Relationship between Respiration Rate and Development of Gas Spaces in the Pericarp of Postharvest Cucumber Fruit¹

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Summary

Cucumber fruits were stored for 9 days at 20°C under unsaturated vapour conditions. The rate of respiration in the pericarp tissue, as measured by O₂ uptake, showed a rise following an initial decrease. The rise was associated with an increase in gas pressure and the formation of gas spaces. Respiration rate reached a peak earlier and then decreased faster than the gas pressure did. Gas spaces developed steadily in spite of a decline in respiration rate and gas pressure. It suggested that a decrease in membrane permeability might be involved in the development of gas spaces.

In fruits stored at 7.5°C, gas pressure in the tissue did not rise and the respiration rate was constantly low when measured at 7.5°C. However, when measured at 20°C, the respiration rate changed in almost the same way as in fruits stored at 20°C.

Introduction

After harvest, cucumber fruits develop the spongy tissues in pericarp which deteriorate fruit quality. The development of spongy tissues was associated with an increase in fruit volume, a decrease in specific gravity and the regaining of a turgid appearance which had disappeared due to moisture loss. They occurred when fruits were held under unsaturated vapour conditions at temperatures of 12.5°C and above(13). The spongy tissues are caused by development of gas spaces largely in cells of the pericarp tissues and the gas spaces had a higher pressure than ambient pressure(unpublished).

The accumulation of gas in the tissue could be brought about in at least two ways; one is a rise of respiratory activity, and the other is an increase in resistance of tissues or cell membranes against the diffusion of gas produced in the tissue or cells. In cucumber fruits stored at non-chilling temperatures the time course of respiration rate after harvest generally showed a decline(3,11), although at chilling temperatures an early rise in respiration rate was reported(3).

In this paper respiration rate as related to the pressure of gas accumulated in the tissue was measured in cucumber fruits stored under unsaturated vapour conditions at two temperature regimes.

Materials and Methods

Cucumber plants(cv. 'Kurume Ochiai H Gata') were grown in a glasshouse. Fruits at the commercial size were picked; mean fresh weight of 130 g and specific gravity of 0.978. These fruits were stored for upto 9 days at 20° or 7.5°C under unsaturated vapour conditions. Four fruits were taken at each sampling time.

Fresh weight, volume, and specific gravity of fruits were measured before and after storage. Volume was taken as the buoyancy of the fruit in tap water divided by density of water, assumed as 1.0 g/ml. Fruit parts between 2.5 and 5, 5 and 10, and 10 and 12 cm from the proximal end were taken and peeled, and the placental tissue removed. These pericarp parts were used for measurement of respiration, gas pressure, and water potential of the tissue respectively.

To determine the water potential, tissue blocks(5×5×5 mm³) were prepared from the

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pericarp. The blocks were soaked at 20°C for one hour in a series of 3 ml mannitol solutions with concentrations differing by 0.01 M. They were blotted on paper and weighed before and after soaking. The concentration of the solution at which the least change in fresh weight occurred was taken to be equivalent to the water potential of the tissue.

For determination of O_2 uptake, three slices of pericarp tissue ($8 \times 8 \times 1.7 \text{ mm}^3$) were prepared and preincubated for 30 min in a reaction mixture of 0.05 M Tris-HCl (pH 7.2) and mannitol, the concentration of which was adjusted to that of the water potential of the tissue. These conditions gave the maximum rate of O_2 uptake by the tissue slices. The rate of O_2 uptake was determined in 3 ml of reaction mixture using a Clark-type oxygen electrode (Rank Bros.). Solubility coefficient of O_2 in the reaction mixture was regarded as 0.00683 at 20°C and 0.00860 at 7.5°C(5). Respiration rate of slices from fruits stored at 20°C was also measured at 20°C. In fruits stored at 7.5°C, the respiration rate was first measured at 7.5°C and then at 20°C, using the same slices but after equilibrating in fresh reaction mixture for 30 min.

