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INFLUENCE OF DISCHARGE PRODUCTS ON POST-HARVEST PHYSIOLOGY OF FRUIT

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Abstract - The experimental results concerning the influence of ozone and positive and negative ions produced by air discharge on the post-harvest physiology of fruit are discussed. It has been found by the authors from numerous experiments that the air discharge products exert an appreciable influence on the process of senescence, the stomatal opening, respiratory intensity and the release rate of ethylene of stored fruit. The influence of discharge products on the process of ethylene generation of picked fruit has also been observed. The above results show that air discharge can find application as a new non-poisonous and energy-saving freshness preserving technique for fruit. Very good results have been obtained by the authors in storing Wenzhou mandarin oranges with this method.

INTRODUCTION

Discharge occurring in air will produce charged particles (positive or negative ions) and new gaseous components. Of the new gaseous components generated, over 99% is ozone. Not a few reports are available on the influence of discharge products on the growth of plants [1]–[6]. Unfortunately, few, if any research reports have been published on the influence of discharge products on the post-harvest physiology of fruit. In recent years, in seeking a non-poisonous, safe and economical technique for preserving fresh fruit, people have become interested in the role of air discharge products in fresh fruit preservation. The germ suppressing function of ozone has found wide application [7]. But so far little has been done to investigate the influence of positive and negative ions and of ozone on the physiology of fruit itself. Moreover, the investigations in the past were in general either for a better understanding of the effects of ozone or that of ions separately to the neglect of the comprehensive function of ozone and positive and negative ions.

In order to study the independent as well as the comprehensive roles of the positive and negative ions and ozone, the authors have developed a special device for generating air discharge products. With this device, numerous tests and observations have been made on Wenzhou mandarin oranges, apples, and tomatoes. The results obtained show that the comprehensive effect of ozone and negative ions is the best for putridity prevention and freshness preserving of the above-mentioned fruit. For this reason, emphasis of this paper will be on an account of the influence of ozone and negative ions on the post-harvest physiology of the above-mentioned fruit.

EXPERIMENTAL DEVICE AND METHOD

The diagrem of principle of the experimental discharge product generator is shown in Fig. 1.

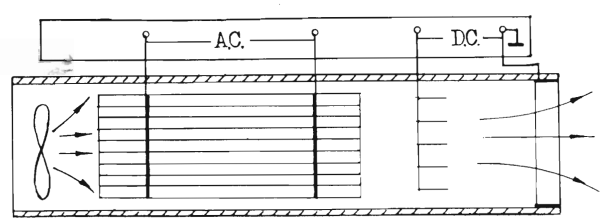


Fig. 1. The discharge product generating device.

It is composed mainly of a discharge chamber and a power control. In the discharge chamber, a fan is mounted to enable air to be blown out first through the ozone generator and then the multi-needle-shaped dc corona electrode (ion generator). By means of the power control, 5 different operating modes can be adopted to obtain discharge products of 5 different compositions, namely, ozone (O_3), air positive ions (N_2^+, O_2^+, etc.), air negative ions (O_2^-, H_2O^-, etc.), ozone and negative ions (O_3, O_3^-, O_2^-, H_2O^-, etc.) and ozone and positive ions (O_3, O_2^+, N_2^+, etc.).

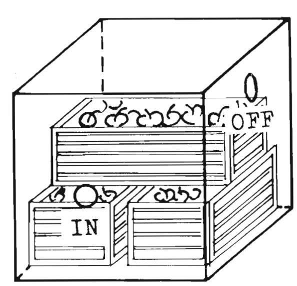


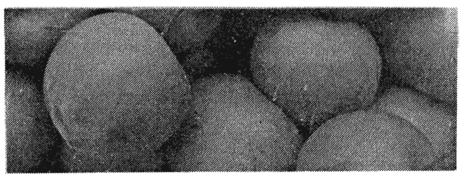
Fig. 2. The test container.

