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CHANGES IN ELECTRICAL CHARACTERISTICS OF AVOCADOS DURING RIPENING

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An ideal method for determining maturity in fruits should be non-destructive and portable so that it may be used on fruits in the field before picking. The present procedure for determining avocado maturity involves the destruction of the fruit used for the test. Procedures have been developed for other fruits (1, 2) based on light absorption which may make possible non-destructive maturity analyses. Such methods are not applicable to the avocado.

Several types of measurements have been considered for possible application to avocados for non-destructive maturity testing. The simplest possibility seemed to be measurement of changes in conductivity of the fruit during growth. Accordingly, one of us (JPR) developed a small, portable conductivity meter for testing the use of this type of measurement in maturity studies. This instrument operated with a low frequency alternating current so that it measured impedance (the sum of capacitive reactance and conductive resistance) rather than simple conductivity. Initial tests indicated that there was, indeed, a tendency for a drop in impedance to occur near maturation of the avocado, but the individual variation between fruits tended to be too large in comparison with the change during maturation for practical use of this simple instrument in its present form (results to be published elsewhere). It was noted, during these tests, that a very large drop in impedance occurred during ripening of the avocado. Other observations seemed to indicate that the capacitive resistance might be responsible for the major part of the impedance of the unripe fruit and that it was this part of the impedance that changed. Therefore, a short study of changes in the basic electrical properties of avocados was undertaken in an attempt to clarify some of the reasons for the observed behavior. Some of the results of this investigation are presented below.

EXPERIMENTAL AND DISCUSSION

Impedance determinations were made by inserting small electrodes into the flesh of the fruits and measuring the impedance to an alternating current using a Heathkit impedance bridge. A Shasta signal generator was used to generate alternating currents with frequencies ranging from 600 to 60,000 cps. Beyond 60 kc, the impedance bridge was completely insensitive and measurements could not be made at higher frequencies.

Design of the electrodes proved to be something of a problem. Initially, simple stainless steel wires were held in a form to allow equal penetration in all fruits. Certain irregularities appeared in the use of these simple electrodes and a more complex electrode was developed to overcome some of these deficiencies. The electrodes finally used consisted of a stainless steel wire (0.037" diam.) enclosed in a stainless steel tube (0.08" i.d.) for most of its length. The central wire was insulated from the shielding tube by a coating of epoxy resin. The tip to be inserted in the fruit was ground to a sharp point exposing only a short length of conducting wire below the sheath. At the other end, the central wire extended from the sheath for attaching clips to lead to the impedance bridge. Two such electrodes were mounted in a plastic form to give a distance between points of one-half inch or one inch. It was found that measurements made with this type of electrode had very little dependence on the depth of penetration in contrast with the measurements made with a simple wire or partially insulated wire electrode.

Measurements were made of impedance changes, using various frequencies of alternating current, during ripening of single avocados. A representative curve for the impedance changes in an avocado with a short ripening period is given in Figure1. The freshly picked avocado shows an impedance at 600 cps which is much greater than the impedance at 60,000 cps. Since the high frequency measurements tend to overcome capacitive reactance and measure only the resistive impedance, this indicates that the major part of the impedance in the normal avocado is due to capacitance. As ripening proceeds, the high frequency impedance remains constant, indicating that no changes occur in the conductivity due to ionic migration. The low frequency impedance shows a rise for a short time followed by a rapid drop to a value not far above the impedance found at high frequency. Thus, it appears that practically all the changes occur in the capacitive reactance during these stages of ripening. Actually, it has been observed that following full ripening, as the tissues degenerate further, the impedance at all frequencies becomes identical and there is a drop to lower levels even at the high frequency.

The shape of the curve obtained at low frequencies seemed to show a possible inverse relationship with the normal respiratory curve for ripening avocados. Accordingly, we carried out experiments in which comparisons were made between the changes in respiration and impedance during the ripening of Fuerte and Hass avocados. Individual avocados were placed in jars at 68° F. and air was allowed to flow over them at a constant rate. The effluent air was analyzed for carbon dioxide by a colorimetric method (3). Impedance values were measured at 1,000 cps once or twice each day, using electrodes spaced one inch apart. Figure 2 shows the results of measurements on Fuerte avocados. The respiration is indicated directly as color value since the shape of the curve is similar to the curve which would be obtained upon conversion of the color value to actual amounts of carbon dioxide.

