Fruit Water Potential Change Related to Tomato Fruit Cracking

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Fruit Water Potential Change Related to Tomato Fruit Cracking

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Abstract

Fruit water potential change of tomato in a simulated cracking process was measured using a commercial psychrometer (L-51 : Wescor Inc., Logan, Utah U. S. A.). The principle of vacuum immersion technique was applied to induce cracking of detached tomato fruits. Temperature at a measuring point was kept constant in order to eliminate possible error in water potential measurement due to the temperature drift.

It was found that the fruit water potential increase is two bars at crack occurrence of tomato epidermis.

Introduction

Tomato fruit cracking has been a long time study subject. There are many factors which may indirectly induce the cracking. Frazier[1,2,3] reported that rain or overhead irrigation could cause the most damage to tomato fruits due to cracking, in addition, amount of foliage, number and size of fruits on the vine, relative extent of root system, root-top ratio, soil salt concentration and nutrient availability are influential factors on crack occurrence. An ambient temperature change sometimes appears to be an apparent cause of sever cracking.[4] The sugar content in the fruit may control parenchyma cell turgidity of which change induce volumetric change of tomato flesh. Temperature effect on sugar transfer throughout the plant,[5] temporary effect on sugar transfer due to watering a water stressed plant[6,7] and shading effect on fruit sugar content were reported.

Tomato fruit cracking is nothing but a mechanical failure of the fruit skin due to parenchyma cell expansion caused by its water uptake which can be considered as the direct cause of the cracking. The water uptake by parenchyma cells should result in a water potential change of the cells.

Recently the water potential of fruit was paid attention to in a tomato fruit cracking study.[8] In the present paper an experimental study was conducted forcusing on the water potential difference before and after the cracking.

Experimental Method

1. *Cracking Simulation*

The principle of vacuum immersion technique developed by Hepler[9] was employed in order to induce fruit cracking artificially. The principle of the cracking simulation employed in this experiment is the following. A suction tube of vacuum pump is at-

tached to the stem end of tomato fruit. Some amount of air in the intercellular spaces is evacuated by the suction to produce a negative pressure within the intercellular spaces. Immediately after releasing the vacuum and detaching the vacuum tube, distilled water is poured into the stem end cabity. The water is forced to penetrate into the intercellular spaces due to the presence of negative pressure in the intercellular spaces. Since the water potential of liquid water now available in the intercellular spaces is higher than the parenchyma cell water potential, the water is quickly drawn into the parenchyma cells. The large number of parenchyma cells which have absorbed the water produced a volumetric expansion. When the strech of the skin caused by the tissue expansion under the skin exceeds some critical level, the cracking occurs.

2. *Instrumentation and Experimental Set-up*

A chamber assembly of leaf psychrometer (L-51, Wescor Inc.) with HR-33 dew point microvoltmeter (Wescor Inc., Logan, Utah, U. S. A.) was used to measure the fruit water potential. The reading of each measurement were recorded on a pen recorder (VOM-5, Bausch & Lomb Inc.). Another chamber assembly of leaf psychrometer (L-51) was used to monitor temperature equilibrium between the transducer and a surface of a measuring point of the fruit. It should be noted that the temperature equilibrium is essential when one measures the water potential. The temperature equilibrium can be monitored by measureing Peltier current. When it is in equilibrium, the current should be zero. The cooling effect at the stem end due to vacuum was compensated with a small electric heater with a temperature controler. The temperature of stem end cavity was monitored constantly with a thermistor installed in the stem end cavity in order to accomplich temperature compensation by the electric heater. The capacity of vacuum pump was 100 liters per minute (Hitach Ltd. Japan).

3. *Procedure*

Seven tomato fruits (pink stage of ripeness) were tested. Each tomato fruit was washed and left in a loboratory to equilibrate with room temperature (24°C) prior to the test. A tomato fruit was mounted on a ring stand. The suberized layer and fiver portion of stem end were removed to place a small heater and a thermistor. Two locations where psychrometers were to be attached were selected near the stem end. The cuticle with a small portion of epidermal and parenchyma cells of fruit was removed at the locations where the psychrometers were to be placed in order to utilize the vapor phase measuring system (Fig. 1).