The fruit to be tested on are divided into a number of groups, each stored in a 1X1X1 m^3 test container with an air inlet on one side and an air outlet on the other. In general both ports are closed and are opened at the same time only when discharge products are used to treat the fruit (See Fig. 2.). The concentration of ozone used in the test is 2-10 mg/m^3 and the ion density is 10^4-10^5 cm^{-3}.

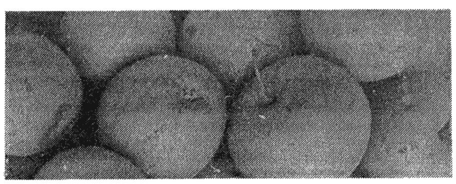
THE INFLUENCE OF DISCHARGE PRODUCTS ON THE SENESCENCE OF RRUIT

For this test, the apples used are divided into 5 groups stored in different test containers. Four of the five groups use air negative ions, air positive ions, ozone and negative ions, ozone and positive ions for treatment once a week, 10 minutes each time. All the tests were performed at ordinary room temperature. 180 days later, the group treated with ozone and negative ions had minimum loss with the fruit intact and lustrous. The apples in the groupstreated with air negative ions though intact were rather poor in lustre. The skin of apples in the group for comparison became wrinkled and lustreless while many of the apples in the group treated with ozone and positive ions and those in the group treated with air positive ions appeared to be in an extremely senescent state with cracked skins (See Fig. 3). The test results show that the positive ions quickened the decay of stored apples whereas the negative ions delayed decay and the comprehensive role of ozone and negative ions would make the delayed senescence even more appreciable.

The Wenzhou mandarin oranges were used for test. One group of mandarin oranges was treated with ozone and negative ions 10 minutes a week and the other group was for comparison. After 120 days of storage at ordinary room temperature, stochastic sampling was made. The changes in the wax, oil sack and parenchyma of fruit skin were observed under a scanning electron microscope. Observation shows that the tiny scalelike wax on the skin of fruit treated with ozone and negative ions remains unchanged and the oil sack and parenchyma are well preserved. In contrast, the surface wax morphology of the group of apples for comparison has greatly changed. Most of the tiny scales have blended and are pressed flat like plates. Evident cell decomposition was observed in the oil sack and parenchyma and some have deformed and begun to crack. Figure 4 shows typical photos of the skin tissue under a SEM. The results of observation show that regular treatment of Wenzhou mandarin oranges with a proper amount of ozone and negative ions can delay the senescence of the fruit.



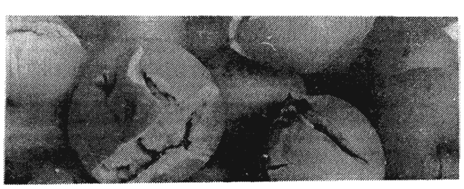
Treated with ozone and negative ions



Treated with air negative ions

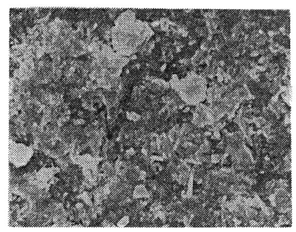
For comparison

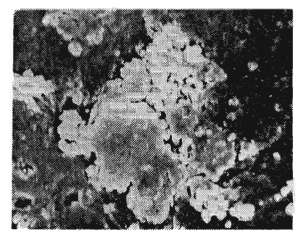
Treated with air positive ions



Treated with ozone and positive ions

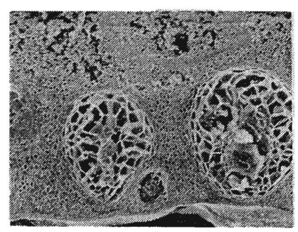
Fig. 3. The influence of different air discharge products on the process of senescence of apples.