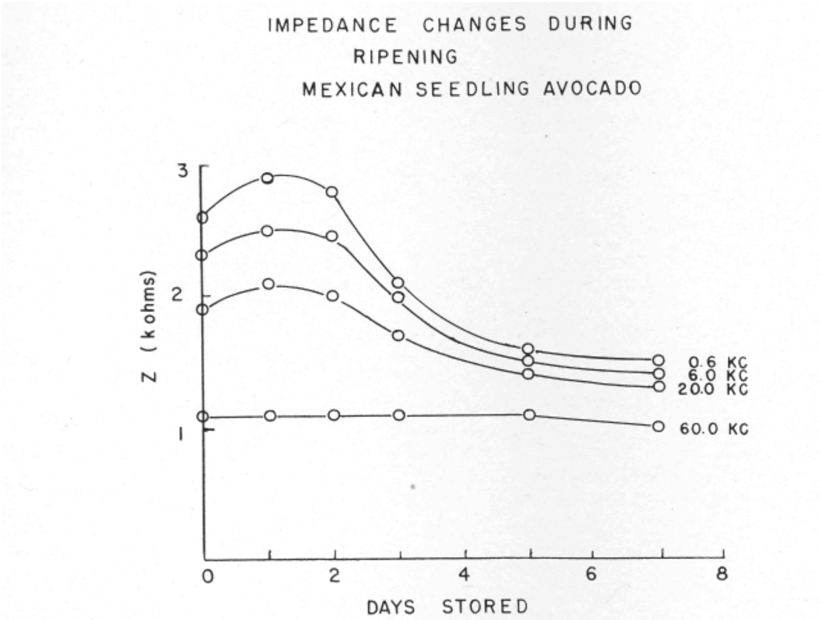

Figure 1. Change in impedance of the avocado fruit during ripening.

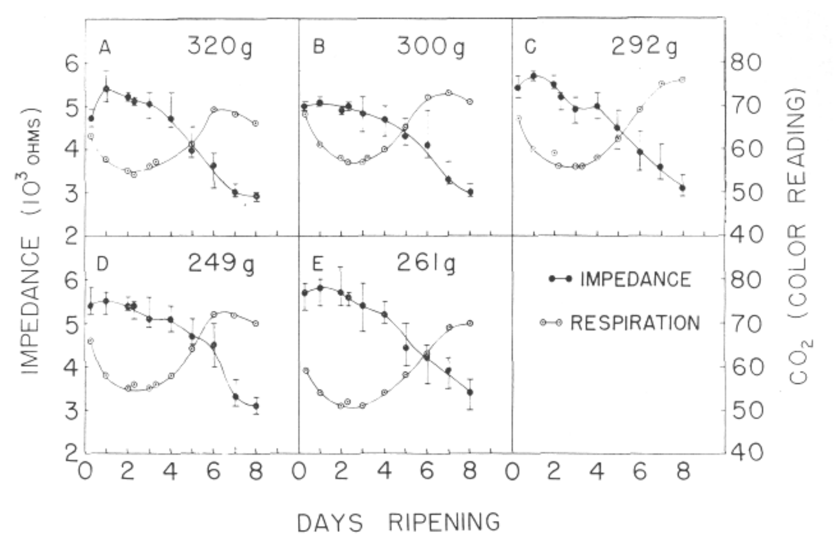

Figure 2. Comparison of changes in respiration with changes in impedance of the Fuerte avocado fruit during ripening.

It is apparent from these curves that there is a good inverse correlation between changes in respiration and changes in impedance of the ripening avocado. Following a rapid drop in respiration and a rise in impedance after picking, the climacteric rise in respiration is reflected in a rapid drop in impedance. Similar results were obtained with Hass avocados except that the longer ripening period following picking resulted in a period of little change in either impedance or respiration between the initial rapid change and the initiation of the changes due to the climacteric.

The significance of these changes during ripening is still a little difficult to evaluate. Certain speculations may be in order at this stage. As pointed out above, during ripening almost all the changes in impedance appear to be confined to capacitive reactance. Therefore, changes must be occurring in some part of the tissue which gives rise to capacitive reactance. Capacitance in tissues may arise from the effects of semi-permeable membranes or to interfaces between phases. Semi-permeable membranes may occur between the cell wall and the cytoplasm, around the mitochondria and microsomes, or between the vacuole and the cytoplasm. Interfaces between phases would occur at any of the areas mentioned above, and, in addition, would surround the suspended oil droplets or any crystalline inclusion in the cell. Following picking, and during ripening, extensive changes may occur in the cell wall, membranes and the composition of the cell contents. All of these changes would affect the capacitance of the tissues. If the permeability of membranes around the cytoplasm were affected in such a way as to eliminate ionic polarization in the region of the membrane, large changes in capacitance would occur. Such permeability changes could also affect the respiration of the tissues due to migrations of substrates outside of their normal storage compartments. Thus, effects on membranes and interfaces could be a major cause of changes in both the electrical impedance and respiration in ripening avocados.

SUMMARY

Electrical impedance of ripening avocados has been measured with alternating currents ranging from 600 to 60,000 cps. These measurements indicate that almost two-thirds of the impedance of the avocado may be due to capacitive reactance.

Comparisons were made between changes in respiration and changes in impedance during ripening of avocados. An inverse correlation was observed between the changes in impedance and respiration.

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