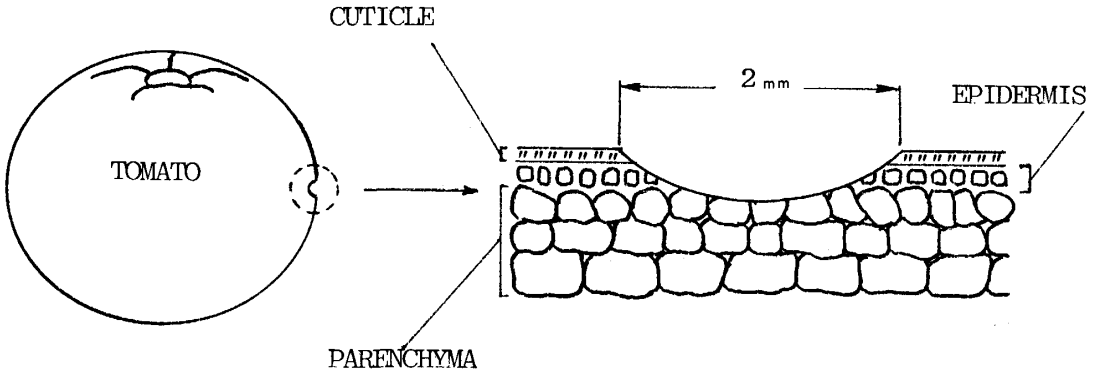

Fig. 1. Removal of cuticle for vapor phase measurement of fruit water potential.

One L-51 psychrometer used for temperature equilibrium monitor was placed on the provided location closer to the stem end so that temperature disturbance from the stem end can be sensed earlier than when it reaches the psychrometer for water potential measurement. Petroleum jelly was used to provide the necessary vapor seal between the psychrometer transducer and tomato skin surface. Finally a small electric heater and a thermistor were placed in the stem end cavity. Fig. 2 shows a schematic view fo transducer set up on a fruit.

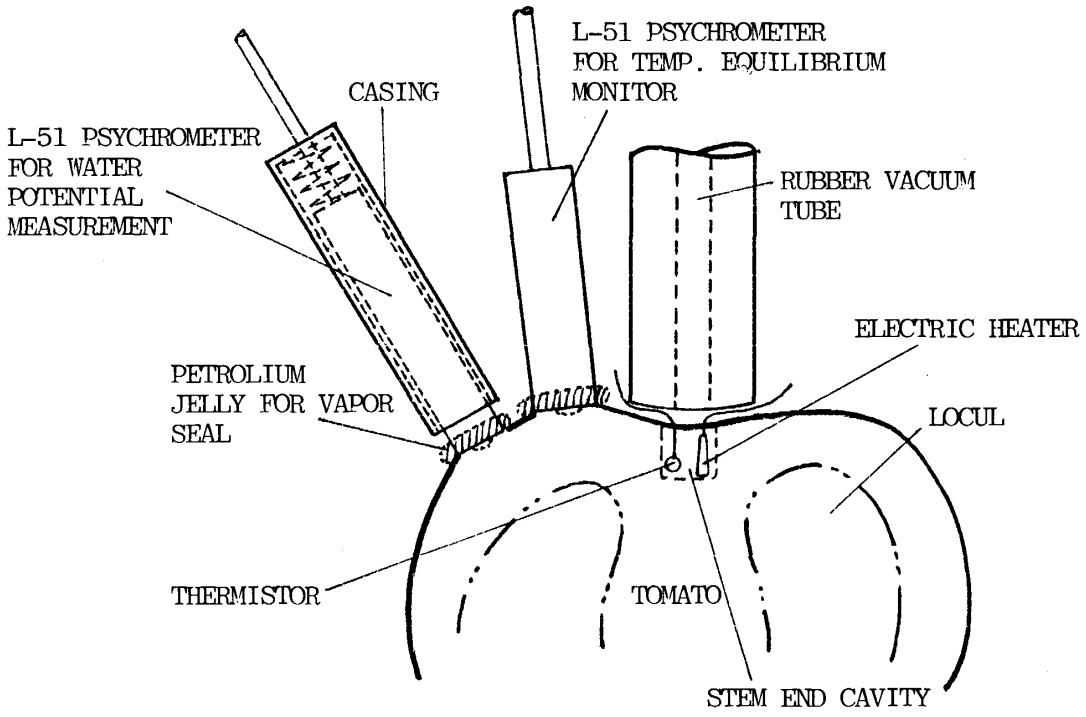

Fig. 2. Shematic view of locations of psychrometer transducers, thermistor, electiric heater and vacuum tube.

