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Study of quality and technological parameters for the storage of greens using ionized water

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ABSTRACT

During the storage of agricultural products, in order to maximally preserve quality indicators and to prevent spoilage, the creation of a special temperature and climate regime in the cold storage boxes, harmless to health and environmentally friendly preparations are used, which along with a temperature environment, allow for long-term, high-quality storage of products, as well as complex sanitary-hygienic measures, the main one of which is disinfection and deodorization of the cold storage boxes. The article discusses the studies on the treatment of agricultural products by ionized water and their further storage, in particular, for the greens storage, there was selected their treatment by „alkaline ionized water" while „acidic ionized water" is used for disinfection of the cold storage boxes. The method of obtaining ionized water and the research object were selected, the storage conditions were established, and the quality and technological indicators of the greens were determined. The reduced density of glucose under optimal storage conditions varies from 28 to 19, and the reduced density of water ranges within 445 to 404 after 10 days of storage. The change of technological indicators after 3 and 10 days of storage amounts to: mass losses – 0.70% and 0.85%, water binding capacity - 70% and 61%, and water holding – 65% and 57%.

Keywords: acidic ionized water, alkaline ionized water, reduced density, greens, storage

INTRODUCTION

Storage and transportation of agricultural products and raw materials have always been and are relevant when solving their processing, production and sale issues. For carrying vegetables and herbs, canvas bags are currently being used, in which the storage and transportation of agricultural products and raw materials have always been and are among the relevant areas when solving issues of their processing, production and sale. For carrying vegetables and greens, canvas bags are currently being used, in which the products to be transported and pieces of ice are stacked layer-by-layer. This method cannot ensure the storage and transportation of herbs even for 2-3 days. Besides, it requires a large amount of ice, which may exceed the mass of greens and vegetables to be transported. This method is very inconvenient and costly. In the best case, the vehicle must have a special refrigerator or container with a suitable microclimate, associated with technical difficulties and large expenditures.

The analysis of scientific studies and labor market research revealed relatively low scientific studies on processing agricultural products using safe and environmentally friendly drugs and towards long-term storage. Therefore, the studies included in the project are highly relevant because the methods and regulatory documents (recommendations) for refrigeration storage enterprises that have been designed based on these studies outline a strategic plan for their effective functioning and for high-quality long-term storage and transportation of agricultural products. It should be noted that these methods are continuously updated in order to reflect modern advances in science and technology.

In modern conditions, the ozonation method of cold storage boxes is used to store vegetables and fruits **[1]**. It should be noted that, despite the significant positive results of the ozonation process, according to the literature data, there are various contradictory opinions regarding its use, in particular, measurements of ozone concentration in the air using the iodometric method cannot provide sufficient accurate measurement of its concentration. Also, the high air humidity in the box causes fast ozone depletion, making it necessary to measure ozone concentration frequently. There also seems to be disagreement about the effects of ozone on microbial cells, so it becomes imperative to consider the effect of the ozone-air mixture on bacteria. It should be remembered that ozone belongs to the first category of danger. According to the sanitary standards of the European countries, the acceptable limits for the ozone content in spaces where people work is 0.1 $mg.m^{-3}$, so, before ozonating the cold storage boxes, it is necessary to seal them and shut down the air distribution fans. Before operation, it is necessary to check the correctness of technological and electrical schemes **[2]**, **[3]**.

The existing method of disinfection of the cold storage boxes involves the following stages: a) disconnection of the refrigeration unit from power supply; b) the release of the cold storage box from the product; c) warming up the cold storage box and the release from ice and snow; d) „wet" processing of the internal surfaces of the cold storage box; e) ozonation of the cold storage box with a concentration of 12-14 ∂გ $∂^{-3}$ and the duration of 10-12 hours **[1]**.

We tried to find such means for the sanitary-hygienic treatment of the cold storage boxes and agricultural products, which would not have the mentioned negative properties and could be used by any staff member. We considered ionized water to be such a preparation for the treatment of the cold storage boxes, in particular, „acidic ionized water", because it has several advantages compared to other disinfectants, while for the processing and transportation of agricultural products, in order to maintain their quality indicators optimally, we chose „alkaline ionized water".

„Acidic ionized water" is a transparent liquid free of sediment with an acid reaction and a slightly stinging taste **[4]**. If the concentration is selected correctly, it has antiseptic, anti-allergic, drying, anti-parasitic, and anti-inflammatory properties **[5]**. Its antiseptic effect corresponds to the iodine, diamond greens, hydrogen peroxide and other treatments, but unlike them, it does not cause chemical burning of living cells and their colouration **[6]**. „Alkaline ionized water" slows down metabolic processes in living cells and destroys microflora and microorganisms **[7]**.

