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# INFLUENCE OF PLASMA CHEMICAL REACTIONS PRODUCTS IN BARRIERLESS GAS DISCHARGE IN THE AIR ON VEGETABLES AND FRUITS STORAGE

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The influence of the products of plasma chemical reactions (including ozone) on the storage of vegetables and fruits has been investigated. It has been shown that the products of plasma chemical reactions effectively suppress the growth of mold. For a number of vegetables and fruits, surface modification occurs, which leads to the loss of the "marketable" appearance. At the same time, the ripening rate of many products decreases.

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## INTRODUCTION

Increasing food security in the world and the growing role of Ukraine in this process determine the need for the development of the agro-industrial complex. An important component of a competitive agro-industrial complex is a developed fruit and vegetable industry. The low efficiency of the technologies used for transportation and storage of products leads to significant losses, which can reach 35…40% of the yield [1]. The only possible solution to this problem is the introduction of advanced technologies for storage and transportation of fruits and vegetables, as well as the development of new technologies [2 - 4]. Among such technologies, it should be especially noted technologies that are based on the processing of air by a gas discharge. In the conditions of a gas discharge of atmospheric pressure, there is an effective production of bactericidal reagents, such as ozone, active radicals, etc. The high efficiency of the using ozonation for bactericidal water treatment, control of biological contamination of grain [5, 6] and other bactericidal applications has long been known.

The concentration of ethylene in the air of food storage chambers, its production during the "respiration" of fruits have a significant effect on the process of ripening and spoilage of fruits and vegetables [7 - 9]. Under the conditions of a gas discharge and when interacting with the products of plasma chemical reactions, the oxidation of hydrocarbon compounds occurs, in particular ethylene, which is one of the "phytohormones" [10, 11].

A good indicator of the amount of products of plasma chemical reactions in the air is the concentration of ozone. The effect of ozone on the storage of fruit and vegetable products is being actively studied [3, 4, 12]. But the influence of the products of plasma chemical reactions is not limited exclusively to the effects associated with ozone, since when air is passed through the plasma chemical reactor, the conversion of hydrocarbon impurities and the production of nitrogen oxides occur [11, 13], which, despite the relatively low concentration (of the order of tens and hundreds of ppb), have a significant influence on the processes of ripening of vegetables and fruits. The work investigated the effect of the products of plasma chemical reactions during air treatment in a barrierless gas discharge (at an ozone concentration of 10 ppm) on the storage of fruit and vegetable products.

## EXPERIMENTAL SETUP

To study the effect of the products of plasma chemical reactions on the storage of vegetables and fruits, a plasma chemical air treatment stand was used, the diagram of which is shown in Fig. 1, and a sealed box with a control batch of products. A control batch of products was placed in the same sealed box and with same air flow.

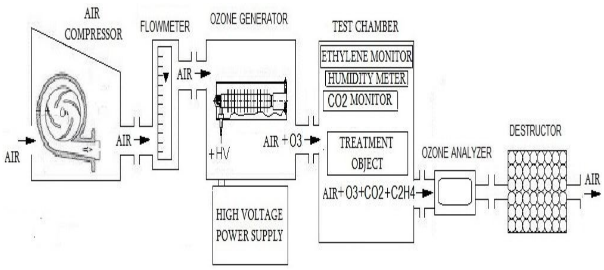


*Fig. 1. The schematic diagram of the experimental stand*

The experimental stand consists of 2 SunSun ACO-003 air compressors, 2 flow meters, a barrierless plasma-chemical reactor, a high-voltage pulse power supply, 70-l sealed Probox boxes, in which vegetables and fruits were located. To control the humidity in the boxes, psychometric VIT-1 hygrometers were used, and to control the ozone concentration in the treated box, an ES-600 ozone concentration meter was used.

On the Fig. 2 is shown a photo of vegetables and fruits in the treated box. Similarly, vegetables and fruits taken from the same batch were placed in the control box. A visual control of the condition of the products was carried out and the sugar content was measured using a Walcom REF 103/113 portable reflectometer.

*Fig. 2. Photo of experimental box*

The duration of one experiment was 15 days. Both the control and experimental boxes were ventilated at a flow rate of 70 l/h.

High-voltage pulsed power supply forms high-voltage pulses of microsecond duration (1300 ns) with a pulse repetition rate of 1…15 kHz and amplitude up to 15 kV. The rise time of the pulse is 500 ns. The current pulse was recorded using a current shunt.

A characteristic oscillogram of the voltage pulse at complex power supply is shown in Fig. 3.

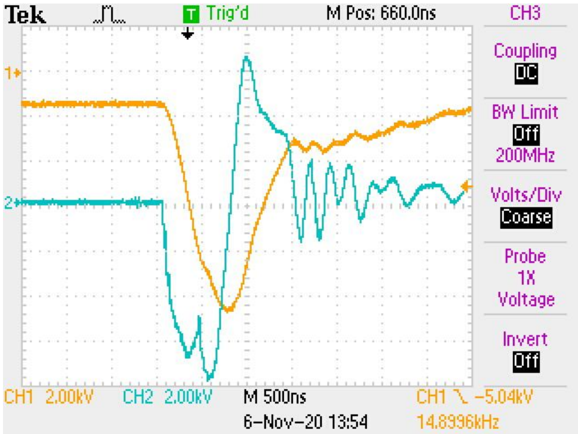


*Fig. 3. The characteristic oscillogram of the supply voltage pulse of plasma chemical reactors*

The electric signals were recorded with a Tektronix TDS-2024 digital oscilloscope, bandwidth of 100 MHz.

