

# Studies on Cherry Scald

1197

## I. Relationship Between Bruising and Respiration in Water<sup>a</sup>

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THE THREE MAJOR STEPS in the handling of cherries before the actual pitting and canning operations are harvesting, transportation to the processing plant, and tank-soaking of the fruit. This last operation has been found beneficial in allowing the fruit to cool and to become firm before being pitted. In recent years the harvested fruit has been transported from the orchards in water tanks (8). This procedure serves to minimize any further bruising of the fruit following the harvesting, and enables the cooling and soaking operations to proceed even before the cherries are transferred to the soaking tanks at the plant itself. Discounting any condition that would spoil the fruit prior to harvesting, the major problem of scald (surface discoloration) arises somewhere between the picking and processing of the cherries. LaBelle (7) and Whittenberger and Hills (13) have observed that the initiation of scald is always preceded by bruising of the fruit. Commercial picking of cherries, by the very nature of the picking process, involves bruising. It was therefore decided that more information on the relationship between bruising and scald could be gained by a continued investigation of the effects of bruising and the methods of handling on the post-harvest physiology and metabolism of the fruit. Since in normal commercial operation, cherries are soaked in water after harvesting, the first experiments in this study were carried out to determine the oxygen consumption of cherries in water. In the experiments both unbruised and bruised cherries were immersed in water at 10° and 30° C. The water was either half-saturated or fully saturated with oxygen.

### MATERIALS AND METHODS

**Materials.** Montmorency cherries from the orchard of the National Agricultural College, Doylestown, Pennsylvania, were used in all of the experiments reported in this study. They were carefully cut from the trees with their stems attached and transported to the laboratory each day in a container lined with absorbent cotton to prevent bruising. Stems were later cut from the cherries so that only enough remained to be grasped by tweezers; the fruit was not handled with the fingers during any phase of the experimental procedures. Weights and volumes of the cherries were determined; the latter by water

displacement. Some of the cherries were bruised by rolling them firmly between the concave surfaces of two small watch glasses. Splitting of the skin was carefully avoided in this procedure.

**Methods.** A Sargent Model XXI polarograph<sup>c</sup> was used to obtain the oxygen current-voltage curves. The cell used for the measurements consisted of a pint-sized Mason jar and a large rubber stopper through which were inserted a thermometer, a platinum wire, and a capillary tube. At the bottom of the jar was a pool of mercury into which the platinum wire extended; this served as the anode. The cathode was provided by mercury dropping through the capillary tube. The cherries were placed in the jar on top of a layer of glass beads which prevented direct contact between the cherries and the mercury. This electrolytic cell was maintained at the desired temperature by immersion in a thermostatically controlled water bath.

Potassium chloride was used as the electrolytic solution. It was diluted as much as possible (0.0001 *M.*) without affecting its conductance so that any possible influence of the dissolved salt on the physiological activity of the cherries would be minimized. Current-voltage curves obtained for dissolved oxygen in a range of diluted potassium chloride solutions showed that well-defined waves could be obtained at this low electrolyte concentration.

The procedure consisted of saturating the electrolytic solution with air by vigorous agitation for ten minutes, and then placing into this solution 30 weighed cherries of known volume. The jar was then carefully sealed by means of the rubber stopper to avoid entrapment of air bubbles over the solution. Readings were taken after an adequate period for equilibration. The oxygen content of an aliquot of the air-saturated solution was determined chemically by the Winkler method (1) for standardization of the polarogram. The reproducibility of the oxygen wave heights for solutions shaken for different time intervals showed that the 10-minute agitation period was sufficient for oxygen saturation. For comparison, some experiments were made after removing half of the oxygen from saturated solutions by bubbling nitrogen gas through them. Polarograms were obtained initially and at time intervals thereafter, and the corresponding wave heights converted to diffusion currents.

A typical polarogram obtained with 30 cherries in the air-saturated solution at 10° C. is shown in Figure 1. Curves A to J denote the successively dissolved O<sub>2</sub> contents from the beginning to the end of the experiment. Each curve shows 2 reduction waves, the first of which reached a maximum and then dropped, so that it did not provide a valid measure of oxygen content. Rather than use maximum suppressors, which may have influenced the respiration of the fruit, the wave heights of the second reduction waves were taken as the basis of the data presented since these were found to be a quantitative measure of the dissolved oxygen content.

