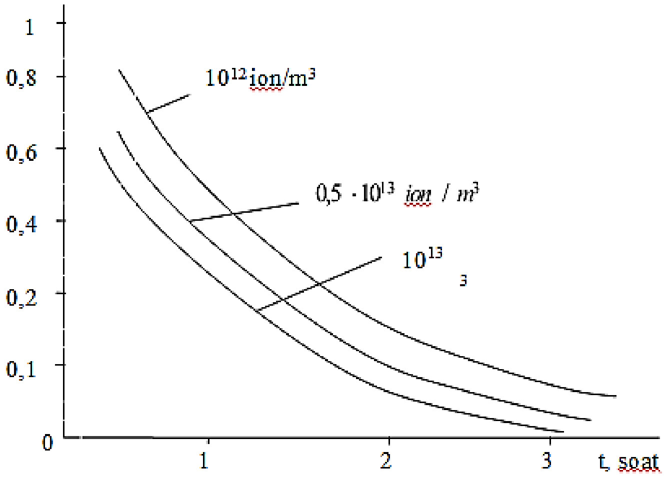

Figure 2. The influence index of microorganisms on the ionization dose in electrical ionization.

In the studies, the air was ionized with positive and negative ions, for which the polarities of the discharge electrodes were switched. The microorganisms (Ps.

gl mold) were equally affected by both the “+” and “-“ ions. The development of mold-forming bacteria on the fruit surface was halted. Based on the results of the above studies, the air ionization volume concentration was set at 10^{12}-10^{13} ions/m³, and the ionization time was determined to be 2-4 hours, repeated once a week in technological production experiments. In these conditions, the process of metabolism in the fruit slows down, and the loss of nutrients and moisture also decreases. The optimal ionization level for the preservation of fruit products was determined based on the long-term storage possibilities of their physicochemical and commodity-dietetic indicators, as well as the conditions ensuring no ozone formation..

The apples were placed for long-term storage in the following variants:

1. In fruit storage chambers equipped with a cooling system at a temperature of 0°C and humidity of 90%, the volume concentration of air ions was 10^{12} ions/m³; 0.5×10^{13} ions/m³, with a treatment time of 2-4 hours. Treatment was repeated once a week.
2. In a storage chamber without a cooling system, with the same ion concentration and treatment time.

Before placing the product in storage, the chambers were cleaned and treated with ionizers at maximum efficiency ($n=10^{13}$ ions/m³) for 6 hours. Then, 50 wooden boxes were placed in each storage chamber variant, stacked 5 boxes high, with 25 kg of apples in each box, totaling 1250 kg of apples in each variant for storage.

1-jadval.

Variants	Storage Regime		Ionization Regime		Storage Results %		
	t,^{0}C	γ,%	n,ion/m^3	τ,soat	Tovar mahsulot	chiqindi	Massa yo’qolishi
1			10^{12}	2	79	21	7
2	0	90	$0,5*10^{13}$	2	86	14	6
3			10^{13}	2	89	11	5,8
4			10^{12}	4	83	17	6,5
5			$0,5*10^{13}$	4	88	12	5,8

6			10^{13}	4	90	10	5,7
7	+(5 - 8)	75	-	-	72	28	9
8			-	-	64	36	10
9			-	-	70	30	9
10			-	-	79	21	9,5
11			-	-	83	17	9,2
12			-	-	86	14	9

The storage results were monitored every month. The apples were inspected, and the boxes were randomly selected and checked. Boxes with up to 10% loss were removed. At the end of the storage period, the chemical composition was determined, and organoleptic evaluation was conducted. The mass loss of the product (evaporated water amount) was determined by weighing the sample boxes and experimental batches (at the end of storage). The temperature and humidity of the fruit storage rooms were monitored using temperature and humidity sensors. The cooling system automatically maintained the microclimate in the room.

