materials in the RH mid-range as discussed by Henderson and Perry (4).

Two tests were conducted at 10°C and 21°C with and without HCM panels. Humidity data were tabulated on an hourly basis and is summarized in Table 1. In general, the effect of the HCM panels was to reduce both maximum and minimum RH. An analysis of variance was performed on the data of humidity variation. Both panel installations and temp were significant. The large temp factor was a result of the direct-expansion refrigeration coil at 21°C.

Table 1. Average maximum and minimum RH conditions.

		With panels			Without panels		
		Max	Min	Diff	Max	Min	Diff
10°C	(Rep. 1)	91.0	87.2	3.8	92.2	88.7	3.5
	(Rep. 2)	91.1	87.4	3.7	92.4	88.0	4.4
	(Avg)	91.0	87.3	3.8	92.3	88.4	4.0
21°C	(Rep. 1)	83.4	70.9	12.5	83.7	72.2	11.5
	(Rep. 2)	79.5	72.4	7.1	83.6	71.9	11.7
	(Avg)	81.4	71.6	9.8	83.6	72.0	11.6

HCM panels reduced average refrigeration operating time from 0.235 hr/hr to 0.175 hr/hr for tests at 21°C, a reduction of ca. 25%. The effect of HCM installation at 10°C conditions was not measured since the refrigeration unit serviced 2 storage rooms. However, in all cases, the HCM reduced maximum humidity levels. This phenomenon was expected from data obtained on equilibrium moisture contents. Other mineral aggregate combinations may have more potential for the high humidity conditions which are required for citrus.

In Table 2, supplemental humidity requirements have been summarized. Humidity requirements at 10°C were significantly reduced by the panels but were not altered at 21°C. With greater moisture requirements at 21°C due to a higher vapor pressure difference and the type of refrigeration unit utilized, the panels were less effective.

In handling the HCM, a small amount of material filtered through the cloth bag container. To observe whether or not the material would cause any peel damage, 50 g of HCM was sprinkled on fruit from 2 cartons of 'Marsh' grapefruit. These samples, as well as control samples, were held at 15°C for 3 weeks and checked weekly for decay and abnormal skin disorders. Decay was minimal, less than 2%, and no skin blemishes were noted.

Table 2. Supplemental humidifying requirements for HCM tests.

Temperature	Panels	Humidifying time, hr/hr
10°C	Yes	0.09
10°C	No	0.14
21°C	Yes	0.04
21°C	No	0.04

No attempt was made to evaluate expected life of HCM, its odor adsorbing characteristics, nor its potential as an area for bacterial growth. These factors would be important in commercial applications and should be evaluated in further study.

Summary

Moisture adsorption characteristics for HCM were developed for 2 storage temp at intermediate to high RH levels. At 92.5% RH and 4 to 21°C, the material adsorbed 6.5 to 7.0% moisture dry basis. The HCM panels effectively reduced refrigeration operating time for fruit stored at 21°C with supplemental humidity requirements remaining constant. In all storage tests, the HCM reduced maximum humidity levels which may be objectionable if fruit desiccation is a primary concern. No detrimental effects were noted when HCM directly contacted 'Marsh' grapefruit.

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PACKINGHOUSE STRATEGIES FOR THE CONTROL OF FUNGICIDE RESISTANT MOLDS

DAVID J. HALL
American Machinery Corporation,
P. O. Box 3228,
Orlando, Florida 32802

JOHN R. BICE
Brogdex Company,
Box 2769,
Pomona, California 91766

Additional index words. packinghouse design, packinghouse sanitation.

Abstract. **The resistance of citrus decay organisms to fungicides has become a considerable problem in handling fruit for the fresh market. Packinghouse design, as well as operation, has a profound effect on the extent to which resistant mold becomes a problem in an individual packinghouse. The methods used in three southern Arizona packinghouses to overcome the problems of design restrictions illustrate how resistant mold can be reduced to a manageable level by a combination of chemical treatments and minor modifications of existing equipment. These examples also indicate pitfalls to avoid in the layout of future packinghouses.**

The introduction of each of the fungicides presently approved for use on citrus has eventually been followed by the discovery of strains of decay organisms that are resistant to it. To date, strains of molds resistant to biphenyl, o-phenylphenol (OPP), sodium orthophenylphenate (SOPP), thiabendazole (TBZ), benomyl, and 2-aminobutane (2-AB also *sec.* butylamine) have been isolated in commercial citrus packinghouses (2, 4, 5, 9).

Handling conditions and packinghouse sanitation greatly contribute to the build-up of resistant strains (3, 9), and increasing demands for fresh citrus has resulted in most packinghouses operating well above their design capacity thus making handling and sanitation conditions generally worse. This is further complicated when a packinghouse must handle a variety of fruit that was not originally planned, as with lemons in Florida (11). In addition to such aspects, most U.S. citrus packinghouses were designed before fungicide resistance was considered a factor in citrus handling. Therefore, packinghouse layout was based principally on considerations of machine and labor efficiency.