„Alkaline ionized water", on the contrary, is a blue liquid in the first minutes of preparation with an intense snowflake-like sediment, which settles entirely in 20-30 minutes. It has an alkaline reaction and a mild taste of baking soda. With its oxidizing properties, „alkaline ionized water" is among the antioxidant drugs, acting as an immunostimulant **[8]**. It is a radioprotective agent, a strong simul and for biological processes and metabolism, which has high extractive and solvent properties, and easily removes slags from the body, including radionuclides. It heals wounds quickly and, accordingly, has antibacterial and antimicrobial properties, but its antiseptic effect is inferior to „acidic ionized water" **[9]**, **[10]**.

Based on the properties mentioned above, we chose „acidic ionized water" as the environmentally friendly and effective means for the sanitary-hygienic processing of the cold storage boxes and containers for carrying fruits and vegetables because its use is not harmful to human health and the environmental safety of natural environment. On the contrary, after taking it, blood pressure is regulated, metabolic processes in living cells slow down, joint pain decreases, and so on. When applied to the skin, it promotes wound healing by destroying microbes **[11]**, including with the flu, preventing food poisoning and restoring cell immunogenesis and the fluid medium pH **[12]**. Accordingly, unskilled staff can perform this work **[13]**.

As for „alkaline ionized water", due to its positive properties, in order to maintain the quality indicators of agricultural products, additional studies are needed on their treatment with this drug, which is a novelty of our research **[14]**. Treating seed material with „alkaline ionized water" is also relevant and needs to be studied to improve its biological and vegetative indicators. At this stage, we studied the storage and transportation technology of agricultural products using ionized water, particularly the issues of maintaining its quality indicators after treating greens with ionized water.

Vegetables and fruits are living organisms, so they are characterized by the exchange of substances with the environment **[15]**. This process consists of two interrelated processes - assimilation and dissimilation. After the collection of products of vegetable origin, important life processes occur, such as: physical processes, processes of biochemical decomposition (reactions) and respiration **[16]**.

Thus, based on the analysis, we can conclude that in order to extend the storage period of the collected fruits and vegetables, it is necessary to stop the respiration process of the collected fruits and vegetables in time, which will lead to a sharp reduction in the process of heat release and, accordingly, to a reduction in mass loss.

The research aims to determine the optimal conditions for maintaining the quality indicators of agricultural products during their storage or transportation using ionized water.

Scientific Hypothesis

Due to its numerous properties, in particular, due to its antibacterial and antimicrobial properties, the „alkaline ionized water" can be used for the treatment of greens under storage conditions in order to maintain its quality indicators because it restores the damaged tissue and prevent the process of moisture evaporation from the inner volume of greens. As a result, it is expected to reduce the loss of mass of greens and maintain its quality for up to ten days. Due to its antiseptic properties, the „acidic ionized water"can be used for the sanitary-hygienic treatment of cold storage boxes, excluding dangers. This will allow us to perform the work by any ordinary low-skilled service personnel, which will have a significant economic effect.

MATERIAL AND METHODOLOGY

Samples

In order to achieve this goal, as the research object, we have selected perishable vegetables – the greens – parsley (*Petroselium Sativum*) and fennel (*Anethum graveolens*) grown in the Imereti region of Georgia, which we bought at the farmers' market in Kutaisi. The results of the research can be used in different environments and on greens grown in different countries because greens cultivated in any country have chemical compositions that are virtually identical. In the market in Kutaisi, we have also bought purified drinking waters „Bakuriani" (Brand: Bakuriani, Borjomi, Georgia; product type: drinking water: Calcium: 25-80 $mg.L^{-1}$; Magnesium: 20 $mg.L^{-1}$; Sodium: 20 $mg.L^{-1}$; Hydrocarbonate: 150-300 $mg.L^{-1}$; Chlorides: 20 $mg.L^{-1}$; Sulfates: $mg.L^{-1}$; Total composition of minerals: 0.20-0.5 $g.L^{-1}$; pH 6.0-8.0; StateSt 85:2019) and „Sno" (Brand: Sno, Kobi-Kazbegi Reg. Georgia; product type: drinking water: calcium: 43-45 $mg.L^{-1}$; Magnesium: 6-10 $mg.L^{-1}$; Sodium: <15 $mg.L^{-1}$; potassium: 0.7-1.2 $mg.L^{-1}$; Hydrocarbonate: 150-200 $mg.L^{-1}$; Chlorides: <15 $mg.L^{-1}$; Sulfates: 15-16 $mg.L^{-1}$; Total composition of minerals: 0.20 $g.L^{-1}$; pH 6.0-8.0; ISO 9001:2015) to obtain ionized water („living" water and „dead" water).

Chemicals

We use it to fill the inner container for storing greens by gas Carbon dioxide (CO2) (Carbon dioxide, LTD Penguin (GE), 99%) and to fill the outer container – by gas Nitrogen (N2) (Gas Nitrogen, LTD Penguin (GE), 98%).

