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AN IN-PACKAGE DEVICE AND METHOD FOR PROTECTING TABLE GRAPES FROM DECAY AND MOISTURE LOSS

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J. P. Gentry and K. E. Nelson

Engineers working in the area of post harvest handling of fresh produce are well aware of the weight loss and resulting economic losses related to humidity in refrigerated storages, and have in many instances provided storages with improved conditions for maintaining quality. However, after leaving storage the produce is often exposed while in transit and in wholesale and retail warehouses to conditions that accelerate moisture losses. Providing conditions desirable for maintaining quality inside the package poses an attractive alternative to some of the post harvest deterioration problems of table grapes.

Decline in quality of table grapes is caused chiefly by decay and moisture loss. Rate of deterioration by the first process follows well known biochemical laws and is reduced 50% or more for each 10°C reduction in temperature. However, moisture loss is a physical factor related to the difference between the vapor pressure of the grape and the vapor pressure of the surrounding air. Vapor pressure differences are normally highest when warm grapes are first exposed to cold air and become lower as the grapes cool.

Warm fruit loses moisture to cold air at a rapid rate even if the air is saturated. However, the rate of moisture loss decreases during cooling to a constant value as the fruit temperature approaches that of the air (2, 5). To stop this loss completely is very difficult since the equilibrium relative humidity for table grapes is approximately 98%.

The rate of evaporation of moisture, after grapes are cold, may be minimized by using the lowest possible air velocity that will prevent a rise in fruit temperature. This allows evaporation from the fruit to raise the humidity of the air at the surface of the berries, thus retarding further water loss.

Grapes respire by combining oxygen from the air with food reserves inside the fruit to produce carbon dioxide, water and heat. The rate is quite low compared to that of other fruit, partly because grapes do all of their ripening on the vine. If we consider only deterioration caused by respiration, it is not as imperative to cool grapes to slow this process as rapidly after harvest as it is many other fruits that have much higher respiration rates and ripen after harvest. However, the effects of respiration cannot be ignored because of at least two undesirable effects: 1) deterioration of quality from utilization of food reserves, and 2) generation of heat.

Decay of table grapes is caused primarily by the fungus Botrytis cinera Pers. This fungus is common in all vineyards and produces spores under favorable conditions which, with moisture such as that from rain or foggy weather, will germinate and infect the fruit, either through skin injuries or by direct penetration of the skin of uninjured fruit.

The term "slip skin" is often given to Botrytis infection during its early development. The fungus loosens the skin so that any slight rubbing or pressure on the berry causes the skin to slip from the pulp. Later stages of infection are commonly called gray mold, from the grayish color formed as the fungus sporulates on the surface of the

berries. The decay process can happen to the fruit in the vineyard before harvest and can also take place in the container after packing.

This decay organism is usually in or on the fruit when packed and if no decay control treatment is applied, it is common to find many of the grapes in the container infected after a few days. Infection may approach 100% if the container is completely closed so that water vapor from the grapes raises the relative humidity to near saturation. It is therefore a dilemma that the high relative humidities which are necessary and therefore desirable to prevent moisture loss at the same time favor the spread of decay.

Because of their large surface-to-volume ratio, stems of table grapes are especially vulnerable to the drying effect of the air. Stem condition is a very important quality factor, and as a result much emphasis has been placed on those factors of cold storage design and operation which reduce moisture loss. These factors include: 1) reduced air velocity after the fruit is cold, 2) maintenance of a relative humidity of at least 90%, and 3) prompt and rapid precooling. Design requirements for cold storages to maintain a high relative humidity have very often demanded significant capital investments in large cooling surfaces and fog-spray humidification systems (3).

Sulfur dioxide fumigation is presently the standard treatment for the control of decay of table grapes. With this treatment it is necessary to fumigate the fruit immediately after packing to surface sterilize the fruit, particularly wounds made as a result of handling. This fumigant is effective, relatively cheap, and safe to use (15). It also retards browning of the stems (16) and its residue is neither visible nor toxic.

In fumigating grapes, the general practice is to accumulate packed grapes in the precooler during the day and fumigate with SO_2 during the evening. This practice does not delay cooling, and the fumigation can be done after most of the personnel have left and are thus not exposed to the irritating vapors of the gas. The gas is delivered from a liquid state in steel cylinders and mixed with the air of the room with fans. All grapes that are stored for two weeks or more are re-fumigated at 7-10 day intervals to prevent the decay from spreading (7).

Though effective, sulfur dioxide has some undesirable attributes:

1) its vapors are very irritating to the eyes and mucous membranes (16);
2) it is injurious to other produce;
3) it bleaches the fruit, especially the pigments of colored berries;
4) it has a very corrosive action on most metal surfaces; and
5) it requires that the containers be relatively open so that the gas can have access to the grapes--thus exposing the grapes to conditions which are conducive to excessive water loss.