The mean pressure of gas in the tissue was determined from the pressure-volume relation, obtained with a pressure chamber following the method previously described(12). The volume of gas spaces in the pericarp tissue was also determined by this method, using another set of fruits stored at 20°C. Volume of water in fruits was estimated from the water content, assuming a density of 1.0 g/ml.

Results

Parameters of fruit

During storage at 20°C, fresh weight of cucumber fruit decreased continuously at a mean rate of 2.6% a day (data not shown). The volume of cucumber fruit initially decreased at the same rate as that of fresh weight, but five days after harvest it began to increase (data not shown). The specific gravity decreased after the fifth day (Fig.

Fig. 1. Specific gravity of cucumber fruits during storage at 20° and 7.5°C under unsaturated vapour conditions.

1). Sensory evaluation indicated a wilting state in fruits on the first to third day of storage, but a turgid appearance was restored on the fifth day when spongy tissues began to develop in the pericarp.

When stored at 7.5°C, fresh weight and volume (data not shown) decreased at a mean rate of 2.4% a day in the same way during storage, with specific gravity showing no decrease (Fig. 1).

Water potential of tissue

During storage at 20°C, water potential of the tissue (Fig. 2) decreased, showing a plateau from the second to the fifth day, but at 7.5°C it decreased after the second day.

Mean pressure of gas

At harvest, mean pressure of gas in the

Fig. 2. Water potential of the pericarp tissue from cucumber fruits stored at 20° and 7.5°C under unsaturated vapour condition. Bars indicate s.e. of each mean.

Fig. 3. Mean pressure of gas in the pericarp tissue from cucumber fruits stored at 20° and 7.5°C under unsaturated vapour conditions. Bars indicate s. e. of each mean.

tissue (Fig. 3) was 1.1 bar, i. e., 0.1 bar above the ambient pressure. At both storage temperatures the pressure decreased to about 1.0 bar on the second day, but at 20°C it then rose, reaching a maximum above 1.1 bar on the fifth day, after which it gradually decreased. At 7.5°C, however, it remained at 1.0 bar, i. e., at ambient pressure.

O₂ uptake of tissue

Oxygen uptake of the tissue in the reaction mixture is shown in Fig. 4. In the pericarp tissue of fruits stored at 20°C, respiration rate, expressed on a dry weight basis, decreased for the first two days but then increased. After reaching a peak on the third day it again decreased. On a fresh weight basis (data not shown), the respiration rate was about 5% of that on a dry weight basis but the pattern was the same. When fruits were stored at 7.5°C, the respiration rate measured at 7.5°C was very low, showing no change on a dry weight basis. On a fresh weight basis it gradually increased towards the end of storage. When respiration rate was then measured in the same slices at 20°C, the rate showed a peak after the initial decline. This pattern of change was almost the same as that found in fruits stored at 20°C.

Volume of gas space and water

The volume of gas space in the pericarp tissue (Fig. 5) showed a significant increase after the fifth day of storage at 20°C. The

Fig. 4. Rate of O₂ uptake in pericarp tissue taken from cucumber fruits stored at 20° and 7.5°C under unsaturated vapour conditions. Measurements were carried out at storage temperature, and in fruits stored at 7.5°C, at 20°C as well. Bars indicate s. e. of each mean.

Fig. 5. Proportion of gas space and water in volume in the pericarp tissue taken from fruits stored at 20°C under an unsaturated vapour conditions. Bars indicate s. e. of each mean.

volume of water decreased concomitantly. The proportion of the residual part, which is ascribed to solid constituents, was about 2% and did not change significantly.