Equipment

We used the „shock" freezing laboratory device ATT05 - Blast chiller/shock freezer 5x GN 1/1, (Thermotechnika Bohemia s.r.o., Brno, Czech Republic) as a disinfection object.

We obtained ionized water using the scheme shown in Figure 1, by electrolysis of drinking water.

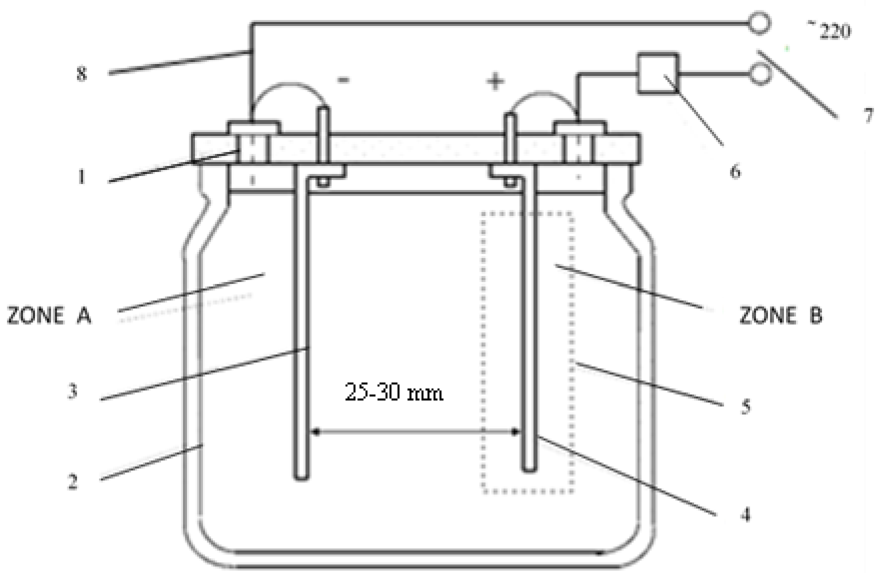

Figure 1 Equipment scheme for obtaining ionized water. Note: 1 – Glass jar cover; 2 – Glass jar; 3 – Electrode (cthode); 4 – Electrode (anode); 5 – Dense canvas bag; 6 – Diode, current rectifier; 7- AC source; 8 – Wire. Zone A – „alkaline ionized water" area; Zone B – „acidic ionized water" area.

Electrodes (cathode and anode 3, 4) made of stainless steel are attached to the plastic jar cover. They are connected to the alternating current source (7) using a current-controlling diode bridge (6). We poured purified drinking water into a glass jar (2) and closed this jar tightly with a cover. Anode (4) is placed in a dense canvas bag (5), which was previou¬sly inserted into the jar and plays the role of a filter. After turning on, the electrolysis process begins.

As is known, water is to be a poorly dissociable substance, and a constant electric field forces water to dissociate. At the cathode, the dissociated water is negatively charged and „alkaline ionized water" is accumulated nearby, while at the anode, the dissociated water is also charged and „acidic ionized water" is accumulated in the canvas bag. We used the resulting ionized waters, known as „alkaline ionized" and „acidic ionized waters" for experiments.

For the transportation of herbs, we have developed a scheme of the container, the working principle of which is shown in Figure 2, and the general view of the container is shown in Figure 3.

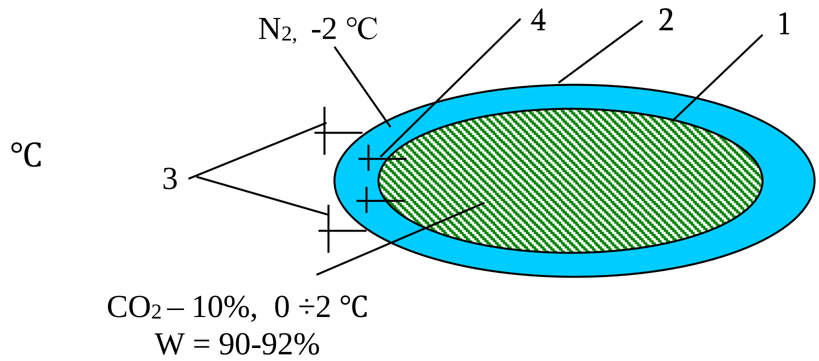

Figure 2 Schematic of a container for transporting greens. Note: 1 – Inner polymer container with herbs; 2 – External polymer container with nitrogen; 3 – Nitrogen inlet-outlet valves; 4 – Carbon dioxide inlet-outlet valves.