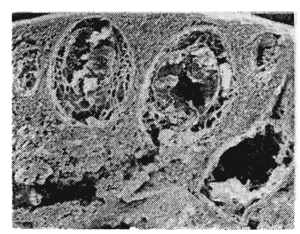




Treated with ozone and negative ions — For comparison

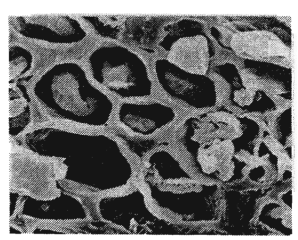
(a) surface waxy tissue

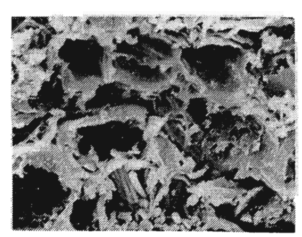




Treated with ozone and negative ions — For comparison

(b) morphology of oil sack





Treated with ozone and negative ions — For comparison

(c) parenchyma

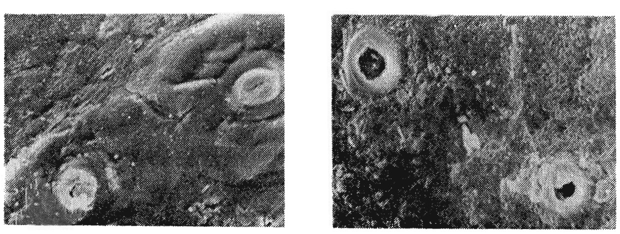
Fig. 4. The skin tissue of oranges stored for 120 days.

THE INFLUENCE OF OZONE AND NEGATIVE IONS ON STOMATAL OPENINGS OF ORANGE SKIN

The Wenzhou mandarin oranges were used. One group of mandarin oranges was treated 10 minutes a week with ozone and negative ions and the other group was used for comparison. Both groups of mandarin oranges were stored at room temperature. 20 mandarin oranges each were taken as samples per time per group on the 8th, 57th and 120th day after the test began. The results of observation of the stomata in the orange skin with SEM are given in Table 1, in which each average value was obtained from the readings of 60 stomate in many orange skins stochastically taken out. Figure 5 shows the typical phyotos of orange skin stomata taken under SEM. Observation results show that the stomatal opening of the skin of Wenzhou mandarin oranges treated 10 minutes a week with ozone and negative ions in the course of storage is reduced by 16-27%.

mode of treatment			with ozone and negative ions	for comparison
stomatal opening (μm)	on 8th day	max. value	6.88	10.32
		min. value	2.75	4.13
		average value	4.47±0.03	6.08±0.04
		relative opening %	73%	100%
	on 57th day	max. value	6.88	10.32
		min. value	3.44	3.44
		average value	4.71±0.04	5.68±0.05
		relative opening %	82%	100%
	on 120th day	max. value	10.32	10.32
		min. value	2.75	3.44
		average value	5.06±0.08	6.00±0.06
		relative opening %	84%	100%

Table 1. The influence of ozone on stomatal opening of orange skin



Treated with ozone and negative ions — For comparison

Fig. 5. Typical photos of the stomatal opening of orange skin.

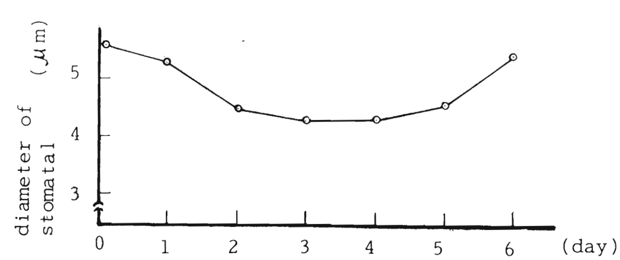


Fig. 6. Variation in stomatal opening in skin of Wenzhou mandarin oranges with time.

The reduction in the stomatal opening of fruit skin will slow down the exchange of gases inside and outside of fruit as well as decrease the evaporation of moisture in the fruit and is therefore favorable to the storage and preservation of fruit.