A study of a lemon packinghouse in Florida by Murdock (7) shows that spores of many of the fungi common to semitropical citrus (10) are carried in the air of the packinghouse. He also demonstrated that using a non-fungicidal solvent wax as a shipping wax apparently entrapped some of these airborne spores thus increasing decay. Since little can be done in most packinghouses to change the basic layout of the house and equipment, other measures must be taken. Some that have been tried include repeated fumigation of fruit handling areas with formaldehyde (4, 10), which has the drawback that all fruit and personnel must be removed from the area to be fumigated.

Another strategy is the introduction of a new fungicide which operates in a manner completely different from the one to which resistance has built up (1, 6). This has limited value in that there are only a small number of fungicides to choose from and, if not done carefully, the possibility exists that a mold population will build up with resistance to more than one fungicide. Entirely new fungicides may be introduced, as they receive governmental approval, but again resistance to these is possible once put into commercial use. (5)

Materials and Methods

Early in the 1971-72 processing season, 3 Yuma, Arizona packinghouses reported an inordinate amount of decay, due to green mold, *Penicillium digitatum* Sacc., and blue mold, *P. italicum* Wehmer, in lemons coming from the degreening rooms. An assay of the airborne mold spore load in the packinghouse was run by an adaptation of the method of Harding (5) which showed a high total count with a high percentage of TBZ resistant mold in these houses.

Analysis of the fruit going into degreening by the use of injury staining with 2,3,5-Triphenyl - 2H - tetrazolium chloride (8) eliminated excessive injury to the fruit as a factor. Since preharvest applications of benomyl were not being used in the groves, this was also eliminated as a possible source of resistant mold.

Therefore it was felt that efforts should be made to reduce the number of spores coming into contact with fruit going into the degreening rooms. By thus reducing the source of contamination, it was felt that the number of rotting fruit could be reduced (7, 10).

A more detailed analysis of the layout and operation of each packinghouse revealed that several factors were contributing to the high counts and to recycling of mold spores that would account for the build-up of resistant mold. The layout of each of the packinghouses studied are shown in Figs. 1, 2 and 3 respectively. No attempt has been made to exactly represent the packinghouse, but only to show the relative position of equipment, processes and degreening rooms with respect to others.

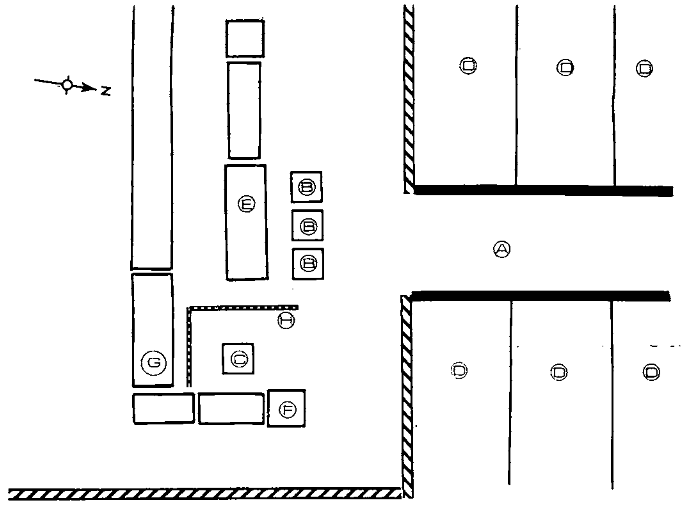

Fig. 1. Layout in Packinghouse No. 1.

In packinghouse No. 1 (Fig. 1), the aisle (A) gave access to the degreening rooms (D) on each side. This allowed a single forklift to take filled bins (B) from the pregrade line (E) into a degreening room and bring degreened fruit from another room to the pack dump (F) on the return trip. Emptied bins were then taken outside and transported to the groves for more fruit.

At the pack dump, fruit was delivered onto a roller-spreader where graders could remove rots. These were conveyed into a hopper (C) which was usually emptied at the end of the day or when filled. The sound fruit continues through the pack line (G) where it is foam washed then waxed with a water emulsion wax.

It was found that there was strong air movement along the aisle between the degreening rooms, toward the bin fillers at the pregrade line. Agar plates (100 mm dia.) exposed at this location gave a count of 644 spores per minute during normal packinghouse operation.

The pack dump (F) has an exhaust hood over it to remove most of the spores knocked loose from decaying fruit when the bins are dumped. Graders stationed at the dump pick off rots, dropping them onto a short conveyor which carries them to a large hopper next to the dump. Decayed fruit falling into this hopper were causing spores to be knocked loose and these would contribute to the overall spore load at the packinghouse.

It was also noted that occasionally bins would be taken directly from the pack dump to the bin fillers when the forklift operator was pressed for time.