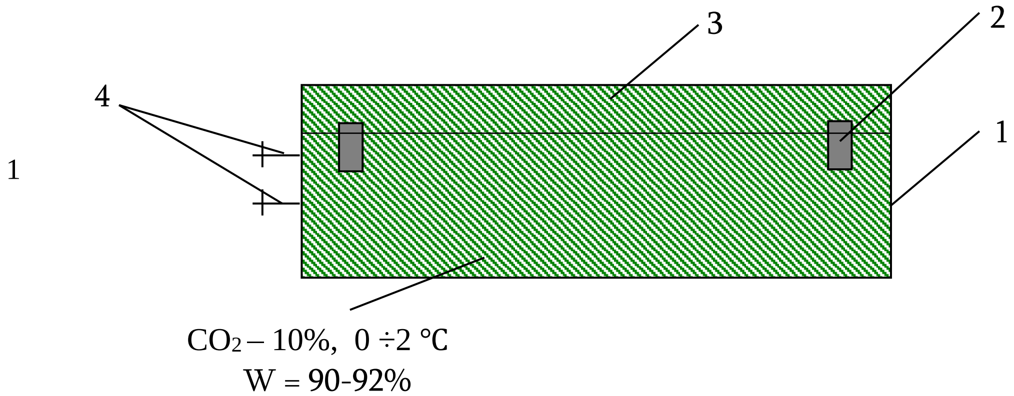

Figure 3 General view of the container. Note: 1 – Polyethylene container with greens, 1.2 x 0.6 x 0.4 m; V = 0.288 m^3; 2 – Locks; 3 – Lid of the container; 4 – Carbon dioxide inlet-outlet valves.

Instruments

Of physicochemical indicators of ionized water, we determined pH **[17]** through the pH Meter of the HM Digital COM-360 models (HM Digital Inc, Rodendo Beach, USA). To determine the mass of the product, we used an electronic digital analytical balance SF-400C model (Toms, Qilin, China) with a weighing accuracy of 0.01 g.

Laboratory Methods

From technological indicators, we determined specific glucose and water content, ionised water's pH value, water-binding capacity, water-holding capacity, and mass losses of greens during storage. We obtained ionized water by the method of electrolysis of drinking water. Of the physicochemical indicators of ionized water, we determined pH value. We determined the specific content of glucose and water by the ratio of the densities in the unit of greens mass relative to the total mass **[18]**. We determined the technological properties of greens as follows: water-binding capacity **[19]** – by pressing, using the method by Grau-Hamm. Water-holding capacity **[20]** - by the difference between the amounts of released moisture of the newly collected products and the moisture released after storage; mass losses during storage **[21]** were determined by the mass difference between the newly collected and stored products. To determine the effect of „alkaline ionized water" on greens, we soaked freshly harvested herbs in a bath of „alkaline ionized water" and left them in atmospheric conditions for some time.

Description of the Experiment

Sample preparation: We collected samples of freshly harvested herbs and temporarily stored them at 10 °C. Later, we treated them with „alkaline ionized water" and took 100 g of each sample for the experiment.

Number of samples analyzed: We analyzed 3 different samples.

Number of repeated analyses: All measurements of instrument readings were performed three times.

Number of experiment replication: The number of repetitions of each experiment to determine one value was three times. The experiment was repeated three times in different days. We bought greens of the same origin and different batches on different days. The average values of the results are given in the article.

Design of the experiment: We washed the newly-harvested greens in a living water bath, delayed them for 1-1.5 min, took it out of the bath, shook them out to remove water drops, delayed them for 10 min and then put them on the table with a layer thickness of 0.10 m for sale, while for long-term storage, we put them on the shelf of the cold storage box with a layer thickness of 30 cm.

Statistical Analysis

To analyze the test parameters of product, a statistical analysis of the obtained data was conducted, and the reliability of the obtained data was assessed by method of mathematical statistics T-test, using the Windows IBM SPSS Statistics version 20.0 program, (IBM, Armonk, New York, USA). We used statistical functions of the average arithmetic value and the average standard error to describe the ordered sample. We chose a reliability value of $p < 0.05$.

