California Avocado Society 1962 Yearbook 46: 94-99

AVOCADO MATURITY STUDIES: A DISCUSSION OF POSSIBLE APPLICATIONS OF VARIOUS PHYSICAL MEASUREMENTS TO NON-DESTRUCTIVE TESTING

Ross C. Bean
Department of Biochemistry, University of California, Riverside

INTRODUCTION

A substantial amount of data has now been collected on the biochemical behavior of maturing avocados in regard to composition and sugar metabolism. Such studies still indicate that improved maturity indices might be developed with biochemical tests but such tests would, of necessity, be destructive of the fruit tested. A procedure which would not require the loss of the sample being tested would be of tremendously greater value than a destructive test. It is impossible to apply any destructive procedure to a large number of fruits to obtain a true index of the range of maturity of a given shipment since each test would require a corresponding loss in fruit sale. A non-injurious physical test, on the other hand, might be applied to a relatively large number of fruits so as to obtain a realistic evaluation of the maturity of a given lot and it would still be possible to market all the fruit tested. In its ultimate development, it might be possible to utilize a properly conceived physical test on a packing line in such a way that all the fruit packed would be tested for maturity and automatically rejected if found to be substandard.

With this in mind, a good deal of attention has been paid to the possible use of various physical measurements for use in maturity tests on avocados. Presented below are some of the areas which have been considered for testing avocados maturity and a discussion of the problems involved in their applications to this end.

COLOR TESTING

Many fruits have a fairly definite color change at or just prior to maturing or ripening and it has been possible to develop reflectance or total light absorption procedures which can measure their maturity without injuring the fruit. It will probably be possible, through procedures of this sort, to develop packing house sorting procedures of an automatic nature for plums, peaches, apricots, tomatoes and some other fruits. While avocados do not have a definite visible color change, it is not necessary for such changes to be visible to the eye since there are instruments available which will measure the invisible changes in ultra-violet or infra-red areas of the spectrum.

Several tests have been made on the visible spectra of Fuerte fruits using extracts in alcohol or in Halowax. Samples of varying maturity in November showed a slight tendency toward loss of color due to chlorophyll while retaining the strong absorption in the far violet which gives rise to the visible yellow color. The absorption of the oils in the ultra-violet made measurements in this region difficult. The differences found between fruit of different maturity (according to oil test) tended to be less than the differences which would occur between different parts of the same fruit. Although this was somewhat discouraging, it does not completely eliminate spectrophotometric determinations for possible application. Work still needs to be done on changes in skin color and with various solvent extraction procedures.

A greater difficulty arises in trying to apply such measurements non-destructively. Equipment for total absorption in a fruit tends to be of such a nature that fairly extensive changes in design might have to be made to apply it to the typical irregular shape of the avocado. Such changes would add substantially to the cost of developing a non-destructive procedure for measuring color changes even if the preliminary studies with extracts or tissue preparations indicated that there might be possibilities in this direction. It must also be realized that, although procedures have been developed for non-destructive spectrophotometric analysis of fruits such as plums and peaches, none of these are yet commercially used.

ABSORPTION OF OTHER SHORT-WAVE RADIATIONS

The relative absorptions of various types of other radiant energy has also been considered. The permeability to X-rays and similar radiation depends on composition and conceivably might be used. However, absorption also depends on thickness of samples, geometry of the measuring surfaces and sample, means of contact and a number of other factors. The complications in measurements as well as the expense of the complex equipment make it rather dubious that such measurements could be applied economically to maturity measurements.

MEASUREMENTS OF HEAT CAPACITY AND TRANSFER

Heat capacities (the amount of heat which must be absorbed by an object to raise its temperature a certain amount) and the rate of conduction of heat from a point of application depend upon structure as well as composition. Since both structure and composition of the avocado change during maturation, measurements of these factors might be used in maturity indices if equipment could be designed for it. It is not likely that it would be readily applied on a large scale since the measurements of this type require a rather extended time period. Other problems, for non-destructive testing, would be concerned with the effects of the various layers of the fruit since the transitions between peel layers, flesh, air space and seed would all affect rates of heat conduction and temperature change. Tests at the tissue level might be feasible although equipment is likely to be expensive.

ULTRA-SONIC MEASUREMENTS

Ultra-sonic radiation has been used very successfully in measuring a wide range of properties in a large number of materials. Recently, it has been used to obtain excellent cross sections of the soft structures of body areas in medicine, augmenting X-rays which give only very little data about the soft tissues. It has been used for detection of flaws in industrial materials, measurement of thickness and determination of hardness or elasticity. It is best applied in determining variations of a structural nature, having to do with hardness, elasticity, rigidity and composition. Since the structural features of avocado tissue change during maturation, it might be possible to use some aspect of ultrasonic measurement for maturity determinations.