Since previous workers had shown that the presence of metallic mercury has no inhibitory effect on the physiological

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<sup>c</sup> Mention of trade name does not necessarily imply endorsement by the U. S. Department of Agriculture over similar products not mentioned.

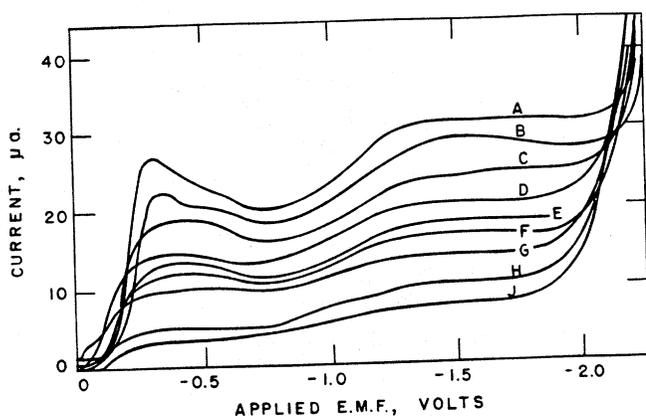


Figure 1. Polarographic waves showing dissolved oxygen levels in water.

activity of biological materials in water (11), no precautions were taken other than to keep the cherries from direct contact with the mercury by means of the glass beads.

A typical calculation of the utilization of dissolved oxygen at 10° C. by bruised cherries is shown as follows:

Total weight of 30 cherries = 95.93 g.  
 Total volume of 30 cherries = 88.8 ml.  
 Volume of stoppered cell = 415.0 ml.  
 Volume of 0.0001 M. KCl = 415.0 - 88.8 = 326.2 ml. = 0.3262 l.

Oxygen content of air-saturated solution (Winkler method) = 9.71 p.p.m. = 9.71 mg./l.

9.71 mg./l. x 0.326 l. = 3.17 mg. of oxygen available in cell.  
 Since 32 g. of oxygen occupies 23.2 l. at 10° C.:

$\frac{0.00317 \text{ g.}}{32 \text{ g.}} \times 23.2 \text{ l. / mole} \times 10^6 = 2291 \text{ } \mu\text{l. of oxygen available in cell}$   
 $\frac{2291 \text{ l.}}{95.93 \text{ g. cherry}} = 23.9 \text{ } \mu\text{l. of available dissolved oxygen/g. of cherry}$

The polarographic wave height (half-wave potential of -0.90 V) at the start of the determination was 137.0 mm. (9.71 p.p.m.)

137.0 mm. = 23.9  $\mu\text{l. of oxygen/g. of cherry}$

At the end of 2 hours the wave height was 87.5 mm. (6.2 p.p.m.)

$\frac{87.5}{137.0} \times 23.9 = 15.3 \text{ } \mu\text{l. oxygen/g. remaining, or}$   
 $23.9 - 15.3 = 8.6 \text{ } \mu\text{l. of oxygen consumed/g.}$

## RESULTS

Composite oxygen uptake values for unbruised cherries and cherries experimentally bruised at room temperature and immersed in water at 10° and 30° C. are shown in Figure 2, wherein it is seen that, as with other materials (9), the respiratory rate increased with an increase in temperature. At the end of 4 hours the total oxygen absorbed by the unbruised cherries was 2  $\mu\text{l./g.}$  at 10° C. and 10  $\mu\text{l./g.}$  at 30° C. Bruising caused approximately a 5-fold increase in the oxygen uptake at 10° C. from 2.0 to 10.5  $\mu\text{l. of oxygen per gram}$ , while at 30° C. the same treatment resulted in approximately a 2-fold increase, from 10.0 to 19.0  $\mu\text{l. of oxygen per gram}$ .

Since 10° C. (50° F.) is the average temperature at which the water in commercial soaking tanks is maintained, it was decided to investigate the relationship between dissolved oxygen levels and the promotion of scald at this temperature. Previous studies on other plant tissues (2, 3, 4, 12) have shown that the respiration rate in air decreased as the available oxygen decreased. The present study showed a similar effect when cherries respired in water in which the level of oxygen continuously decreased. In Figure 3 it can be seen that the rate of respiration was related to the amount of oxygen present, and that the respiration rate decreased as oxygen was depleted. In a series of experiments in which experimentally

bruised fruit was immersed in fully aerated solutions, at the end of four hours the available dissolved oxygen was above 5 p.p.m., and no scalding was observed. When similarly bruised fruit was immersed in solutions half-saturated with dissolved oxygen, scald formation was observed after approximately 3 hours at which time the remaining oxygen concentration was usually below 3 p.p.m.