RESULTS AND DISCUSSION

During our experiments, we tried to determine the metabolic conditions of herbs, characteristic of them with the environment **[15]**. As mentioned above, after harvesting the products of plant origin, important life processes occur, such as physical processes, processes of biochemical decomposition (reactions) and respiration **[16]**. Of the physical changes, we can distinguish the processes of moisture evaporation, density and color change **[22]**. Evaporation of moisture from vegetables and fruits depends on their type, quality, morphological and chemical composition. The rapid process of moisture evaporation is facilitated by: the large size of cells and intercellular spaces in the products; the insignificant thickness of the upper layer of cells; the relatively weak water-holding capacity of protoplasm due to the small protein content in the colloidal state; large evaporation specific surface area and so on **[23]**. Moisture evaporation accompanies the product from its picking through the storage process until the end of ripening **[14]**. Intensive evaporation of moisture occurs at the beginning of storage, then there is a period of minimal evaporation, and finally, evaporation increases again in connection with over-ripening/wilting **[15]**. Loss of moisture by-products has a great impact on its durability and affects its appearance, so the more moisture the product loses, the faster it is infected and deteriorates **[14]**, **[15]**, **[23]**. Chemical changes in fruits and vegetables are associated with the respiration and ripening processes. The essence of respiration lies in the enzymatic oxidation of complex organic substances (fermentation process) and the release of energy. The external expression of respiration is the absorption of oxygen from the air and the release of CO_2. Along with this, a large amount of heat is released, which was not used by the cell during its vital activity **[16]**. In general, taking into account external factors, plant products produce not only respiration with oxygen (aerobic), but also oxygen-free respiration (anaerobic). Monosaccharides, disaccharides, polysaccharides, fats, organic acids, tannins, glucose and so on are primarily spent on respiration **[15]**, **[16]**, **[22]**. The intensity of respiration depends on many factors, of which one of the main factors (parameters) is temperature. Its reduction drastically reduces the intensity of respiration **[16],** so we should direct the storage process to this point because respiration is the process of decomposition of substances in the products.

The internality of respiration is also affected by the atmosphere's composition, which is considered when storing fruits and vegetables in a regulated environment.

As we mentioned above, respiration is accompanied by the release of heat. The largest amount of heat is released by greens. For example, at 20 °C, greens release about 0.12 $W.kg^{-1}$ of energy per hour, while fruits release – 0.013-0.020 $W.kg^{-1}$ of energy **[22]**.

We performed the following works:

- Analysis of neutral media and temperatures **[17]**, conducted in previous studies that we conducted, during which the quality and structure of the greens were preserved as much as possible **[18]**, **[19]**.
- We developed a process that practically produced ionized water („acidic ionized water" and „alkaline ionized water") in the laboratory and determined its quality indicators **[18]**.
- We selected the research objects and determination of methods of their treatment methods with „acidic ionized water" and „alkaline ionized water" **[18]**.
- We studied the qualitative and technological indicators of herbs treated „alkaline ionized water" water under different storage conditions and determined optimal storage parameters **[18]**, **[24]**, **[25]**.
- We compared the wet treatment method of the cold storage boxes with ionized water **[1]**, **[15]**.

Through early research **[24]**, **[25]**, **[26]**, **[27]**, **[28]**, we examined issues of storage and transportation **[26]** of the herbs in various ambient conditions, in particular: for two different temperatures (0 - + 5 °C) of the gaseous and inert media at different concentrations of carbon dioxide and nitrogen (8%, 10%) **[27]**, for different velocities of conditioned air (0.00145 $m.s^{-1}$, 0.0029 $m.s^{-1}$ and 0.0145 $m.s^{-1}$) **[25]** and finally in combined ambient conditions **[24]**. We selected the values of the specific contents of glucose and water as qualitative parameters of greens, because they are the two major components of the chemical composition of greens, which determine the quality of the products. (The physical process of respiration of herbs is determined by the reaction of glucose decomposition, which ensures its quality). Based on the above experimental studies **[24]**, **[25]**, **[26]**, **[27]**, **[28]**, we determined the optimal parameters for storing and transporting greens in the mentioned ambient conditions **[28]**.

The optimal storage parameters in the collection point:

- Air temperature – 0 °C,
- Air circulation speed – 0.0145 $m.s^{-1}$,
- The thickness of the layer of herbs – 0.3 m,
- Relative humidity – 90-92%,
- Carbon dioxide (CO_2) concentration – 10%.

We have developed the construction of the container for transporting greens (Figure 2, Figure 3), the type of inert gases to be filled in the container, and the optimal storage parameters (results are given below):

Inner container:

- Carbon dioxide (CO_2) – 10%,
- Temperature – 0-2 °C,
- Layer thickness – 0.3 m,
- Relative humidity – 90-92%.

Outer container:

- Nitrogen (N_2) – 90-93%,
- Nitrogen (N_2) entering temperature – (-2 °C).

We have further studied the treatment and storage of the greens using ionized water, particularly „alkaline ionized water".

We developed the process of obtaining ionized water. We determined the quality parameters of „acidic ionized water" and „alkaline ionized water".

We have determined:

- Tap water – pH = 7
- „acidic ionized water" – pH < 7
- „alkaline ionized water" – pH > 7

In the case of living water, we conducted tests in two directions: 1 – in order to maintain the quality of the greens on the shelves of the trading network, we treated a 10 cm-thick layer of the herbs on the shelf with only „alkaline ionized water", and during 10 days we calculated the values of the specific contents of glucose and water therein. For longer-term storage of the herbs, we placed the herbs treated in „alkaline ionized water" in the cold storage box, where the air temperature was 0 °C, the air circulation speed was 0.0145 $m.s^{-1}$, the thickness of the greens layer was 0.3 m, and the relative humidity was 90-92%, and for 10 days, we calculated the values of the specific contents of water. We used a control sample – ordinary greens without any treatment for comparison. We placed 0.3 m thick greens under normal environmental conditions and measured the values of reduced densities of glucose and water (Figure 4, Figure 5).