The air velocity in many storage rooms is much less than optimum for precooling, so some plants have special precooling rooms where grapes are cooled with high-velocity air before storage. After grapes are cooled, the air velocity should be the minimum which will maintain uniform temperatures (10 to 20 fpm in the channels between the lugs). However, this air velocity should be increased to 300 fpm during fumigation to insure rapid penetration and purging of the gas (6, 7).

Experimental Methods to Control Decay with Minimal Dessication of the Fruit

Botrytis decay in stored table grapes has been controlled effectively by placing a pad treated with dibromotetrachloroethane (DBTCE) inside the container (1, 9). The DBTCE crystals sublime slowly with the result that the vapors prevent the spread of decay, thus making it possible to control decay in closed containers. In fact, DBTCE is most effective in completely closed (not sealed) containers. Grapes protected from decay by DBTCE and packed in an unvented polyethylene-paraffin-coated corrugated container lost only one-tenth as much moisture as similar grapes packed in conventional vented containers and protected by SO_2 (4).

The necessity for rapid cooling of table grapes to prevent deterioration has long been expounded, but the use of closed containers results in slower cooling. Because cooling in the closed container must be accomplished by the conduction of heat through the container, the efficacy of this method was questioned. To evaluate the effect of delayed cooling on table grapes, a study was made in which Thompson Seedless grapes were packed and held for 0, 24, 48, 72, and 96 hours at 80°F before cooling. When the fruit was cold, it was stored at 39°F and 90% RH until evaluated for moisture loss and decay. The results are shown in Table 1. From this and previous DBTCE studies, it was concluded that the deterioration of table grapes was much less when the moisture loss from the grapes was prevented by the use of an unvented container with a moisture barrier, even though it takes longer to cool

the grapes. However, it should be noted that it is still important to cool grapes, but the time of cooling in this unvented container is not as critical as once believed.

Although DBTCE provided excellent control of decay for as long as six months in closed containers, it cannot be used until it is cleared by Federal Food and Drug Administration. Assuming that such clearance would involve considerable time and expense, research was directed toward other chemicals which would be less restricted in their use.

Unvented Container Research with Sulfur Dioxide

Some important advantages other than improved fruit quality indicated by the use of unvented containers were: 1) expensive equipment required to maintain high humidity no longer necessary, 2) elimination of the convential SO_2 gassing would result in dramatic reduction in the corrosion of metal surfaces of the storage, and 3) make possible the storage of tree fruits and other produce in the same storage with grapes.

Because the potential benefits to be derived from using unvented containers appeared so attractive, efforts were directed toward the use of SO_2 released inside the unvented container--a decay control chemical whose use would not be encumbered by legal restrictions. Ideally, with such a container it would be necessary to have sufficient SO_2 evolve within 6 hours of packing to surface sterilize the grapes, thus preventing infection from spores present on the fruit (7). This treatment would have to be followed by a very low continuous concentration

of SO_2 to prevent or retard the spread of decay from infections established in the vineyard and not eliminated by the packer (8). The first or fungicidal treatment would need to be somewhat severe to produce a quick kill and build up sufficient free SO_2 (sulfurous acid) in the juice of wounds to prevent subsequent infection. However, the duration of the exposure would need to be short to minimize bleaching injury.

The second or fungistatic treatment could be much less severe because fungus growth would need only to be held in check as established infections cannot be eradicated (7). Minimal concentrations would be especially desirable because the long exposure periods during storage would aggravate the bleaching problem.

Sodium bisulfite ($NaHSO_3$) has been used to generate SO_2 in export sawdust-filled chest shipments of grapes for many years (13, 14). It is normally placed on top of the sawdust and grapes before the chest is lidded. However, it is more effective if mixed with the sawdust (11). The $NaHSO_3$ under these conditions will release SO_2 for about two weeks. In practice; however, the treatment is highly irregular an as a result, largely ineffective.

Sodium bisulfite releases SO_2 by slow oxidation. The rate of SO_2 release is greatly increased when the sodium bisulfite is placed in high-humidity air. It was determined that by controlling the accessibility of moisture vapor to the sodium bisulfite the rate of SO_2 release could be controlled (12).

In an attempt to create the ideal SO_2 application inside a container, fast release devices were constructed with sodium bisulfite ($NaHSO_3$) in tissue packets, and slow release devices were constructed by putting sodium bisulfite in sealed wax-coated soda-straws. Six of the fast release packets and three of the slow release packets were placed inside excelsior-filled envelope type pads (Figure 1).

The effect of these two-stage release devices on decay and bleaching of grapes was determined with grapes which were packed in closed polyethylene-coated liners within wood containers. Two pads were used in each container, one above and one below the fruit. Several studies were conducted with treatments consisting of: nine fast- and slow-release dose combinations, an SO_2 gassed control and a no-SO_2 treatment. For the first release packets, the dose per container was 1.8-5.4 grams, divided among 12 packets. For the slow release packets the dose was 4.8-10.8 grams, distributed in 6 tubes.