Discussion

The rise in pressure of gas, which occurred on the third day of storage at 20°C, was concurrent with such incipient changes as a decrease in specific gravity and an increase in volume of fruit. Coincident with the rise in pressure of gas, the rate of O₂ uptake began to increase. Since respiratory quotients for stored cucumber fruits were reported to be near unity(3,11), the rate of CO₂ production will be equal to that of O₂ uptake. Therefore, the increase in pressure of gas is due to accumulation of CO₂ largely in cells of the pericarp tissue (unpublished). It is noted, however, that the rate of O₂ uptake reached a peak earlier and then decreased faster than the gas pressure did. In spite of the decrease in respiration rate, gas spaces developed steadily towards the end of storage (Fig.5). It means that CO₂ continued to accumulate despite the rate of O₂ uptake decreasing. For these changes to occur, initiation of anaerobic respiration or reduction of gas permeability will be necessary, although occurrence of anaerobic respiration is not consistent with respiratory quotients reported for stored cucumber fruits, i.e., about unity(3,11). Therefore the rise in rate of O₂ uptake from the second to third day may have been related to a decrease in gas permeability of membrane.

The trend in volume and specific gravity of fruits during storage at 7.5°C was in accord with those of fruits stored at a temperature of 10°C and below(13). The absence of a respiratory peak and the lower rate of respiration during storage at 7.5°C (Fig.4) could account for those phenomena, as well as the failure to regain gas pressure (Fig. 3). When respiration rate was measured at 20°C, the pattern was almost the same in tissues from fruits stored at 20°C and at 7.5°C. This means that chilling injury did not occur in fruits stored at 7.5°C and that, at both storages, the physiological conditions which are related to respiration, changed in the same way in spite of different temperatures. Thus, it seems unlikely that this rise in respiration rate is determined by the amount

of substrate available for respiration, since the amount would not be the same in fruits stored at 20° and 7.5°C.

It will be noted that the loss of moisture is a process common to both storage conditions. An indication of the involvement of water stress was shown in a previous paper, in which there was no accumulation of gas in fruits if they were held under wet conditions so that they absorbed sufficient water (14). A respiratory rise following an initial decline was reported for root pieces of cassava when they were stored at low humidity with an area of the periderm removed, but not when they were stored at high humidity(6). Brix (2) reported that in loblolly pine seedlings the respiration rate decreased as the water stress became higher but that at an advanced level of water stress there was a substantial increase in respiration rate. These facts suggest that the respiratory peak found in the present paper could be related to water stress.

In cucumber fruits which were stored at non-chilling temperatures the respiration rate only declined without showing an apparent peak but a plateau several days after storage(3,11). This difference from the present results may be due to mild water stress in those experiments which were carried out under aeration with an atmosphere saturated with water vapour.

A decrease in the respiration rates in the dark following irradiation of the shoot has been reported for whole plants(1,7), intact leaves(4) and intact roots(8,9). It is possible that the respiration rate of leaves during the dark period is influenced by the supply of readily available substrate(4). The free-space sugar levels in stems declined rapidly once photosynthate transfer to the stem was halted(10). Therefore, the initial decrease in respiration rate of fruits stored at 20°C (Fig.4) is likely to be caused by the depletion of such substrates as transported from the vines shortly before detachment. Thus, the respiration rates over the first two days could be regarded as occurring under different physiological conditions from those of the later days when water stress has more important

effects.

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収穫後のキュウリ果実における果肉の呼吸と気体蓄積の関係

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摘 要

収穫したキュウリ果実(品種「久留米落合H型」)を20°C, 不飽和水分条件下に9日間貯蔵した。果肉片の酸素吸収速度は一度低下したのち上昇した。この上昇は果肉内気体の圧力増加と蓄積開始に対応していた。しかし、酸素吸収速度は気体圧力に比較して早くピークに達し、その後の低下が急速であった。この間、気体の蓄積は進行した。酸素吸収量の低下にもかかわらず、気体圧力の低下がゆるやかで、気体蓄積が進んだ事実から、気

体の蓄積に膜の透過性の低下が関与している可能性が示唆された。

7.5°Cで貯蔵した果実では、果肉内気体の圧力は低下してほぼ大気圧に等しくなり、7.5°Cで測定した果肉片の酸素吸収速度は貯蔵期間中低く保たれた。しかし、この果肉片の酸素吸収速度を20°Cで測定すると、貯蔵期間中の変化は20°C貯蔵果の果肉片で得られた結果とほぼ同じであった。