The difficulties arise in the diverse properties of ultrasonic waves. Soundwaves are subject to both refraction and reflection. A sound wave propagated through an avocado would be reflected in different degrees by a large number of surfaces within the fruit (interfaces between the skin and flesh, between flesh and air space, between air space and seed, etc.) and obtaining quantitive evaluation of the absorption due to internal friction (from change in structure) would be quite different. Mapping the internal features of the avocado would probably be accomplished readily but the quantitative evaluation of break-down in cell structure which would be indicative of maturity would not be obtained easily.

Ultrasonics might be of sound value in destructive testing. A suggestion has been made that the measurement of oil content by determination of its concentration in Halowax extracts might be more accurate if the degree of reaction to an ultrasonically vibrating knife were measured rather than using the present refractometer procedure. Changes in viscosity due to dissolved substances may be measured much more accurately than changes in refractive index.

ELECTRICAL MEASUREMENTS

The most promising area for non-destructive testing of avocados appears to be in the use of electrical impedance measurements. Impedance in a biological tissue depends on a number of factors including the concentration of ionic substances in the cells, the capacitive effects of cell membranes and of droplets or discrete particles in the cells (such as oil droplets) and on the characteristics of the measuring signals. In avocados, several factors are in the process of changing in such a way that they might contribute to the determination of maturity through impedance measurements. Oil content is increasing resulting in a greater capacitive effect due to the interface effect between the droplet and the aqueous phase. Membranes in the cell are probably changing to some degree. Concentrations of dissolved substances in the cytoplasm also vary with age and other factors.

A previous article (1) has given some background on the type of equipment used for simple measurements of impedance using inserted probes during ripening. Rapid changes in impedance of harvesting avocados were observed under these circumstances. Similar tests on maturing avocados were not so clear-cut but gave some rather definitely promising results. A field test was made which enlisted the aid of the State Department of Agriculture laboratory in Escondido. For a period of a week, a substantial portion of the fruit which they tested for oil content was also subjected to a determination of impedance value using the hand test meter previously described. Several varieties of fruits were included in the tests and there were wide variations in temperature at time of test and in time from harvest. However, even under these conditions, the data for Fuerte fruit, illustrated in Figure 1, showed a reasonable correlation with the oil content. A second series of tests, done under laboratory conditions by harvesting the fruit, bringing to a constant temperature in a water bath and then testing within four hours after harvest gave a much better degree of correlation as shown by the points plotted in Figure 2. It is quite possible that more refined equipment, using electrodes described in the previous article (1) would give rise to still better results.

These simple tests are subject to several problems in application. Impedance changes greatly following harvest as the ripening commences, so that a fruit testing immature immediately after harvest might, upon re-testing at a later time, be found to pass the test. The present equipment is not temperature compensated and the resistance of the fruit itself will show wide variations with change in temperature. There is also a relatively wide range of resistance in different parts of the fruit. Finally, the test as it is now done, requires the insertion of two small electrodes into the fruit flesh. Although the injury is not great, it would still tend to destroy the individual fruit for normal marketing. A slight modification has been tried in which only one electrode was inserted through the stem (improved electrode). A water or salt bath was used as the other electrode. After inserting the first electrode, the impedance meter was observed as the fruit was lowered slowly into the bath until it was completely immersed. It was found that this procedure gave impedance values proportional to those obtained by the usual method if the impedance was taken as the minimum just prior to having the conducting solution reach the stem. More experiments are planned along this line to determine whether this could have any practical value.