Nine berries previously infected with Botrytis cinera Pers. were spaced evenly in each packed container at mid-depth to establish an initial level of decay. These berries had been inoculated and infected according to the method of Nelson and Baker (8). Bleaching injury was determined by measuring the diameter of the bleached pedicel area on a random sample of berries selected from each container. Decay spread and bleaching injury were evaluated after appropriate storage intervals.

The results of these studies indicated that each stage had a significant effect on decay. Decay was inversely related to dose for

each stage, with the higher dose combinations providing better control than fumigation of the check lot. Bleaching responses showed the opposite relation. The first stage dose had no significant effect, but the second stage had a highly significant effect with bleaching related directly to dose (12).

These results demonstrated that grapes could be packed in an unvented water-vapor-barrier container, cooled satisfactorily, and stored for as long as two months with no decay. At the same time, this fruit lost less than one-tenth the amount of moisture lost by fruit packed in conventional vented containers. This small moisture loss was reflected in crisper berries, plumper and greener stems, and less shatter of berries.

These results were so encouraging that a patent on a device and method for testing picked grapes was applied for, and investigations to refine the device so that it could possibly be manufactured were undertaken. After screening a number of materials, polyethylene coated freezer paper was selected for the slow release moisture barrier material. Slow release devices with doses ranging from 1.9 to 7.7 gram were constructed from the polyethylene coated paper.

The dose of $NaHSO_3$ was divided into twelve parts which were spread over a 12" x 16" sheet of the poly-coated paper, and another sheet of the poly-coated paper was placed over the $NaHSO_3$ and heat sealed in a grid pattern to the bottom sheet. The slow-release dose of $NaHSO_3$ was thus contained in twelve packets of the poly-coated paper.

The first-stage release sheet was constructed with doses ranging from 0.5 to 2.5 grams. The dose was divided into twelve parts and spread over one side of the slow-release device described above. A sheet of 36-lb. Kraft paper was then glued in a grid pattern to the slow-release device so that the fast-release $NaHSO_3$ was contained in twelve packets, one side of which was Kraft paper, which is readily permeable by water vapor. The first-stage release and the second-stage release device were thus constructed in one unit.

Results with this SO_2 release device were very similar to those obtained with the earlier device. Sulfur dioxide was measurable in the containers with the higher dose levels after two months. From the sixteen different dose combinations studied, a first-stage dose of 1.5 grams with a second-stage dose of 5.7 grams was considered an acceptable compromise, both from a decay and bleaching injury standpoint, and further work was confined to this dose combination.

Manufactured Release Devices and Commercial Shipments

A multiple packaging machine (Figure 2) was adapted to produce the SO_2 release devices shown in Figure 3. The machine produces the first-stage release by heat sealing tea bag paper to 36-pound Kraft paper, with the dose of $NaHSO_3$ distributed in sixteen packets. The second-stage release is produced on the same machine by heat sealing two sheets of polyethylene-coated paper together with the dose of $NaHSO_3$ also distributed in sixteen packets. In application, the fast-release devices are placed next to the fruit with the slow release devices behind them. Normally one of each are placed above and below the fruit in each container.

During the 1967 season, approximately 20 test shipments which included all the major varieties of table grapes produced in California were made with grapes packed with these SO_2 release devices. Reports from these tests have without exception been quite enthusiastic as to the condition of the fruit as compared to that in the standard lug. The berries have shown a much brighter and fresher condition and the stems have been fresher, plumper and greener than those of fruit packed in the standard vented containers.

Acknowledgements

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Table 1. Effect of delayed cooling on dryness of stems of Thompson Seedless grapes packed in various containers when held at 80°F before cooling.

Container Type	Dry stems (% of length) Holding period at 80°F (Hours) 0	24	48	72	96
Standard lug and liner	26	33	53	95	98
Vented Polyethylene-Paraffin Coated Corrugated Container	14	26	34	51	77
Unvented Polyethylene-Paraffin Coated Corrugated Container	0	3	4	7	9