At 30° C. bruised cherries immersed in fully aerated water for 4 hours did not exhibit distinct scald spots but bleached out homogeneously over the entire cherry and became very light in color. Immersion in oxygen-deficient water accelerated this same process. It was further observed that neither high temperatures nor low oxygen levels produced scald in unbruised cherries.

## THEORY

The rate of disappearance of oxygen from the aqueous solution is proportional to the concentration of dissolved oxygen and to the weight (concentration) of the cherries. This can be represented as a second-order kinetics equation:

$$-\frac{d[\text{O}_2]}{dt} = k[\text{O}_2][\text{cherries}] \quad (1)$$

Since the concentration of cherries is far in excess of the available oxygen, it can be assumed that for any given experiment, the concentration of the cherries is a constant, which can be included in the specific rate constant, resulting in the pseudo first-order equation:

$$-\frac{d[\text{O}_2]}{dt} = k'[\text{O}_2] \quad (2)$$

where  $k' = k[\text{cherries}]$

Integration of equation 2 results in the pseudo first-order equation

$$-\ln[\text{O}_2] = k't + C \text{ or } -\log[\text{O}_2] = \frac{k}{2.303}t + C' \quad (3)$$

Therefore, a plot of the negative common logarithm of the concentration of oxygen remaining in solution against time should yield a straight line whose slope is a measure of the specific reaction rate constant for the respiration of the cherries in water at the given temperature.

That this is the case is shown in Figure 4 in which the concentrations of the oxygen remaining at any given time, expressed as negative logarithms, are plotted against time, for the respiration of 30 bruised cherries at 10 and 30° C. The slope of these linear plots yielded specific reaction rate constants of 1.58 and  $8.30 \times 10^{-3}$  per minute for the bruised cherries at 10° and 30° C., respectively, showing that the respiration of cherries in water at these temperatures follows the mathematical derivation of a pseudo first-order equation. Since the intercept of equation 3, C, was found to be zero, it was possible to

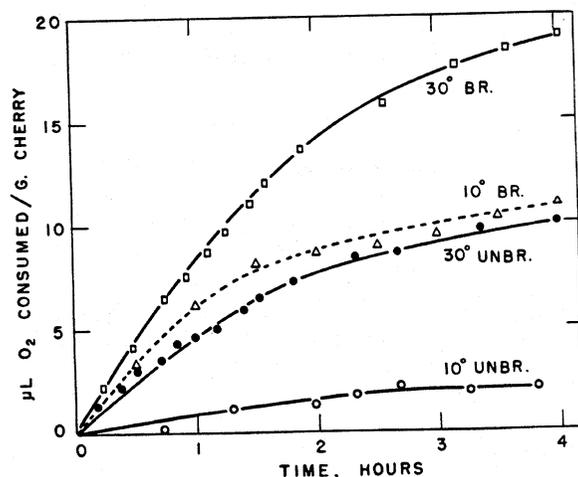


Figure 2. Oxygen consumption of bruised and unbruised red tart cherries in water at 10° and 30° C.

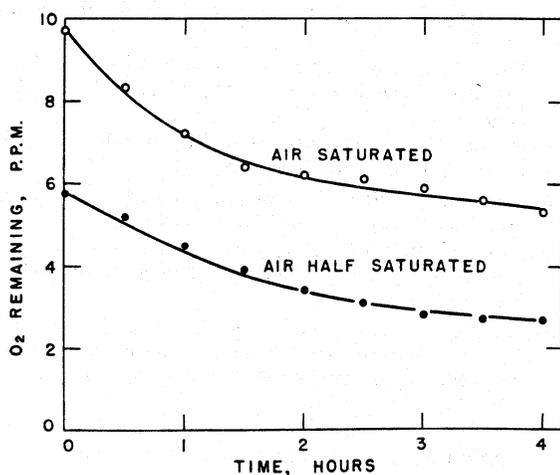


Figure 3. Oxygen consumption of bruised red tart cherries at two levels of dissolved oxygen in water.

calculate the specific reaction rate constants from the equation

$$k = 2.303 \left( - \frac{\log[\text{O}_2]}{t} \right) \quad (4)$$

The ratio of the  $k$  values for 30 and 10° C. resulted in a calculated temperature coefficient factor ( $Q_{10}$ ) of 2.3 which is in good agreement with  $Q_{10}$  values reported for other fruits (5).