In Fig. 2 the spring attached to the psychrometer provides a relatively constant pressure between the transducer and the skin surface, and avoid a possible pressure damage due to the fruit expansion. Initial water potential was measured before appling vacuum. The vacuum was applied for fifteen minutes. During the vacuum application, the temperature at the stem end where the vacuum tube was attached was controlled by the small heater manually to compensate the temperature depression due to the vacuum. The temperature equilibrium was confarmed (± 0.05 V Peltier effect) prior to each water potential measurement. The fruit water potential was measured 5 minutes after starting vacuum application. Immediatly after 15 minutes vacuum application, distilled water stored at room temperature was poured into the stem end cavity with a syringe. Five minutes after the distilled water was poured, the fruit water potential was measured. A final measurement of the fruit water potential was taken several hours after the cracking.

Result and discussion

Table 1 gives water potential values of seven tested tomato fruits at four different critical stages of the cracking simulation. Cracking was initiated on all tested tomato fruits except #5 within five minutes after pouring distilled water. Inspite of crack occurrence in tomato #1, the result indicates no change in the fruit water potential. This was because distilled water did not penetrate into the portion where the psychrometer was attached. The water penetration was visually observable. When the water was drawn into the intercellular spaces near the skin, the skin became darkened locally. Average value of fruit water potential difference between initial value and value when a crack occured was two bars. Within several hours after cracking it seems that the water potential level. Fig. 3 shows the trend of the fruit water potential change (mean values of five cracked tomato fruits; #1 and #5 were not included). Murase[10] conducted a tomato skin failure test. Assuming the water potential value of skin is - 6 bars and a slow deformation for the cracking process, the failure strain value (0.1) and failure stress value (3900 KPa) obtained by Murase[10] may be used to calculate the failure energy of tomato skin. It is interesting to know that the energy required to fail a unit volume of tomato skin is 195 KJ/m^3 (1.95 bar). Some portion of energy put into the tomato system by forcing the water to penetrate was consumed to rupture the skin and some other portion of the energy was stored in the parenchyma cells. However, the energy density related to the different processes is roughly the same.

Table 1. Changes in fruit water potential values during fruit cracking simulation. (bar)

TOMATO NO.	INITIAL W. P.	W. P. AT VACUUM APPLICATION	W. P. AT WATER APPLICATION	6 HOURS AFTER	DIFFERENCE	CRACK OCCURRENCE
1	−6.4	−6.4	−6.4	−6.4	0	−
2	−6.8	−6.4	−4.8	−6.8	2.0	+
3	−6.0	−6.0	−4.4	−6.0	1.6	+
4	−5.6	−5.6	−3.6	−5.6	2.0	+
5	−6.4	−6.0	−6.0	−6.0	0.4	−
6	−7.2	−7.2	−5.2	−6.8	2.0	+
7	−6.8	−7.2	−4.4	−6.4	2.4	+
AVERAGE	−6.5	−6.5	−4.5	−6.3	2.0	