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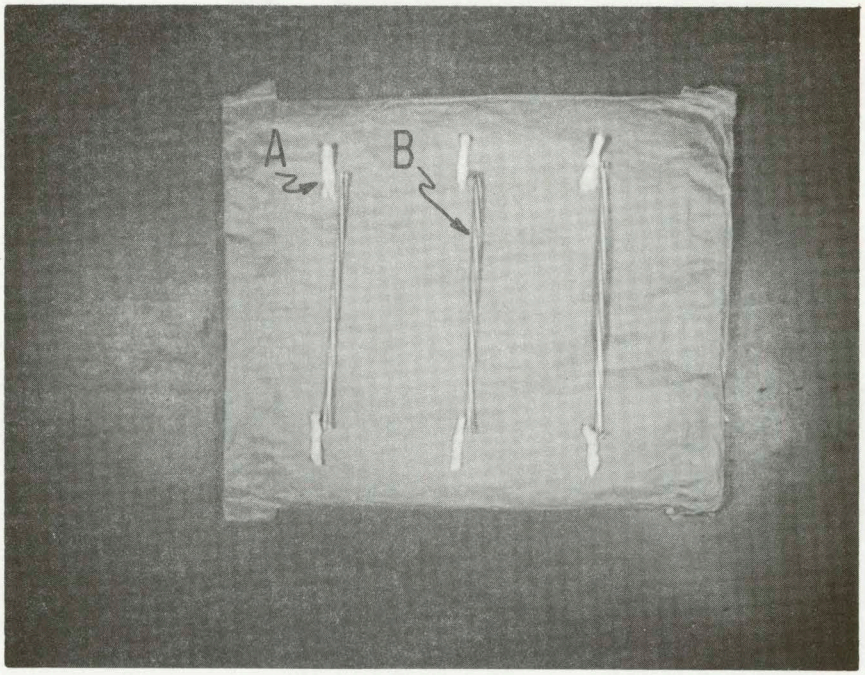

FIGURE 1. Experimental SO_2 release devices were placed inside cushion pad approximately in position shown.
A) tissue paper first-stage SO_2 release devices,
B) waxed straw second-stage SO_2 release devices.

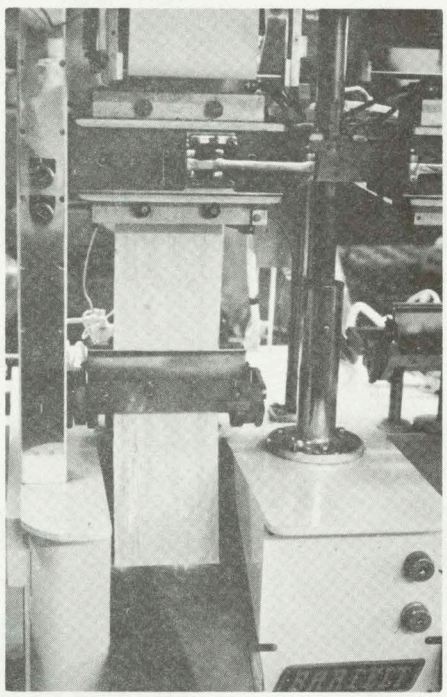

FIGURE 2. Multiple packaging machine used to manufacture SO_2 release devices.

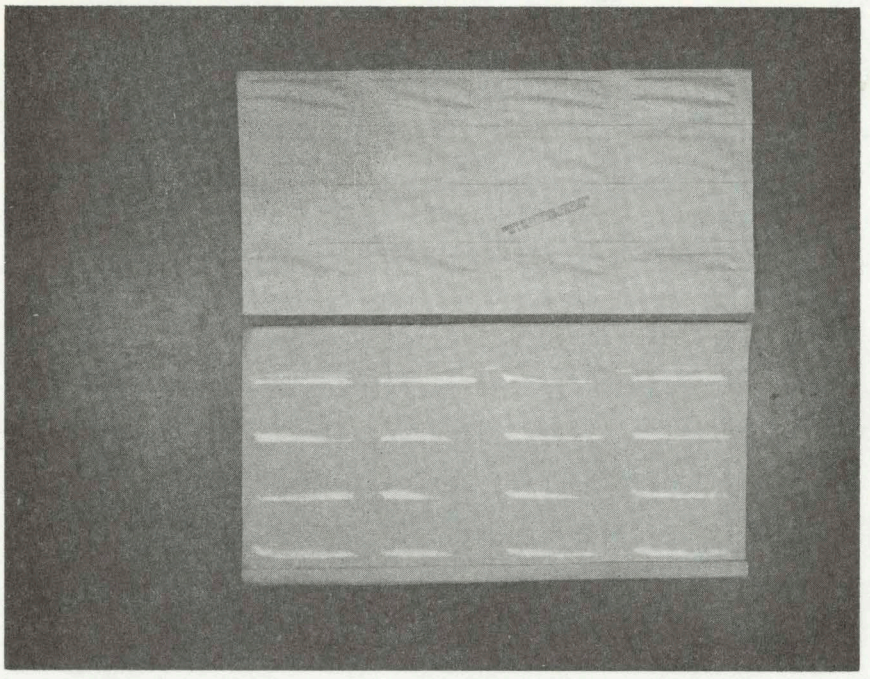

FIGURE 3. Manufactured SO_2 release devices. In first stage at bottom $NaHSO_3$ visible through tea bag paper. Second stage at top shows heat sealing grid pattern.