As can be seen from the figures, when treating greens only with „alkaline ionized water" (Figure 4, Figure 5, curve 3), the values of reduced densities of glucose and water during the first three days and almost the fifth day

(Figure 4, Figure 5 curves 1, 2) coincide or are very close to the values of these qualitative indicators of storage of greens in the combined mode, while during the storage of the greens treated with „alkaline ionized water" in the air-cooled to 0 °C for 10 days, these values (Figure 4, Figure 5, curve 2) are close to the storage quality parameters of the greens under optimal conditions in a combined gaseous medium (Figure 4, Figure 5, curve 1). In this case, we also used a control sample - ordinary greens without any treatment. We placed greens with a layer thickness of 0.3 m under normal environmental conditions and measured the values of reduced densities of glucose and water. The control sample completely lost its quality after the first three days (Figure 4, Figure 5, curve 4).

Figure 4 and Figure 5 illustrate the convergence of the results of curves 1 and 2, indicating that the costs incurred to obtain the descriptive results of curve 1 are inappropriate compared to the costs incurred to obtain the descriptive results of curve 2.

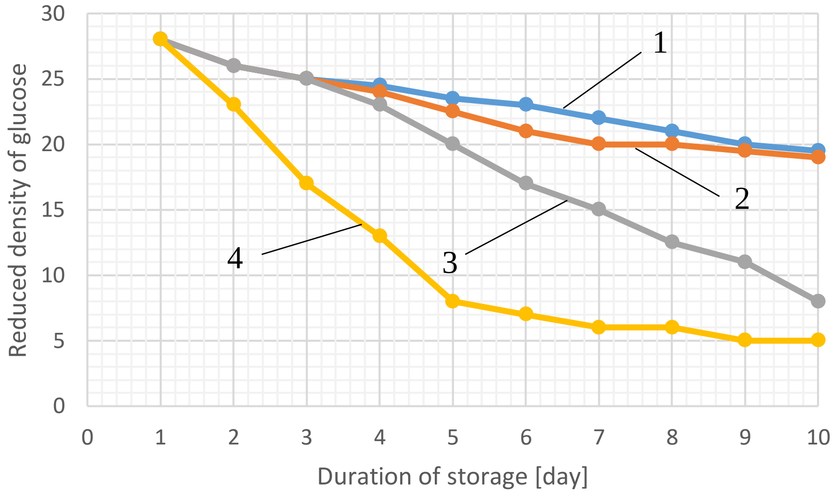

Figure 4 Changes in the reduced density of glucose in the herbs over time under different storage conditions. Note: 1 – combined gaseous medium; 2 – „Alkaline ionized water"-treated and cooled to 0 °C medium; 3 – treated only with „alkaline ionized water"; 4 – Control sample – ordinary greens without any treatment.

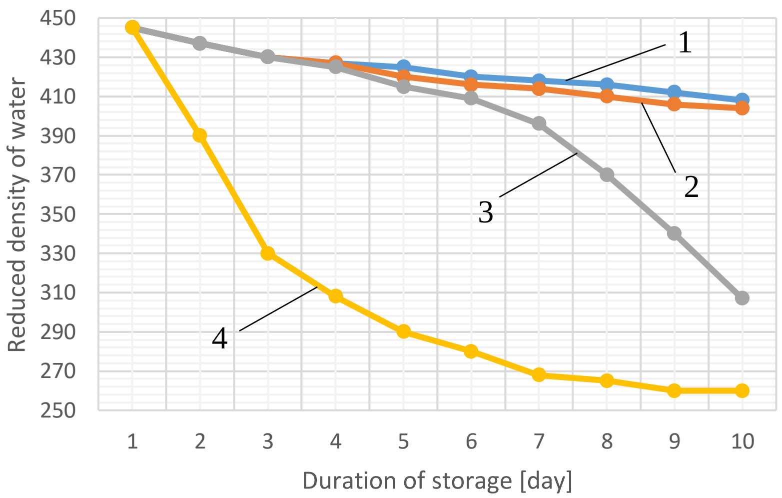

Figure 5 Changes in the reduced density of water in the herbs over time under different storage conditions. Note: 1 – Combined gaseous medium; 2 – „Alkaline ionized water"-treated and cooled to 0 °C medium; 3 – Treated only with „alkaline ionized water"; 4 – Control sample - ordinary greens without any treatment.

Based on the above-described experiments, we have determined the optimal storage parameters for the greens in the collection point (cold storage box).