In order to learn about the law of variation in the stomatal opening of the orange skin, continuous sampling was made of Wenzhou mandarin oranges harvested a week before and treated with ozone and negative ions for observation. Figure 6 shows the results of continuous sampling observation. The stomate in the fruit skin did not immediately reduce in size but did so gradually after a period of time until the third or fourth day when the limit was reached. Then, they were gradually restored. The cycle of variation was about 7 days.

THE INFLUENCE OF OZONE AND NEGATIVE IONS ON THE GENERATION OF ETHYLENE AND RESPIRATORY INTENSITY

Tomatoes harvested when green and beginning to ripe were used. One group was treated with ozone and negative ions 15 minutes per day while the other group was for comparison and stored at room temperatures 6-19°C for observation of the variation in the respiratory intensity (release rate of CO_2) and ethylene release rate. The results are shown in Figs. 7 and 8. It can be seen from Fig. 7 that, in the beginning 10 days, there was little difference in respiratory intensity between the two groups. However, when the respiratory peak was reached, the respiratory intensity of the group treated with ozone and negative ions was appreciable lower than that of the group for comparison. The curves in Fig. 8 show that in the beginning 10 days there was little difference in the ethylene release rate between the two groups. But afterwards the ethylene release rate of the group treated with ozone is evidently lower than that of the group for comparison.

The generation of ethylene exerts an extremely significant influence on the ripening and senescence of fruit. In the course of generation of ethylene by fruit, there is bound to be the stage of ACC formation. With a view to observing the influence of ozone and negative ions on the generation of ethylene, observation was made on the amount of ACC formed.

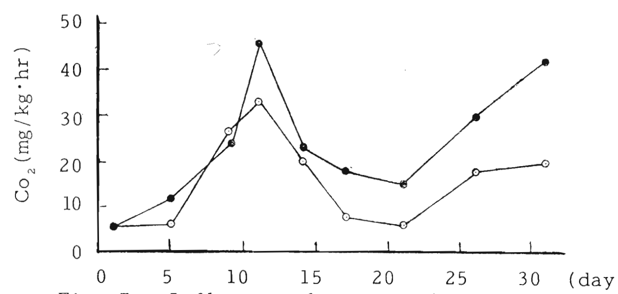


Fig. 7. Influence of ozone and negative ions on respiratory intensity of tomatoes during storage.

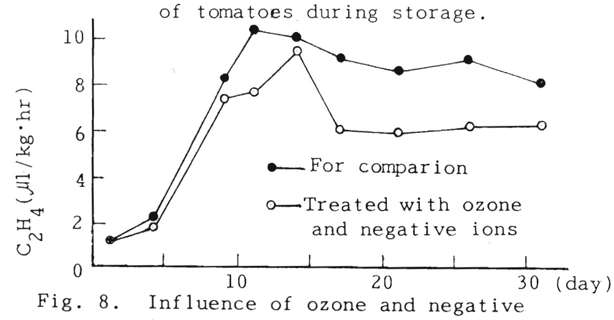


Fig. 8. Influence of ozone and negative ions on release rate of C_2H_4 of tomatoes during storage

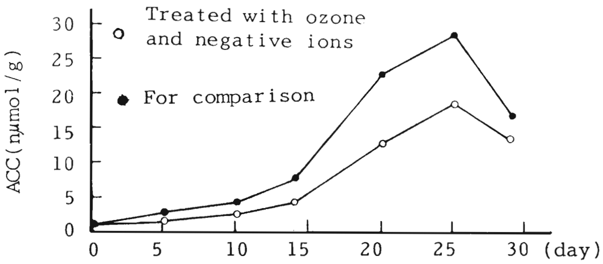


Fig. 9. The influence of ozone and negative ions on amount of ACC formed during storage of tomatoes.