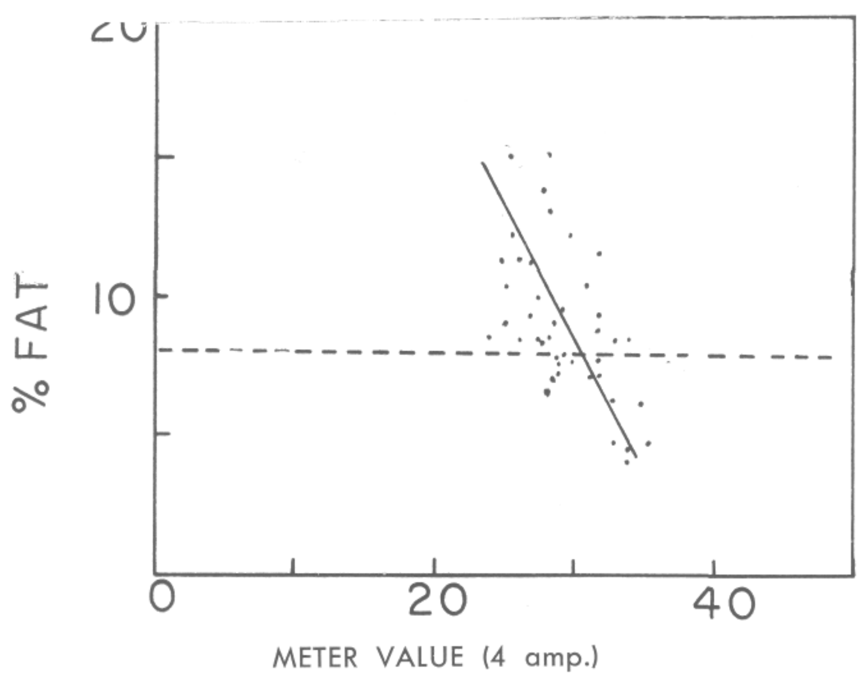

FIGURE 1. Correlation of impedance meter readings and oil content of avocados in field tests. Impedance is given in arbitrary units.

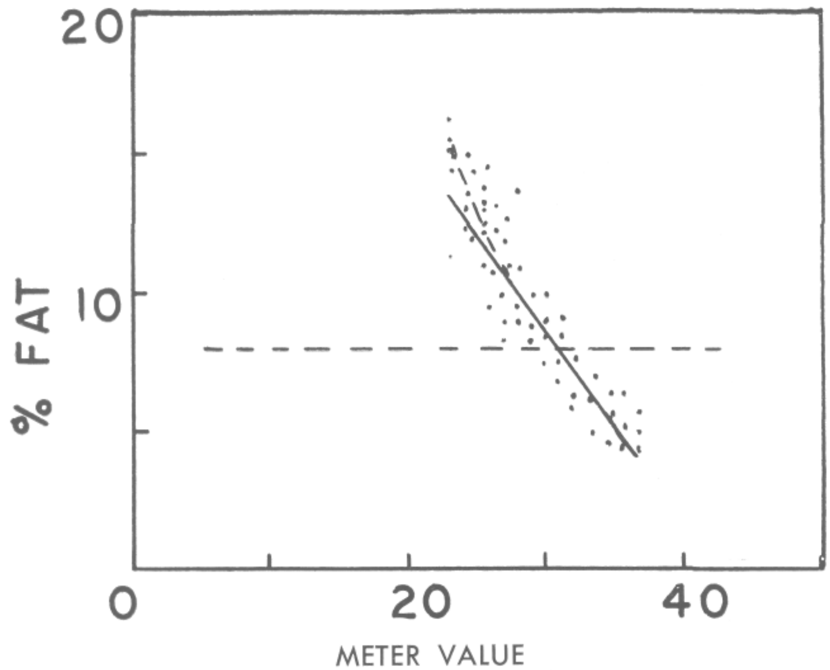

FIGURE 2. Correlation of impedance meter readings and oil content of avocados under laboratory conditions. Impedance is in arbitrary units.

In seeking a way around the problem of fruit injury by insertion of electrodes, a number of experiments have been done using high frequency conductivity apparatus. Under favorable conditions high frequency measurements may be used to determine the conductivity of materials or some aspects of capacitance without actual contact with electrodes. Conductivity of solutions may be measured in a glass container with the solution separated from the electrodes by the thickness of the glass.