### DISCUSSION

An increase in temperature from 10° to 30° C. resulted in a 5-fold increase in the respiratory rate of the submerged cherries. This would roughly correspond to the rule-of-thumb doubling of the kinetic rate for each 10° rise in temperature. Bruising at 10° C. resulted in a 5-fold increase in respiratory rate, while at 30° C. only a 2-fold increase was noted. The observation that at either temperature the rate of respiration was increased by bruising suggests that extensive metabolic changes must have taken place. Such factors as changes in the permeability of the fruit skins and cell membranes and altered enzyme activities must be considered in order to explain the increase in oxygen utilization of the bruised fruit over that of the unbruised fruit while under water. Further, since the oxygen absorption of the bruised cherries resulted in linear pseudo-first order plots (Figure

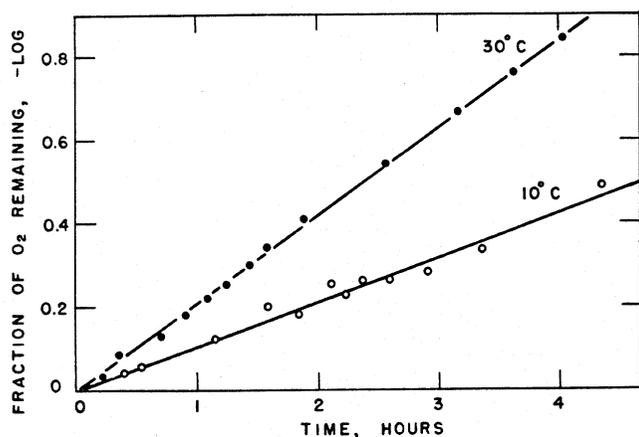


Figure 4. Pseudo-first order plots for the respiration of bruised red tart cherries in water at 10° and 30° C.

4) it would indicate that the respiration rate-determining factor at any one temperature (in the case of bruised fruit) is the availability of the dissolved oxygen.

Scald formation was also studied and the results of replicate experiments showed that bruising followed by low oxygen concentrations were contributing factors to its formation. Scald formation did not occur with bruised fruit when sufficiently high oxygen levels were maintained. The importance of oxygen availability in storage conditions of fruits was pointed out earlier by Hill (6). Nelson (10), who found that breakdown diseases of vegetables occurred in storage at low oxygen levels in air, suggested that the cause of these diseases may have been the internal release of toxic substances resulting from the reaction of hydrolytic enzymes with plant sugars. Since in the present study it was observed that scalding did not occur with unbruised fruit submerged in water regardless of oxygen concentration, it would appear that the initiation of scald is primarily dependent upon bruising which brings about a disruption of normal respiratory systems within the fruit.

The fact that scald was induced in the relatively short time of 3 to 4 hours in these experiments is probably due to the severe manner of bruising used on the fruit. In commercial practice, the extent of bruising resulting from the harvesting procedures no doubt runs the gamut from slight bruising to that equaling the severity of the technique used in these experiments. For this reason there is usually a longer delay in the appearance of scald in actual practice. A preliminary survey of commercial soaking and hauling tanks made during the 1956 season (unpublished data) showed that in a number of these tanks the dissolved oxygen levels were less than 2 p.p.m. The high incidence of scald observed in these tanks may have been a function of the bruising of the fruit and the fact that the oxygen concentrations had reached critical levels.

### SUMMARY

A study has been made of the oxygen consumption of red tart cherries while submerged in water at 10° and 30° C. It was observed that both an elevation in temperature and bruising increased the respiratory rate. Calculation of the kinetic data for the respiratory rate of bruised cherries resulted in pseudo first order plots, showing that the rate-determining factor was the concentration of dissolved oxygen. Scald formation was observed with bruised cherries at low oxygen concentrations. At 10° C. bruised cherries scalded when the oxygen level fell below 3 p.p.m. At 30° C., however, bruised cherries scalded even in fully aerated water. The fact that unbruised cherries at these same low oxygen concentrations did not scald indicates that bruising and the consequent disruption of the normal respiratory system is the primary factor in scald formation.

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