Treatment with „alkaline ionized water"; air temperature – 0 °C, air circulation speed – 0.0145 m.s^{-1}, The thickness of the layer of herbs – 0.3 m, relative humidity – 90-92%.

Losses in the mass of greens (Table 1), values of moisture binding capacity (Table 2) and values of moisture retention capacity (Table 3) were determined after three, ten and twenty days of storage using different storage methods, as these parameters do not provide decisive values and this accuracy is sufficient to confirm the quality.

Table 1 Greens mass losses when using different methods to store.

Greens storage duration, [days]	**Mass losses in different storage conditions, [%]**		
	Traditional mode T = 2-5 °C v = 0.1m.s^{-1} relative humidity up to 90%	Treated only with „alkaline ionized water"; The thickness of the layer of greens – 0.3 m.	Treated with „alkaline ionized water"; Air temperature – 0 °C, Air circulation speed - 0.0145 m.s^{-1}, The thickness of the layer of greens – 0.3 m, relative humidity – 90-92%.
Three [days]	1.5	1.55	0.70
Ten [days]	2.1	2.50	0.85
Twenty [days]	4.0	6.80	1.50

Table 2 Greens water-binding capacity when using different methods to store.

Greens storage duration, [days]	**Water-binding capacity, [%] of the total weight**		
	Traditional mode T = 2-5 °C v = 0.1 m.s^{-1} relative humidity up to 90 %	Treated only with „alkaline ionized water" The thickness of the layer of greens – 0.3 m.	Treated with „alkali- ne ionized water"; Air temperature – 0 °C, Air circulation speed – 0.0145 m.s^{-1}, The thickness of the layer of greens – 0.3 m. relative humidity – 90-92%.
Three [days]	60	57	70
Ten [days]	55	39	61
Twenty [days]	40	34	50

Table 3 Greens water-holding capacity when using different methods to store.

Greens storage duration, [days]	**Water-holding capacity, [%] of the total weight**		
	Traditional mode T = 2-5 °C; v = 0.1 m.s^{-1}; relative humidity up to 90%	Treated only with „alkaline ionized water"; The thickness of the layer of greens – 0.3 m.	Treated with „alkali- ne ionized water"; Air temperature – 0 °C, Air circulation speed – 0.0145 m.s^{-1}, The thickness of the layer of greens – 0.3 m, relative humidity – 90-92%.
Three [days]	52	51	65
Ten [days]	47	40	57
Twenty [days]	33	30	51

As shown in the tables, the samples treated with „alkaline ionized water" had the best technological parameters; air temperature – 0 °C, air circulation speed – 0.0145 $m.s^{-1}$, the thickness of the greens layer – 0.3 m, relative humidity – 90-92%. It is also worth noting the fact that after three days, the technological parameters of the herbs stored in the cold storage boxes by the traditional method and under conditions of storing the sample treated only with ionized water are close to each other, which confirms the correctness of the above studies (the specific cotents of glucose and water) and once again demonstrates that the greens can be stored cost-effectively for 3-4 days only if they are treated by „alkaline ionized water".

Disinfection of the cold storage boxes is important for preserving quality indicators of greens during storage **[29]**. Here, too, ionized water can be used, only in this case, it is a matter of „acidic ionized water". The bactericidal effects of ozone have been documented on various organisms, including Gram-positive and Gram-negative bacteria and spores and vegetative cells. In this review, ozone's chemical and physical properties, its generation, and antimicrobial power with two suggested mechanisms were explained and many advantages of ozone use in the food industry **[30]**. The multifunctionality effects of ozone in food processing, in both gaseous and aqueous form, have promoted its use in the food industries to meet the increased consumer preference for a healthy diet and ready-to-eat products. However, ozone may present undesirable effects on physicochemical characteristics on certain food products at high concentrations. The combined uses of ozone and other techniques (hurdle technology) have shown a promotive future in food processing. It can be concluded that applying ozone technology to food requires increased research; specifically, treatment conditions such as concentration and humidity for food and surface decontamination **[31]**.

Ozone avoids and controls biological growth on vegetables, keeping their attractive appearance and sensorial qualities, assuring nutritional characteristics' retention and maintaining and increasing the shelf-life. However, if ozone is improperly used, it causes deleterious effects on products, such as losses in their sensory quality. For effective and safe use of ozone, specific treatment conditions should be determined for all kinds of vegetables **[32]**.

The review discusses research related to pathogen inactivation and DBP formation by chlorine and ozone during the washing of produce, meat and seafood. In particular, the research highlights the difficulty of inactivating pathogens on food but the efficacy of these disinfectants for controlling pathogen cross-contamination through the wash water. This review highlights the need for research on the initial transformation products of disinfectant reactions with biomolecules since these products may present a risk for consumer exposure by remaining within the food **[33]**.