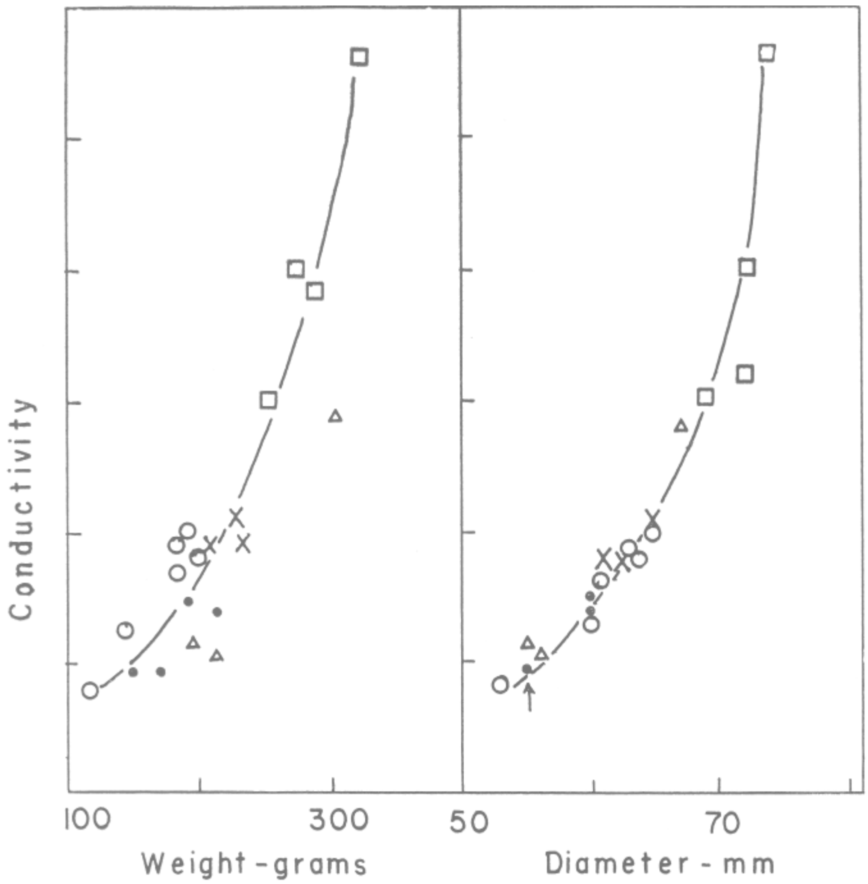

FIGURE 3. High frequency impedance measurements in avocados with fruit in contact with insulated ground electrode. o-Hass; x-Ryan; z-Iwo; y-Dickenson; k-Unidentified. Conductivity is in arbitrary units.

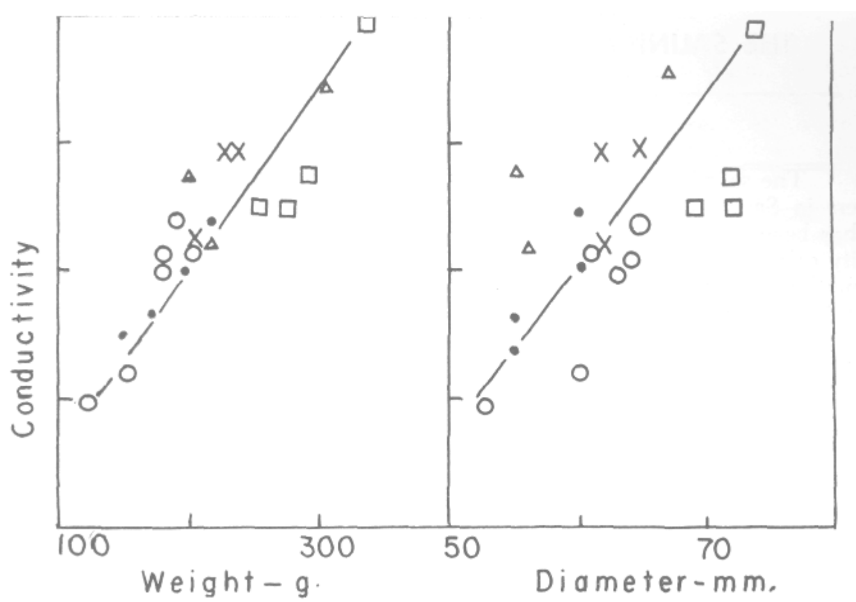

FIGURE 4. High frequency impedance measurements in avocados with fruit contacting insulated live electrode. See Figure 3 for identifications.

Using a capacitance matching apparatus having a signal frequency of 4.7 megacycles (Sargent Oscillometer) with various electrode arrangements, some very interesting results were obtained. With two parallel elliptical plates as electrodes and with a fixed air gap, when the fruit was in contact with the polyethylene insulated ground plate it was possible to obtain a very good measure of the diameter of the fruit and a somewhat poorer determination of the weight (Figure 3). Using the same conditions except that the fruit was in contact with the live plate insulation, a very good correlation was found between the relative conductance and the weight of the fruit, regardless of variety (Figure 4). With both electrodes in contact with the fruit no reasonable correlations were found. With the system immersed in water some weak correlation was found with the maturity of the fruits (rate of ripening and quality) but outstanding exceptions were also found (not shown).

DIRECTIONS FOR FUTURE RESEARCH

Although some of the results are erratic and a great deal of basic work has to be done on methods and equipment, the work with impedance measurements does show some hopeful promise. The present crude equipment does not give sufficiently accurate and reproducible results and much remains to be solved in the area of electrodes for use with fruits. Of the various physical measurements given above, the impedance measurements appear to be the least troubled with theoretical problems in application. Color measurements in the ultra-violet may still be possible although these would almost certainly be destructive tests. For the present time, research will continue to press in the impedance area with some work also being carried on in the spectrophotometric determinations.

REFERENCES

1. R. C. Bean, J. P. Rasor, and G. G. Porter (1960). Changes in electrical characteristics of avocados during ripening. Calif. Avocado So., Yearbook, 44:75-78.