STUDY OF THE EFFECT OF PLASMA CHEMICAL OXIDATION OF ETHYLENE IMPURITY ON THE EFFICIENCY OF BANANA STORAGE

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The effect of the products of plasma chemical reactions (including ozone) on the storage of fruits and berries was studied. Being the product of greatest commercial interest, bananas were selected as the test object. It was shown that the growth of pathogenic microflora is effectively inhibited by the products of plasma chemical reactions. It was shown that the use of a plasma chemical system, due to which ethylene concentration is reduced and ozone concentration is simultaneously maintained at the level of several ppm, could reduce the amount of spoiled products by several times.

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INTRODUCTION

Worldwide, the postharvest losses of fruits and vegetables currently range from 25 to 40 % in developed countries and up to 50 % in tropical developing countries [1]. The main reasons of such losses are the decrease in mass due to respiration, evaporation and germination, losses of water and dry substances (from 10 to 35 % of the total mass loss). These high losses are associated with the lack of packaging, storage and improper transportation technologies [2]. There is a lack of proper technologies for postharvest handling of fruits and vegetables at the retail and wholesale levels, which results in low quality fruits and vegetables in the consumer market. If the maximum level is exceeded, the product becomes unfit for sale. Another reason is the losses associated with the presence of pathogens, which can reach 100 % in case of mass distribution. Seriou's consequences can also be caused by mechanical damage (the third group of losses), especially at the final stage of storage, when the pulp softening in fruits and vegetables occurs as a result of ripening and their strength is decreased. This factor is significant for the process of transportation (especially over long distances). The quality of fresh and processed fruits depends on postharvest handling during harvesting, transportation and storage and should be effectively controlled to maintain the best fruit quality at harvesting [3].

Bananas take the third place in the world fruit production (104.6 million tons) after citrus fruits and grapes [4]. The banana fruit is grown in more than 100 countries, mainly in subtropical regions [5]. The largest banana sales markets are North America and Europe, followed by Japan and Eastern Europe [6]. Bananas are major starchy crops of considerable importance in developing countries. They are consumed both as food that gives energy and as a dessert [7]. Bananas are giant perennial plants growing in Southeast Asia. In order for fresh bananas to reach the consumer in good condition, all technological requirements should be met, such as the application of the most suitable temperature and humidity, as well as appropriate packaging and treatment methods. Good handling during harvesting can minimize mechanical damage and reduce subsequent losses in the consequence of microbial attack [8].

Deterioration of quality indicators is specified by both natural causes (ripening, aging, growth activity, etc.) and the influence of external factors (environment, damage, pathogens), which reduce the consumer properties of products and result in the sale price decrease. Ethylene is very important in the ripening and storage of fruits and berries. This phytohormone is responsible for aging processes in plants. In order for unripe fruits to quickly acquire a marketable appearance (for example, green oranges turn orange, and green bananas turn yellow), they should be artificially treated with ethylene. Since ethylene is a hormone, it affects plants even in very low concentrations. Therefore, it is extremely important to control its concentration in storage facilities. High ethylene concentration in air causes premature death of plant cells.

The easiest way to remove excess ethylene is ventilation, but this method is poorly compatible with the use of other storage technologies (maintenance of temperature, humidity and oxygen concentration). The existing technologies are either unstable or require a significant amount of additional equipment, as well as significant financial and energy investments, which negate the positive effect of their use. Therefore, the development of alternative methods for preventing the negative impact of ethylene on crop storage is of great interest [9, 10].

Ethylene is decomposed by ozone, which allows storing products that are sensitive to ethylene produced by the product itself during storage. Ozone is very effective in removing ethylene by the following chemical reaction (1) [11]:

$$H_2C=CH_2 + O_3 \longrightarrow CO_2 + H_2O. \qquad (1)$$
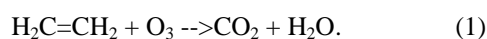
As a result of the previous studies of ozone disinfection technologies for storage, in the presence of food products as well (potatoes, grain, onions, grapes,

etc.), it was shown that losses could be reduced by 30…40 % [12]. At the same time, the products were not contaminated with harmful impurities and retained their nutritional and organoleptic properties [13].

Therefore, the goal of investigation is to study the effect of plasma-chemical air treatment in storage and shipping facilities on extending the shelf life of bananas.