The main focus of this review is on the effects of ozone on the fresh produce quality, defined by the maintenance of texture, visual quality, taste and aroma, and nutritional content. Furthermore, ozone has been found to be efficient in reducing pesticide residues from produce. The treatments that can reduce microbial contamination of the product without adversely hurting its visual, textural and nutritional quality can be recommended and subsequently incorporated into the supply chain. A good understanding of all the benefits and limitations related to the use of ozone is needed, and relevant information has been reviewed in this paper **[34]**.

The use of ozone has been identified as a feasible solution to reduce microorganisms present in food, in this way extending the shelf-life of fresh produce. Several factors that may affect the efficiency of ozone treatment have been identified, e.g. microbial populations, ozone concentration and time of exposure, type of produce, temperature, relative humidity and packaging material **[35]**.

The food industry is interested considerably in using ozone to enhance the shelf-life and safety of food products and in exploring new sanitiser applications. This interest was recently accompanied by a US governmental approval of ozone for the safe use, in gaseous and aqueous phases, as an antimicrobial agent on food, including meat and poultry. Ozone has a strong microbicidal action against bacteria, fungi, parasites and viruses when these microorganisms are present in low ozone-demand media **[36]**.

The effect of ozone on post-harvest garlic bulbs was evaluated. The data collected showed that ozone treatment did not affect the aromatic profile of garlic. A significant detrimental effect of ozone treatment on garlic decay was observed. Our results encourage using gaseous ozone treatment to contain garlic fungal decay during its storage **[37]**.

The effect of ozone treatment on total phenol, flavonoid, and vitamin C content of fresh-cut honey pineapple, banana „pisang mas", and guava was investigated. The fresh-cut fruits were exposed to ozone at a flow rate of 8 ±0.2 $mL.s^{-1}$ for 0, 10, 20, and 30 min. Ozone treatment significantly decreased the vitamin C content of all three fruits. The study shows promising results for enhancing antioxidant capacity of some fresh fruits by ozone treatment, although the positive effect is compromised by a reduction in vitamin C content **[38]**.

Rinsing or dipping vegetables in water saturated with ozone could be an alternative environmentally friendly and safer process since no harmful by-products or residues are formed. Immersing vegetables in water pre-saturated with ozone (0.5 $mg.L^{-1}$) did not make any difference because the total microbial count decreased by approximately 0.5 log simultaneously. Sanitation treatments were most effective when vegetables were dipped in continuously ozonated (0.5 $mg.L^{-1}$) water, leading to a decrease of 2 log of microbial load in the first 15 min and 3.5 log after 30 min of exposure **[39]**.

Employees of the State Technical University of Georgia **[1]** investigated that ozonation of the cold storage boxes for 12 hours with a 10%-concentration of ozone and every 4-hour break ensures a reduction in the bactericidal composition in the air and on the walls of the cold storage boxes by 93-97%. According to our research, it was revealed that during the wet treatment of the walls, ceiling and floor of the cold storage boxes by „acidic ionized water", 80% of bacteria are killed on average, the same effect according to findings of the research is 86.5% **[1]**, which is acceptable from an economic point of view (Table 4).

Table 4 Indicators of sanitary-hygienic treatment of the cold storage boxes.

Type of sanitary treatment	Indicators		
	Duration of operation [hr]	**Duration of operation, [week]**	**Reduction of bactericidal composition [%]**
Ozonizing	12	1	86.5
„Acidic ionized water" treatment	-	1	80.0

CONCLUSION

Experimental studies show that the treatment of greens with only „alkaline ionized water" is enough to preserve their quality indicators and appearance on the shelves for 3-5 days at the lowest cost, while as for longer-term storage, at this time, less costs are achieved to preserve better quality indicators through the use of a cooled air medium along with „alkaline ionized water" treatment (Treated with „alkaline ionized water"; Air temperature – 0 °C, Air circulation speed – 0.0145 $m.s^{-1}$, The thickness of the layer of greens - 0.3 m. relative humidity – 90-92%). Sanitary treatment of the cold storage boxes for the greens should be carried out with „acidic ionized water" at weekly intervals, which, with less energy consumption, produces about the same effect (Reduction of bactericidal composition – 80%) as ozone generators. Experimental studies show that the treatment of greens with only „alkaline ionized water" is enough to preserve their quality indicators and appearance on the shelves for three days at the lowest cost, while as for longer-term storage, at this time, less costs are achieved to preserve better quality indicators through the use of a cooled air medium along with „alkaline ionized water" treatment. Sanitary treatment of the cold storage boxes for the greens should be carried out with „acidic ionized water" at weekly intervals, which produces about the same effect as ozone generators but with less energy consumption. In our hypothesis, we have expressed the opinion that „alkaline ionized water" and „acidic ionized water" can be used to store agricultural products without taking precautions, and they give almost the same results as ozone treatment which was confirmed by the results of our research. The obtained results agree entirely with our opinions in the hypothesis.

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