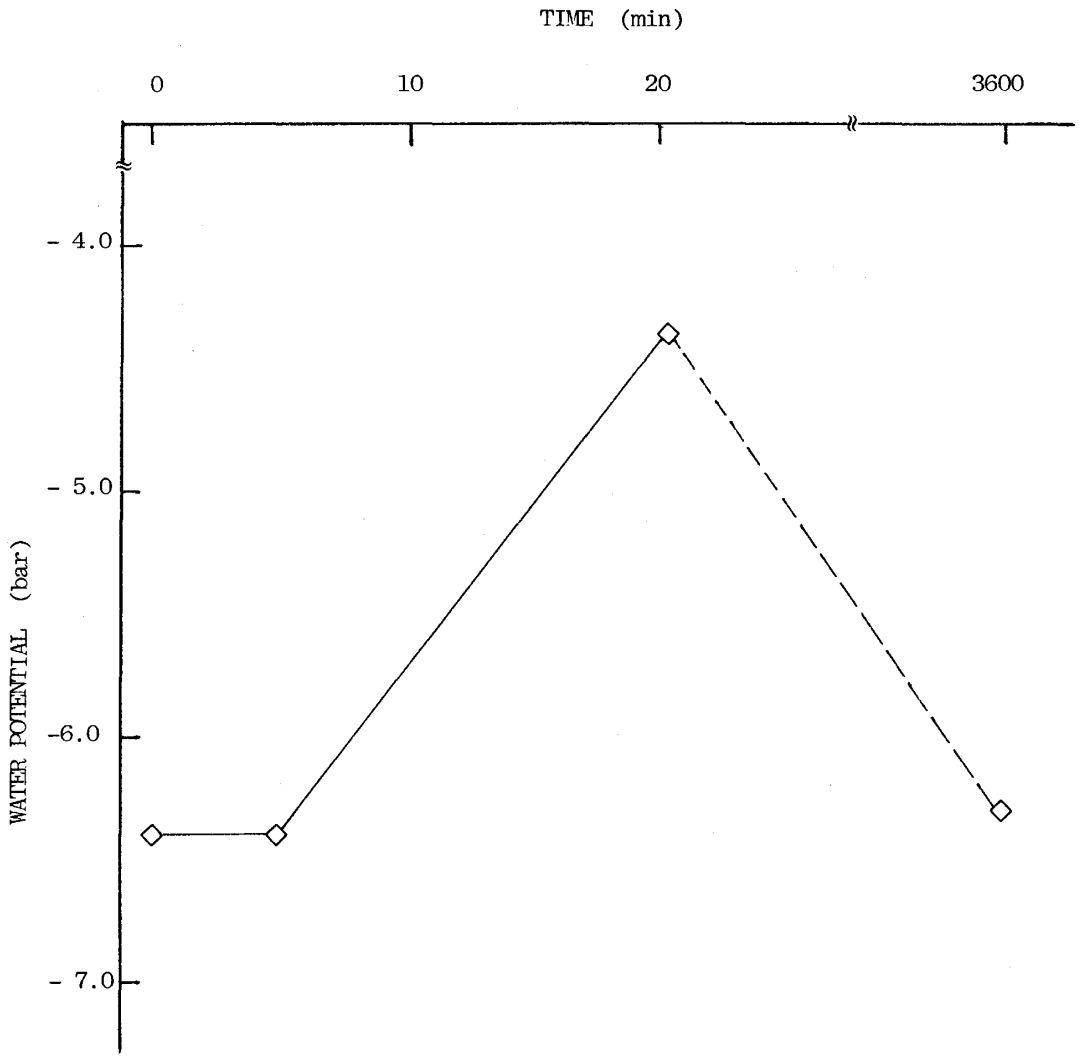

Fig. 3. Fruit water potential (mean value) change during the cracking simulation.

Conclusions

1. The fruit water potential increase is two bars (mean value) at crack occurrence.
2. It was found that the amount of energy requireds to rupture a unit volume of tomato skin is roughly the same amount of energy of a unit of water stored in parenchyma cells.
3. Leaf psychrometer (L-51) can be used for in-situ measurement of fruit water potential as long as the temperature equilibrium between the transducer and fruit surface is maintained.

References

1) FRAZIER, W. A. (1934). A study of some factors associated with the occurrence of cracks in the tomato fruit. *Proc. Am. Soc. Hort. Sci.*, **32**, 519-523.
2) FRAZIER, W. A. (1935). Further study on the occurrence of cracks in tomato fruit. *J. Am. Soc. Hort. Sci.* **33**, 536-541.
3) FRAZIER, W. A. (1947). Final report on studies of tomato fruit cracking in Maryland. *Proc. Am. Soc. Hort. Sci.*, **49**, 241-255.
4) REYNARD, G. B. (1960). Breeding tomatoes for resistance to fruit cracking. *Proc. Plant Sci. Seminar. Campbell Soup Company.*
5) BÖHNING, R. H., KENDALL, W. A. and LINCK, A. J. (1953). Effect of temperature on growth and translocation in tomatoes. *Am. J. Bot.*, **40**, 150-153.
6) PLAUT, Z. and REINHOLD, L. (1965). The effect of water stress on (c) sucrose transport in bean plant. *Aust. J. Biol. Sci.*, **18**, 1143-1155.
7) REINHOLD, L. (1975). The effect of externally applied factors on the translocation of sugar in the phloem. The hebrew University of Jerusalem. Israel. In : *Phloem transport.* Editted by S. Arnoff et al. Plenum Press. New York and London.
8) HERERRA, H. E. (1978). Tomato fruit cracking in relation to water potential change. *Unpublished Master's Thesis. Dept. of Agri. Eng. Michigan State University. East Lansing, MI. U. S. A.*
9) HEPLER, R. (1961). The measurenent and inheritance of fruit cracking in the tomato. *University of Illinois, Unpublished Ph. D. Thesis.*
10) MURASE, H., MERVA, G. E. and SEGERLIND, L. J. (1979). Failure mode of vegetative tissue. *ASAE Paper* **No. 79-3094**. *St. Joseph, MI. U. S. A.*