METHODS AND MATERIALS

To study the effectiveness of the plasma-chemical method for air treatment to extend the shelf life of bananas, the products were divided into two batches and placed in separate Hasky plastic containers (Fig. 1).
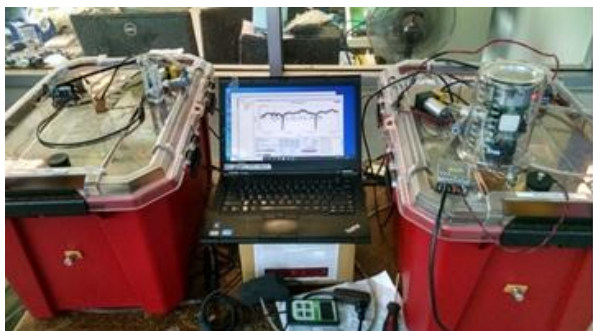

Fig. 1. Photo of the experimental stand for studying the effect of plasma chemical oxidation of ethylene impurity on the efficiency of banana storage

In the first experimental container, circulating air was treated by a plasma-chemical system (Fig. 2,a). The control batch was in the second experimental container, where the air circulated as well (Fig. 2,b).
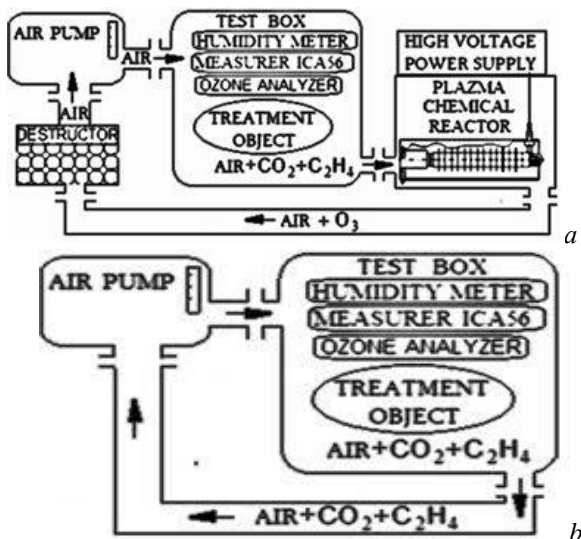

Fig. 2. Structural diagram of the experimental unit for air treatment in the plasma chemical system (a) and control container (b) during banana storage

Forced circulation of air in the containers was performed with the help of air compressors at the rate of 4 l/min. The air flow was steady and regular. The air movement rate was 2.4 m/min. The volume of both containers was 90, 30 dm^3 of which was the volume of bananas. The total weight of bananas in the experimental and control containers was 12.1 and 12.4 kg, respectively.

Ozone concentration, as well as air temperature and moisture content, were measured using the sensors located in the experimental containers. Ethylene concentration was measured using the ICA56 meter (in the experimental container) and monitored by sampling from the circulation lines of both containers. For the ICA56 meter, an electrochemical sensor with ethylene sensitivity of 0.2 ppm is used. This sensor has a cross sensitivity to CO (40 %), ethanol (72 %), CO_2 (0%), H_2C (220 %), and therefore, the control method for measuring ethylene is used. Control samples were analyzed using a Thermo Scientific Trace 1310 gas chromatograph with a flame ionization detector. The chromatograph was pre-calibrated using calibration gas mixtures with ethylene concentration of 10 and 100 ppm. The flame ionization detector was used to measure the concentration of organic substance at very low (10...13 g/s) and very high levels, having a linear response range of 107 g/s. Power consumption of the plasma chemical system was 4 W×h. A barrierless plasma chemical reactor developed and manufactured at the Institute of Plasma Electronics and New Methods of Acceleration of the National Science Center "Kharkov Institute of Physics and Technology" was used for gas treatment in the experimental container. The research was conducted at the temperature of 18...20 °C. Ozone concentration was maintained at the level of 5 ppm. Treatment time was 5 days.

RESULTS

As a result of experimental studies, it was shown that there was no visible growth of pathogens for the treated banana samples after 5 days of storage in a container with circulating air treated in a plasma chemical reactor (PCR) at room temperature. For the control samples stored in a container with circulating air, visible growth of pathogens was observed after storage (Fig. 3).

Fig. 3. Photo of bananas stored in the container, the air in which was treated by a plasma chemical system (a) and control container (b)

As a result of morphological observation of the pathogenic microflora, it was suggested that it may belong to the Fusarium species. The plasma chemical system disinfected the storage atmosphere and may play an important role in extending the shelf life of bananas. It was previously shown that the products of plasma chemical reactions effectively suppressed the growth of pathogenic microflora [14].

The ripening of bananas was also observed in accordance with the degree of coloration of the banana peel. The data of observations are presented in Table. It is shown that bananas stored in the container with air treated by the plasma chemical system remained more unripe than those stored in the control container (see Table).

The degree of banana coloration in the container with air treated by the plasma chemical system and in the control container during 5-day storage

Treatment	Storage, days				
	1	**2**	**3**	**4**	**5**
Control	3	4	5	6	7
PCR	2	2	3	3	3

1 – Green; 2 – Green/a trace of yellow; 3 – More green than yellow; 4 – More yellow than green; 5 – Yellow with a green tip; 6 – All yellow; 7 – Yellow/a few brown spots.

