BRIEF PAPERS

BEHAVIOR OF CITRUS FRUIT UNDER SPECIAL RESPIRATORY CONDITIONS AS AN EXPEDIENT INDEX OF VITALITY

(WITH THREE FIGURES)

There is an ever recurring demand for some simple indicator of the vitality of citrus fruit in relation to its keeping quality in storage and transportation. A few such indicators have been tentatively suggested, as for example the KMnO₄ method by Klotz.¹

In April, 1935, the writers undertook to utilize toward this end the respiratory processes of citrus fruit under simple but specific conditions. The general method adopted consisted of filling with fruit a container capable of being made perfectly air-tight, and afterward recording the pressure changes as respiration of the fruit altered from approximately normal to the anaerobic type.

One kind of container used was of 2.5-gallon capacity and designed to withstand pressures of at least 50 lb. per square inch. These containers were equipped with mercury manometers 175 cm. in length. The chief characteristics observed in this set-up were the rate of change and the final pressure attained. The results proved very interesting but such containers were unwieldy and the end point was reached only after two to three weeks. The range of final positive pressures observed in this manner was 40 to 165 cm. of mercury. The curves of such pressure increase made, after an initial delay, a straight line day after day until near the end point. For convenience, and to shorten the period of observation, the method was modified to allow a closer following of pressure changes previous to reaching a positive pressure of 10 to 20 cm. of mercury. This condition called for batteries of low pressure containers consisting simply of 2-quart Mason jars of the "wide mouth" type, and finally, of 1-gallon wide mouth glass jars commonly used for mayonnaise (fig. 1). Both sizes of containers were equipped with mercury manometers 26 cm. long. The covers of the 1-gallon jars were made of steel disks 5 inches in diameter and ½ inch thick. To these were cemented pure gum gaskets ¼ inch thick. Connections to the manometers were made by means of copper tubes passing through the center of the steel disks. The jars and lids were placed in strong oak frames so that the lids could be bolted down tightly while in use. The period of observation on fruit in these containers varied with the temperature. The majority of tests were made at 72° F., at which temperature the period was usually 24 to 72 hours. Many comparative tests, however, were carried out at 56°, 46°, 42°, and 38° F.


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A temperature of 56° proved satisfactory, except that the period of observation became about double that at 72°.

Fruit having an initial respiratory ratio of less than unity began to develop a negative pressure at once, but after the development of nearly anaerobic conditions the pressure began to rise, at first relatively slowly; with complete anaerobic conditions the pressure rose more rapidly and assumed a constant rate of increase throughout the remainder of the test.

Fruit having an initial respiratory ratio considerably greater than unity began to develop positive pressure at once; at first relatively slowly and faltering, then more rapidly, from which time the rate of pressure increase became constant.

Apparently when the ratios were close to unity the early pressure changes were either slightly negative and then soon positive, or positive then slightly negative (or only dropping to a lower positive pressure) and finally strongly positive so that an "S" curve was shown when plotted. (See A and B, fig. 3).

The great variety of pressure changes produced by different fruits has been astonishing. The direction (positive or negative) and rate (slope of

2 The relative values of the respiratory ratios mentioned here are assumed from fruit behavior in the tests.

3 Chemical tests showed that the O₂ was almost completely absorbed by the time of maximum negative pressure.
the curve) of the pressure changes and the total negative pressure (if it occurs) seem to constitute the most valuable characteristics. When comparing curves constructed from data which show initial negative pressure two very good practical indices have been noted; namely, first, the number of hours elapsing before the curves return to the X-axis (i.e., atmospheric pressure); and, second, the area of the figure bounded by the X-axis and that portion of the curve lying below it. The area was determined by means of a planimeter. Barometric changes are sometimes large enough to effect small variations in the curves.

Lemons have indicated that their respiratory ratio remains less than unity until a late stage of maturity, but the rate of development of negative pressure and return to atmospheric pressure decreases as the fruit matures. In respect to this characteristic, freshly picked lemons in general showed the following order, "dark greens"; "light greens"; "silvers"; and "tree ripe." However, silvers sometimes gave the greatest negativity, and frequently greater than dark greens. Typical curves of "dark green" and "tree ripe" lemons are shown in figure 2. The responses of such lemons after being held in storage for varying periods gradually became slower, although the relative position of the curves keep somewhat the same. After a few weeks at 56° F. the tree ripe lemons developed little or no negative

![Figure 2](https://www.plantphysiol.org)
pressure, at which stage they had probably almost passed the period of commercial usefulness. Extensive tests are under way for correlating the characteristics of the pressure curves obtained from lemons with the subsequent behavior of the latter in transit and market. The present respiratory tests on lemons have shown in addition to the above, effects of oil spraying, relative humidity, temperature, irrigation, and ethylene treatments. Some effects of ethylene seemed still to be in evidence nine weeks after treatment.

Immature grapefruit (of pre-harvest season) have indicated respiratory ratios less than unity, but grapefruit fresh from the grove at early commercial harvest season have shown ratios slightly greater than unity. The pressure curves of the latter type were usually "S" shaped (fig. 3). The ratios did not increase rapidly as the season advanced, but old fruit from the tree, or long-stored fruit, showed the capacity to develop continuous positive pressures indicating large ratios. An increased respiratory activity has been noted for grapefruit which have pitted in storage.

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**Fig. 3.** Pressure curves of early season grapefruit (Coachella, California). Tests made at 72° F. All fruit from same trees. A, freshly picked; B, as A but picked 6 weeks later. The remaining curves are of fruit picked at the same time as A, but held in storage for 6 weeks at temperatures indicated.
A relatively small number of tests have been made upon late season Valencias (1935) and the present season (1935–36) Washington Navel oranges. The results indicate a situation closely resembling that for grapefruit with perhaps a slightly greater tendency to show initially positive curves.

In a cursory manner the special respiratory test has been made upon apples, pears, grapes, tomatoes, lettuce, and other fruits and vegetables. The responses were frequently very interesting and suggested that the method might have a wider application than to citrus, as a simple and rapid test of maturity or vitality.

The work of correlating the types of pressure curves obtained from fruit with its likely subsequent behavior on the market is very great. The practical value of the method can be determined only through its trial by many workers upon different varieties of fruit and in different localities. This situation is taken as justification for this preliminary report.—E. M. Harvey and G. L. Rygg, Bureau of Plant Industry, U. S. Department of Agriculture, Pomona, California.

BEHAVIOR OF STOMATA OF IRRIGATED WHEAT PLANTS

Introduction

It is known that stomata respond very markedly to environmental changes, especially to variations in the water supply, but their reaction is often very complicated. The writers have studied the stomatal movements of irrigated wheat plants in order to determine the possibility of using certain characteristic changes as indices of different irrigation procedures, and especially for the determination of the time of acute necessity for irrigation.

The work was carried on during the summer of 1933 in the Volga district at the Valuika Agricultural Experiment Station.

Materials and methods

The soft wheat, *Erythrospermum* 0841, sown on April 26, was the material used in our investigation.

The degree of opening of the stomata was determined by the alcoholic method of Lloyd. Counts were made, with a microscope, of the number of stomata that were fully open, half open, slightly open, and completely closed. A fully opened stoma was about twice as large as one half open, and these, in turn, three times larger than those slightly open. The total opening for all the stomata was calculated by multiplying the percentage of fully opened stomata by 10, the half opened by 5, and the slightly opened by 1.6. Thus, if all the stomata were completely open, the greatest number

1 A more detailed account of the results obtained in this investigation will be presented in another paper.