The overall result in each variant was determined based on the mass of the product placed for storage and the mass of the well-preserved product at the end of the storage period. According to the standard, when stored for 5-6 months, fruit products lose up to 6% of their mass. Losses may also occur due to fruit being infected with various microorganisms or decaying. Total waste should not exceed 10%. The status of the results after 6 months is presented in the table (Table 1). When placed in various containers, apples and grapes stored in wooden boxes with paper padding were observed to be well-preserved. The corners of the boxes were made 5-8 mm higher, ensuring that when the boxes were stacked, air gaps remained between them, allowing the air ions to reach the fruit. For mathematical processing of the storage results and determining optimal conditions, the following regression equation will be used.

$$Y=a_o+a_1x_1+a_2x_2+a_3x_3+a_{12}x_1x_2+a_{23}x_1x_2+a_{13}x_1x_3+a_{123}; \qquad (1).$$

Here: y - experimental result, product quantity, % X1 - factor, volume concentration of air ions 10^{12} ions/m³ - 10^{13} ions/m³; X2 - treatment time, hours (up to 6 hours); X3 - air temperature of the storage chamber (0-10°C); a0, a1...a123 - regression coefficients, which are determined from the following expression:

In the experimental studies (Table 1), we determine the values of the regression coefficients based on the results obtained and get the following equation:

$$Y=79+2,44x_1+2,34x_2-6,4x_3-0,7x_1x_2+0,2x_1x_3+0,68x_2x_3-0,3x_1x_2x_3; \quad (2).$$

Without considering the interactions between the factors, the expression simplifies to the following form:

$$Y=79+2,44x_1+2,34x_2-6,4x_3 \quad (3).$$

It can be seen from this equation that the important factor in the process is the air temperature. Based on this, it is recommended to store fruit products for long periods only in storage rooms with cooling systems. In storage rooms without cooling systems, the product can be stored in good condition for up to 2 months.

By processing the mathematical model, optimal treatment regimes were determined in technological production experiments. Based on the subsequent results, the regression equation obtained takes the following form:

$$Y=84+4,2x_1+3,46x_2-2,44x_1x_2 \quad (4).$$

In this case, the fruit products in both the experimental and control variants were stored at the same temperature of 0-10°C, meaning that when the cooling regime was the same, the fruit products in the experimental variants were preserved in good condition, taking into account the electrotechnological effects. The optimal air ionization regime is 0.9×10^{13} ions/m³, with a treatment time of 4 hours. In this case, the product quality was $y = 90\%$.

Conclusion

As a result of the studies, the requirements for the operating modes of the electroionizer were determined, meaning it must generate unipolar ions at a concentration of 10^13 ions/m³ in the storage chamber.

The experiments show that when air is ionized for storage, the losses of fruit products are reduced by 1.7 times, the product is preserved at 90%

quality within 6 months, and water loss does not exceed 6%.

Automating technological processes improves the storage condition and quality indicators of fruit products. The yield of marketable products increases, and the storage process becomes human intervention-free. The stability of air conditions in the room is ensured, and the incidence of disease decreases.

List of used literature.

1. I.A.Karimov. Jahon moliyaviy-iqtisodiy inqirozi, O’zbekiston sharoitida uni bartaraf etishning yo’llari va choralari. Toshkent, O’zbekiston, 2009.
2. Qishloq xo’jaligidagi iqtisodiy islohatlarni chuqurlashtirish dasturi (2005-2010 yillar).- T.: O’zbekiston, 2009.- 96 b.
3. Пирматов, Н. Б., Маткосимов, М. М., & Махамаджанов, С. Ю. (2024). Исследование по использованию асинхронной машины в генераторе, изготовленном на микрогидроэлектростанциях из возобновляемого альтернативного источника энергии. Альтернативная энергетика и экология (ISJAEE), (2), 79-85.
4. Berdiyev, U., & Matqosimov, M. (2024). Prospects for the use of renewable energy sources. *Bulletin news in New Science Society International Scientific Journal*, *1*(3), 215-221.
5. Turatbekova, A., Masharipova, M., Umarova, F., Xalmurodova, E., Rustamova, R., Abdixoshimov, M., & Teshaboyev, R. (2024). Biologik faol o'simlik terpenoidlari va biologik faollik mexanizmlarini o'rganish. E3S Web of Conferences da (563-jild, 03076-bet). EDP fanlari.