Humidity, temperature, pressure, amount of volatile organic compounds (VOC), ozone concentration, carbon dioxide concentration, dust content per unit volume were measured in the containers. In the graphs (Fig. 4), the dependence of measured parameters on time (24 h) is shown for the control batch (a) and the batch with air treated by the plasma chemical reactor (b).
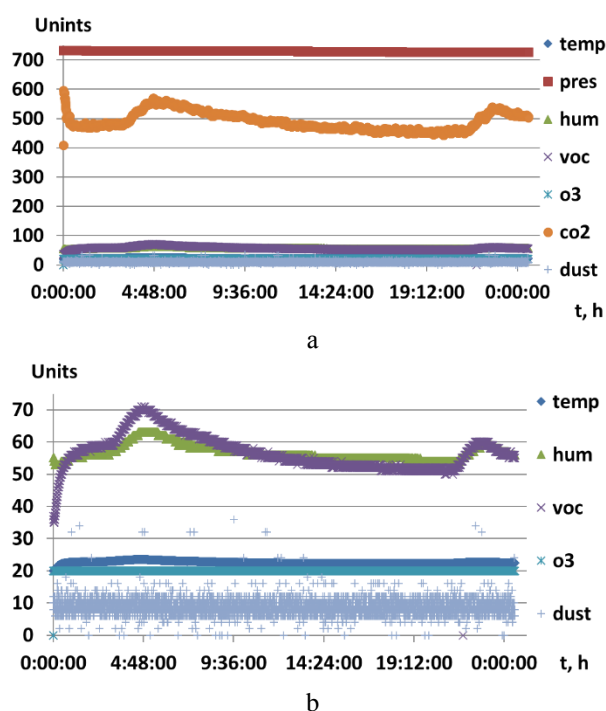

a

b

Fig. 4. Change of the parameters measured in the experimental containers for the control batch (a), for the batch with treated air (b)

It is shown that the pressure, temperature and concentration of VOCs almost did not change. A gas chromatograph HP 6890 with FID detector was used to measure ethylene concentration.

Experimental studies were conducted to control ethylene concentration (C_2H_4) during banana storage. In Fig. 5, the dependence of ethylene concentration for the control and experimental containers is shown.
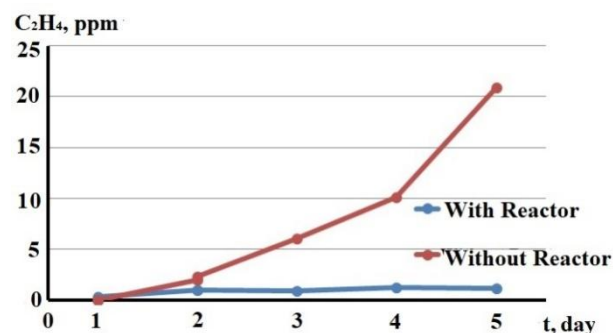

Fig. 5. Dependence of ethylene concentration for the control and experimental containers on the storage period

It is shown that the ethylene level in the control container start rising sharply on the third day. In the experimental container, the level of ethylene is 2 orders of magnitude lower than that measured in the control container and practically did not change during the entire period of the experiment.

CONCLUSIONS

The effectiveness of using the plasma chemical technology to reduce the concentration of ethylene impurities to extend the shelf life of bananas was studied. It is shown that the use of the plasma chemical system, which reduces ethylene concentration and simultaneously maintains ozone concentration at the level of several ppm, can reduce the number of spoiled products by several times.

It was demonstrated that when using the systems based on a barrierless PCR, a significant (more than 10 times) decrease in the equilibrium concentration of ethylene in air is possible.

When using the plasma chemical system during banana storage, the level of ethylene is 2 orders of magnitude lower than that measured in the control batch and practically did not change throughout the entire period of the experiment.

Thus, the plasma chemical method of extending the shelf life of bananas has demonstrated high efficiency and has good prospects for application

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ДОСЛІДЖЕННЯ ВПЛИВУ ПЛАЗМОХІМІЧНОГО ОКИСНЕННЯ ДОМІШКИ ЕТИЛЕНУ НА ЕФЕКТИВНІСТЬ ЗБЕРІГАННЯ БАНАНІВ

М.О. Єгоров, Г.В. Таран, В.І. Голота, О.О. Замурієв, П.О. Опалєв

Досліджено вплив продуктів плазмохімічних реакцій (у тому числі і озону) на зберігання плодово-ягідної продукції. Як тест-об'єкт вибрано банани, які мають найбільший комерційний інтерес. Показано, що продуктами плазмохімічних реакцій ефективно пригнічується зростання патогенної мікрофлори. Показано, що використання плазмохімічної системи, яка знижує концентрацію етилену і одночасно підтримує концентрацію озону на рівні декількох проміле, може зменшити кількість зіпсованої продукції у кілька разів.