of d-limonene. The optical rotation is still the most sensitive and diagnostic test for purity. It is recommended that for storage in drums (55 gal.), the drums should be filled completely, preferably with hot limonene, and 50-100 p.p.m. of butylated hydroxytoluene added. This amounts to 9-18 grams of B.H.T. per 400-pound drum. The cost of this treatment is 2.2-4.4 cents per drum (.005 to .01c/lb.). Iron or structural steel is recommended for tank construction. Air should be scrupulously excluded by purging with nitrogen (preferred) or carbon dioxide gas. By the use of automatic pressure valves and any suitable gas source, a constant pressure should be maintained on the tank. This system would allow for expansion and contraction due to temperature changes as well as for periodic additions and withdrawals of limonene.

**LITERATURE CITED**


## CHANGES IN CARBON DIOXIDE CONCENTRATIONS WITHIN FRUIT AND CONTAINERS DURING STORAGE

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Citrus and many other fresh fruits and vegetables are marketed in film bags (polyethylene, cellophane, pliofilm). These bags are relatively impermeable to carbon dioxide, oxygen and water and water vapor, and under some conditions these physical characteristics can be used to advantage. Under other conditions the use of film bags for temporary storage may have a disastrous effect on fruit respiration and hence upon fruit storage life.

This is a report on the change in carbon dioxide concentrations within film bags and inside fruit during and after various storage conditions and packinghouse practices.

**Literature Review**

The values of modified atmosphere have been recognized since 1920 when Kidd and West (5) began their extensive studies on “gas storage” of apples. As a result of early works, the storage of fruits in other than normal concentrations of gases has become as common a practice as has reduced temperature storage. Both tend to slow down metabolic changes of fruit by either a build-up of an end metabolic product or by slowing enzymatic changes as a result of sub-optimal temperature.

Biale (1) reported optimum gas concentrations for lemon storage to be 10 per cent oxygen and 5 per cent carbon dioxide.

Hopkins and Loucks (3) reported 54 per cent stem-end rot of oranges stored three weeks in sealed containers compared to 10 per cent in open containers; however, no data was presented on carbon dioxide and oxygen levels.

Decay of Oranges stored in ventilated film bags was reduced as the number of ¼-inch holes was increased from 8 to 64 (4). Hayward et al. (2) also reported a decrease in decay of oranges stored in film bags containing up to 100 holes. There were indications that more ventilation would further reduce decay; however, the bursting strength of the film was sharply weakened at the upper limit. No internal gas analysis was included in either of the above reports.

**Materials and Methods**

A Fisher Clinical Gas Partitioner, a gas chromatography apparatus with a recorder of 1 mv for full scale deflection, was used for quantitative gas analysis.

Two sets of columns were compared. The first set was made of silica gel and Molecular Sieve 18X. The second set contained 30 per cent hexamethyolphosphoramide (HMPA) on 60-80 mesh Columnpak and a Molecular Sieve 5A. Figure 1 shows the recorded distribution of gas peaks as they are detected (A. Silica Gel-Molecular Sieve 13X and B. HMPA-Molecular Sieve 5A). Gas samples were taken with a hypodermic needle and syringe, and injected into the
machine through a rubber septum. The area under the curve (Figure 1) is calculated and compared to a standard curve for the particular column used.

This method permits the utilization of a small gas sample for analysis varying from 0.1-1.0 ml, depending on the gas concentrations. A gas sample may be extracted from the inside of a fruit or from a package containing fruit without disturbing the gas atmosphere.

Gas samples were taken with a hypodermic needle. A tire patch was placed on the surface of the polyethylene bags or over a hole in the jar where fruit was held. The details of each experiment are discussed separately below.

RESULTS

Changes in the carbon dioxide content in polyethylene bags with and without fruit.—The first experiment performed was with one quart 1.5 mil polyethylene bags. Two bags were filled with a 5 per cent carbon dioxide—95 per cent oxygen mixture and closed tightly. Two other bags (tightly closed) contained tangerines. Fig-

Figure 1. Strip recorder charts showing the placement of the gas peaks as they emerge from the columns and are recorded. A. Silica Gel - Molecular Sieve 13X. B. HMFA - Molecular Sieve 5A.

Figure 2. Carbon dioxide changes in 1.5 mil polyethylene bags containing (1) tangerines and (2) 5 per cent carbon dioxide and 95 per cent oxygen.