Observation results are given in Fig.9, in which the curves show that for tomatoes treated with ozone and negative ions, the amount of ACC formed is obviously reduced. The above-mentioned test results show that ozone and negative ions are not only capable of eliminating the ethylene gas released by metabolism of fruit, but can suppress the generation of ethylene in the course of ethylene formation.

Results similar to those of tomatoes have been obtained in tests on Wenzhou mandarin oranges. After storage of 120 days, the group of mandarin oranges treated with ozone and negative ions had a respiratory intensity (CO_2 release rate) of 6.54 mg/kg·hr while the respiratory intensity of the group for comparison was 14.38 mg/kg·hr. As the amount of ethylene released by mandarin oranges was so small that it was hard to measure, gases were taken out with a needle from the air chamber in the fruit for laboratory test. The results obtained are: for the group treated with ozone and negative ions, the ethylene content in air in the air chamber was 1.0 ppm while that in the air chamber of the group for comparison was 2.8 ppm.

AN EXAMPLE OF APPLICATION

The germ-suppressing function of ozone and negative ions has long since been known. The experiments described in the foregoing sections show that an appropriate amount of ozone and negative ions can delay the process of senescence of fruit without damaging the fruit. Therefore, treating fruit with ozone and negative ions produced by air discharge can be adopted as a convenient and non-poisonous fruit freshness preserving method. By means of the device shown in Fig. 1, the authors have performed experiments on 2,5000 kilograms of Wenzhou mandarin oranges in storage. The mandarin oranges for experiment are stored in 10 ordinary small rooms with temperature adjusting equipment. The space volume of each room is 40 m^3 and 2,500 kg of Wenzhou mandarin oranges are stored in each. For nine of the ten rooms, ozone and negative ions are blown in with a discharge product generator once a week and the blowing in lasts 30 minutes each time. The remaining room is for comparison and air is blown in for 30 minutes each time. The layout of the small rooms for storing Wenzhou mandarin oranges is shown in Fig. 10. The results of sampling after the fruit is stored 90 days are as follows:

	water loss	rotten fruit	good fruit
group treated with ozone and negative ions	7.1%	1.9%	91%
group for comparison	6.7%	25.3%	70%

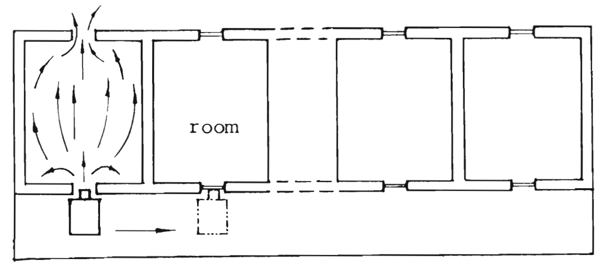


Fig. 10. The layout of small rooms for storage experiment on Wenzhou mandarin oranges.

Actual application shows that the preservation of fresh Wenzhou mandarin oranges with ozone and negative ions can greatly reduce loss in storage while maintaining the same quality and taste of the fruit. As the power of the discharge product generator is only 150 W, the power consumption during the entire period of storage is less than 10 Kw·hr. Therefore, it is very ideally energy-saving to store Wenzhou mandarin oranges at room temperatures with this method.

CONCLUSIONS

In order to investigate the influence of air discharge products on post-harvest physiology of fruit, an air discharge product generator has been developed, which is capable of generating a combination of discharge products of 5 different compositions. Experimental observation of apples, mandarin oranges and tomatoes shows that the combination of ozone and negative ions in discharge productsis most beneficial to mandarin oranges, apples and tomatoes in storage. Ozone and negative ions are capable of inducing the stomata in the skin of mandarin oranges to shrink and suppressing the generation of ethylene of fruit in storage. The ethylene release rate is decreased and the respiratory intensity of fruit is lowered, thus delaying the process of senescence of fruit. Hence ozone and negative ions produced in air discharge can be used to preserve fresh fruit. Successes have already been achieved in actual preservation of Wenzhou mandarin oranges with this method.

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