Measurements of ozone concentration in the air were performed with a ozone concentration meter Ozone Solution PPM Ozone ES-600 with an accuracy of 0.1 ppm.

## RESULTS

On the Figs. 4 and 5 are shown graphs of temperature and humidity control for one of the experiments.

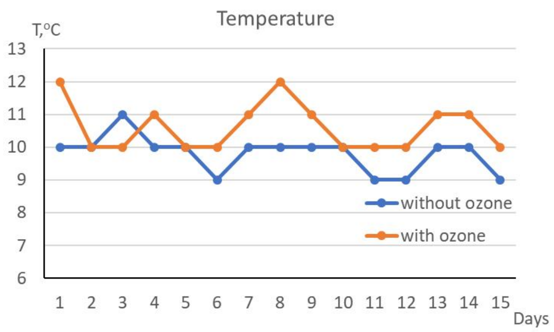


*Fig. 4. The air temperature in the boxes*

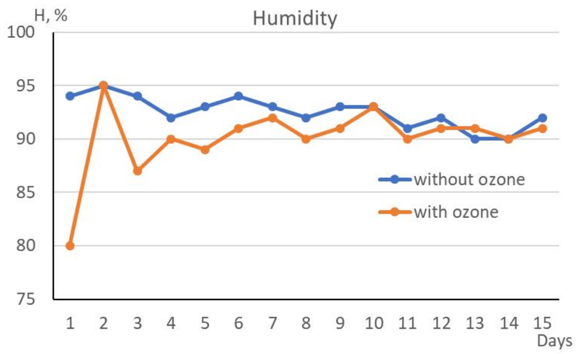


*Fig. 5. The air humidity in boxes*

It can be seen from the graphs that after setting the storage mode, the temperature and humidity did not fluctuate significantly, being at the same levels for both boxes. The temperature was maintained at 11°C, and the humidity in the range of 90…95%. The ozone concentration in the experimental box was monitored every 3 days and remained at the level of 10…11 ppm.

On the Fig. 6 is shown photographs of eggplant from the control and experimental boxes.

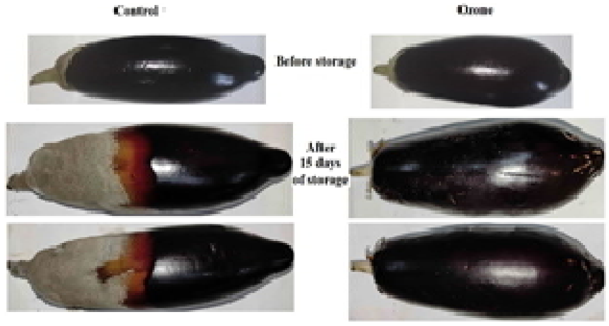


*Fig. 6. The photos of eggplants before storage and after storage in a box, the air in which was treated with the products of plasma chemical reactions and control*

On the photo is shown that the eggplant in the control box rotted and became covered with mold, which did not happen in the treated box, which correlates with the results obtained in [8]. On the Fig. 7 is shown photographs of a lemon from the control and treatment boxes.

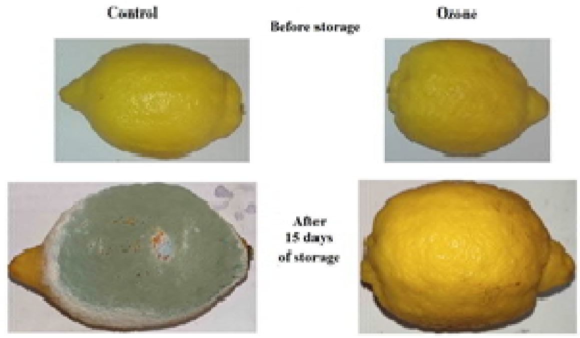


*Fig. 7. The photos of lemons before storage and after storage in a box, the air in which was treated with the products of plasma chemical reactions and control*

On the photo is shown that the lemon in the control box has rotted and covered with mold, which did not happen in the experimental box.

On the Fig. 8 is shown photographs of quince from the control and experimental boxes.

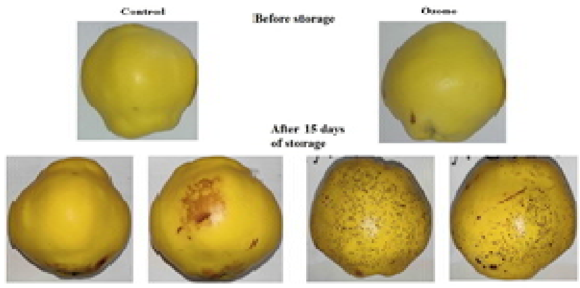


*Fig. 8. The photos of lemons before storage and after storage in a box, the air in which was treated with the products of plasma chemical reactions and control*

On the photo is shown that the quince in the control box just ripened, and in the experimental one it became covered with black dots, which can be associated with both the "scalding" effect of ozone and the influence of other products of plasma chemical reactions. A similar picture, only the covering of the fruit with white dots, is observed on a number of other products, for example, on a cucumber (Fig. 9).