Figure 3. Variation of carbon dioxide content of 1.5 mil polyethylene bags (without holes) containing Hamlin oranges. Bags were randomly selected from the packing table without special attention to tightness of closure.

Figure 4. Carbon Dioxide content in 1.5 mil polyethylene bags with ventilated holes; O and X — no holes; filled circles — 1, 4 and 8 pin holes; filled rectangles — 1, 4 and 8¼ inch holes. Bags contained Pineapple oranges.
Figure 2 shows the change of carbon dioxide content within these bags. The measured carbon dioxide content of the bags containing 5 per cent carbon dioxide showed a fast decrease in carbon dioxide reaching an equilibrium with air in about one day. While the carbon dioxide content decreased rapidly in that bag, the carbon dioxide content in the bags containing tangerines increased steadily to approximately 7 per cent within six days at 70° F. Even though it was shown that carbon dioxide could escape from a polyethylene bag, the rate of carbon dioxide production by the tangerines exceeded the rate of carbon dioxide loss and actually built up the carbon dioxide concentration in the bag.

Variability in carbon dioxide accumulation in polyethylene bags containing fruit.—Eight 1.5 mil five-pound polyethylene bags without holes were filled with fruit, packed into a bag master carton, and placed in 70° F. storage. The bags were closed with draw strings and no attempt was made to seal them.

Figure 3 shows the variation in carbon dioxide content in the different bags over a 13-day period. Some bags increased to a 7 per cent carbon dioxide level and remained high over the entire period. Others increased in carbon dioxide content and then decreased. This set of curves represents the variability in closing procedures and could also represent the effect of handling the bags every time a gas sample was removed. However, it does show that where fruit is enclosed in a tight polyethylene bag there may be as much as 7 per cent carbon dioxide in the enclosed atmosphere of the bag.

Effects of differential perforation of polyethylene bags on carbon dioxide accumulation.—To determine the effectiveness of holes in a polyethylene bag on reducing the carbon dioxide concentration in the atmosphere surrounding the fruit, different amounts and kinds of holes were punched in 1.5 mil five-pound polyethylene bags in the area occupied by the fruit. The bags were filled with Pineapple oranges, tightly sealed at the top, and hung on nails in a 70° F. storage room. The treatments are given in Figure 4 which shows the carbon dioxide concentration in each of the bags over a period of eight days. The carbon dioxide concentration in the polyethylene bags without holes increased to approximately 10 per cent during the first day and remained quite high over the entire period. There was an inverse relationship in the carbon dioxide content in the bags and the number of pin holes in the range of one, four, and eight where the additional holes in the bags reduced the carbon dioxide content.

Increasing the hole size to ¼-inch further reduced the carbon dioxide content of the air surrounding the fruit. Increasing the number of ¼-inch holes to four and to eight holes per bag maintained the carbon dioxide level at approximately 1 per cent. It should be noted that over the eight-day storage period the carbon dioxide content in the bags containing four ¼-inch holes slowly increased to 2 per cent.

Accumulation of carbon dioxide in gas-tight jars containing fruit.—The previous experiment showed that carbon dioxide would accumulate up to 10 per cent in a polyethylene bag containing fruit. The question arose as to the amount of carbon dioxide that would build up in gas-tight containers of fruit.

Fruit were placed in one-pint Mason jars, some jars with one and some with two fruit. The lids of the jars had a hole covered with tire patching to permit sampling of the gas with a hypodermic needle and syringe.

Figure 5 shows the rapid accumulation of carbon dioxide up to 50 per cent in these sealed
containers. Although exact oxygen content could not be measured, it decreased very rapidly. It was apparent that these fruit were still producing carbon dioxide at a rapid rate even though the oxygen content was very low.

Effects of various packinghouse treatments on internal carbon dioxide content of fruit.—The tangerine, with its small central cavity, lends itself to internal atmospheric studies. One such study was instigated using the same Fisher Clinical Gas Partitioner that utilizes samples as small as 0.1 ml.

Information was desirable on the carbon dioxide concentration gradient from internal atmosphere to the atmosphere immediately surrounding the fruit such as exists in controlled atmosphere or polyethylene bags.

Internal carbon dioxide measurements were made on tangerines receiving the packinghouse treatments shown in Figure 6.

Gas samples were obtained by submerging the fruit in water and inserting the syringe needle into the center core of the fruit through the stylar end. Daily measurements were made on three fruit from each treatment and the average values were plotted. The unwashed fruit showed that the lowest internal carbon dioxide with the fruit receiving the commercial wash having a slightly higher internal carbon dioxide. The reason for this variation is not apparent. Both the waxed and the waxed plus hydrocooled fruit had a high internal carbon dioxide with the trend the same; however, the hydrocool treatment was higher during the entire period of study. This is explained by the layer of wax on the surface which apparently reduces the rate of gaseous exchange due to its impermeability. It has long been suspected that a sudden change in temperature of fruit such as hydrocooling has certain deleterious effects. The higher internal carbon dioxide of the hydrocooled fruit is another thread of evidence to support this theory.

Summary

The data show that carbon dioxide in a closed 1.5 mil polyethylene bag will diffuse out of the bag and come into equilibrium with the carbon dioxide content of the atmosphere. When citrus fruits were placed in the same type of enclosed bag, the carbon dioxide content of the air in the bag (even though carbon dioxide may diffuse through the bag) increased up to 7 to 10 per cent.

When fruits were placed in a gas tight jar, the carbon dioxide content in the jar increased to as high as 80 per cent.

The carbon dioxide content of air inside eight five-pound polyethylene bags containing fruit varied from 0.5 to 7.5 per cent within two days, depending on the tightness of the closure and the time the analysis was performed after packing.

When holes were punched in the five-pound polyethylene bags the carbon dioxide content was maintained at levels between 1 and 12 per cent, depending on the number and size of holes.

In view of these data a minimum of four to eight ¼-inch holes per five-pound polyethylene bag is necessary to prevent carbon dioxide accumulation above 1 per cent.

Observation of the carbon dioxide concentration within the fruit showed that increasing the number of packinghouse treatments increased the carbon dioxide concentrations. Waxing and waxing plus hydrocooling brought about higher carbon dioxide concentrations with the latter treatment having the highest values ranging between 7 to 10 per cent.
PICKING CITRUS FRUIT BY MECHANICAL MEANS

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Picking citrus fruit is an operation which involves separation of the fruit from a tree and placement of it into a suitable container on the ground. Hand picking is a strenuous and time consuming task which requires the major portion of the hand labor needed in producing and harvesting a citrus crop. It is becoming increasingly difficult to find suitable labor willing to do this type of work as long as they can find work elsewhere.

Previous attempts to pick citrus by mechanical means have not been very successful. These attempts included tree shaking and separation of one fruit at a time by snapping the supporting twig or by pulling the fruit with a suction force. Patents on such devices date back before the turn of the century.

Problems associated with the design of fruit picking equipment differ greatly from those associated with the design of equipment for harvesting annual row-crops. A citrus tree represents a major investment which must produce a profitable return to the grower for many years. Therefore, any picking device or method must not damage the trees in any way which would reduce their annual production or their productive life. Also, the fragility of the fruit requires that it be handled with care. However, this is more important for fruit produced for the fresh fruit market than for fruit produced for processing. Not only do these requirements have to be met, but the machine and the method which is to be used must be justified economically. That is, the machine must save enough on labor requirements over hand picking to offset the investment and operating costs. These and other design problems associated with fruit picking equipment seem insurmountable when measured by past knowledge. However, research has revealed basic information which may make their solution less difficult.

Methods of Fruit Separation.—Oranges, grapefruit and tangerines are attached to their supporting twig through a small button (calyx). It is at this button that separation occurs when the fruit is picked. The conventional hand method of separating this fruit is illustrated in Figure 1.

In Florida most oranges and grapefruit are separated by grasping the fruit in hand and rotating it and at the same time giving it a sharp jerk at an angle to its major axis. As shown in Figure 1, separation forces A and B are acting on the button. Force A is the reaction of the twig to force B which is applied by the hand. These forces are applied progressively around the button as the fruit is rotated, thus reducing the danger of plugging, that is removing part of the peel with the twig. If force B were applied as a straight pull or quick jerk parallel to the axis of the fruit, it would be transmitted equally to the entire button. This would increase the total force requirement as well as increase the danger of plugging. Tangerines, which are highly susceptible to plugging when picked in the same manner as oranges and grapefruit, are usually clipped close to the button using small hand clippers.

The motions employed in the conventional method of separation are varied and complex. They are extremely difficult to duplicate by mechanical means. These motions as nearly as possible are broken down into categories in Figure 1 and listed as spinning, tree shaker No. 1 and tree shaker No. 2 concepts. The motions in these categories are more easily duplicated by mechanical means.