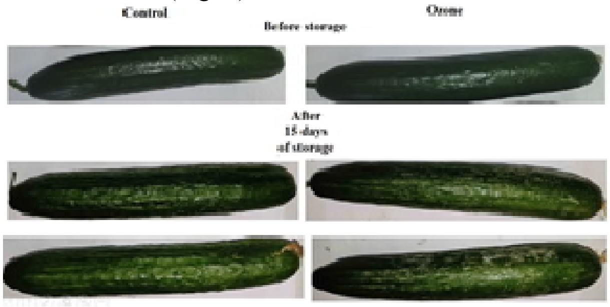


*Fig. 9. The photos of cucumbers before storage and after storage in a box, the air in which was treated with the products of plasma chemical reactions and control*

Thus, vegetables and fruits differ in the possible influence of the products of plasma chemical reactions. Table describes the condition for all test products after 15 days of storage.

| Product name | Control | | Ozone | |
|---|---|---|---|---|
| | Amount of sugar , %Brix | Changes | Amount of sugar , %Brix | Changes |
| Tomat | 4 | Mold has appeared | 3 | Without changes |
| Quince | 14 | Without changes | 13 | Black dots appeared. The fruit is overripe. |
| Sicilian Orange | 12 | Without changes | 10 | Without changes |
| Mandarin | 15 | Without changes | 13 | Without changes |
| Grapes | 13 | Without changes | 13 | Without changes |
| Eggplant | | Mold has appeared | | White dots appeared |
| Carrot | | Became lethargic, Mold has appeared | | Has dried up and become lethargic |
| Beetroot | | Became lethargic, Mold has appeared | | Has dried up and become lethargic |
| Pear | | The decay process has begun, Mold has appeared | | The decay process has begun |
| Pepper | | Became lethargic | | Without changes |
| Cabbage | | Mold has appeared | | Darkened from above, inside unchanged. |
| Onion | | Started to sprout | | Without changes |
| Chilli | | Became lethargic , Mold has appeared | | Became lethargic |
| Lemon | | Became lethargic , Mold has appeared | | Without changes |
| Cucumber | | Without changes | | White stripes appeared |
| Mushrooms | | Got sticky, Mold has appeared | | Dried up |

It can been seen Table that for a number of vegetables and fruits, treatment with products of plasma chemical reactions slowed down the ripening processes (lower sugar level). But at the same time, the products of plasma chemical reactions can also have a negative effect on the storage of a number of vegetables and fruits, such as quince, cucumber, cabbage, etc. The products of plasma chemical reactions, and primarily ozone, completely suppress the formation of mold at an ozone concentration of 10 ppm, which by itself can significantly reduce the loss of products during transportation and storage.

## CONCLUSIONS

When processing fruit and vegetable products with products of plasma chemical reactions, both positive and negative effects are possible, depending on the type of product. Thus, the treating of plasma chemical reactions products doesn't have a universal effect and requires the formation of separate methodological approaches for application.

Processing of products with products of plasma chemical reactions allows suppressing the development of mold and reducing losses during transportation and storage.

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## ВЛИЯНИЕ ПРОДУКТОВ ПЛАЗМОХИМИЧЕСКИХ РЕАКЦИЙ В БЕЗБАРЬЕРНОМ ГАЗОВОМ РАЗРЯДЕ В ВОЗДУХЕ НА ХРАНЕНИЕ ОВОЩЕЙ И ФРУКТОВ

***М.А. Егоров, Г.В. Таран, Д.В. Кудин, О.О. Замуриев, П.О. Опалев***

Исследовано влияние продуктов плазмохимических реакций (в том числе и озона) на хранение овощей и фруктов. Показано, что продуктами плазмохимических реакций эффективно подавляется рост плесени. Для ряда овощей и фруктов происходит видоизменение поверхности, которое приводит к потере «товарного» вида. При этом скорость дозревания многих продуктов снижается.

## ВПЛИВ ПРОДУКТІВ ПЛАЗМОХІМІЧНИХ РЕАКЦІЙ В БЕЗБАР'ЄРНОМ ГАЗОВОМ РОЗРЯДІ В ПОВІТРІ НА ЗБЕРІГАННЯ ОВОЧІВ І ФРУКТІВ

***М.О. Єгоров, Г.В. Таран, Д.В. Кудін, О.О. Замурієв, П.О. Опалєв***

Досліджено вплив продуктів плазмохімічних реакцій (в тому числі і озону) на зберігання овочів і фруктів. Показано, що продуктами плазмохімічних реакцій ефективно пригнічується ріст цвілі. Для деяких овочів і фруктів відбувається видозміна поверхні, яка призводить до втрати «товарного» вигляду. При цьому швидкість дозрівання багатьох продуктів знижується.