In order to reduce the number of spores coming into contact with the fruit, the following steps were initiated:

1. In order to contain the drift of spores from the pack dump, a partition (H) was erected to partially enclose this area.
2. A spray of chlorinated water was installed at the pack dump. The spray was set to deliver sufficient water to wet the fruit thoroughly. Chlorine content was maintained at 75 ppm. A wetting agent-buffer was included to maintain the pH between 7.4 and 7.6, to increase the effectiveness of the treatment and reduce odor and corrosion. This also reduced the spores coming from the rot bin as the wet fruit did not easily release spores to the air.
3. The airflow in the aisle (A) was reversed by reversing one existing fan and installing an exhaust through the roof.
4. As each degreening room was emptied, the walls, air passages, floors and ceilings were sanitized with a spray of 1000 ppm quaternary ammonium sanitizer (Cleansan 537) before loading again.

5. Instead of loading bins which come from the pack dump for immediate use in the field, these bins were set aside and the house's inventory was drawn on. This allowed these bins to sit approximately one week before reuse.

6. The fungicide used at the pregrade line was changed from TBZ at 1250 ppm to 1.75% 2-AB. Assays for TBZ and 2-AB resistant mold were run periodically until TBZ resistance was eliminated and 2-AB resistance began to appear then the fungicide was again changed back to TBZ.

7. The fungicide OPP was applied at the pack line, first in the wax only then, as the season progressed and the fruit became "weaker", in foam at the washer.

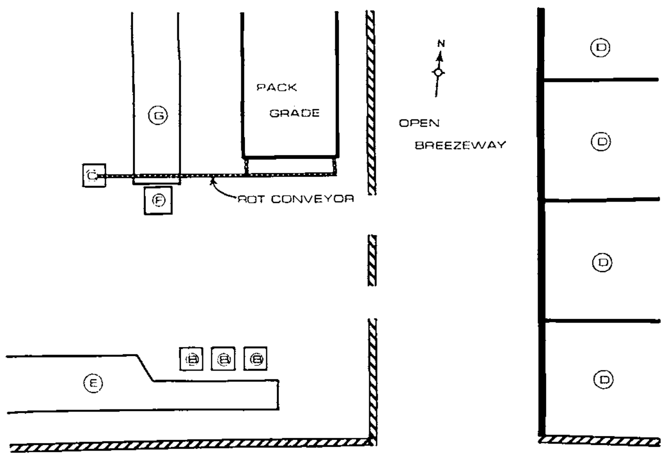

Fig. 2. Layout in packinghouse No. 2.

Packinghouse No. 2 (Fig. 2) followed the same basic procedure as No. 1 with these exceptions. The degreening rooms were separated from the rest of the packinghouse by an open breezeway approximately 12 meters (40 ft) wide and a prevailing breeze from the Northwest reduces the chances of spores drifting between the degreening rooms and the packinghouse.

The pack dump (F) is equipped with an exhaust hood and graders pick off rots from a roller spreader. The rots are placed on a belt conveyor which carries rots picked off at the grading table to an open hopper (C). From here, the fruit continue through the pack line (G) where it is foam washed and waxed with solvent wax.

It was found that the prevailing breeze was causing a drift of spores from the pack dump and rot hopper directly to the bin fillers (B) on the pregrade line. Spore counts at these fillers were typically 150 spores per minute per 100 mm plate, which was higher than counts taken at the dump. (Typically 40-60 spores per minute).

The procedures recommended here included:

1. Cover the rot conveyor except where necessary and enclose the rot hopper. Thoroughly clean the rot hopper after dumping so as to reduce the spores brought into the house.

2. Doors on the north side of the building which were often left open were to be kept closed as much as possible thus reducing air flow across the plant.

3. Degreening rooms were fumigated with formaldehyde after every third loading. This was much more practical than spraying with a quaternary as these rooms were extremely large. Also their separation from the packinghouse made it possible.

4. Increase the blower speed at the pack dump hood to draw more air thus reducing the amount of spores escaping.

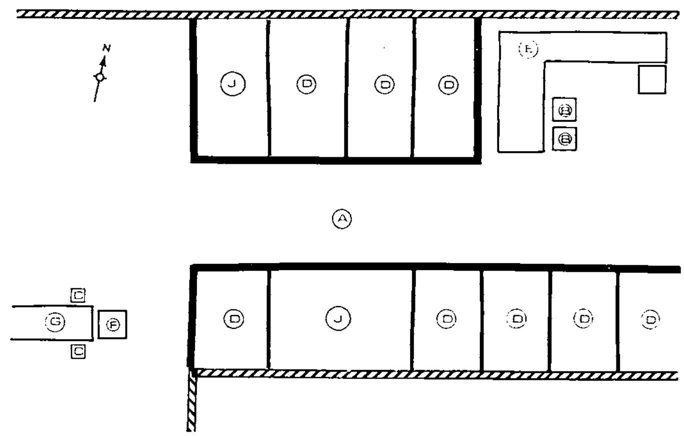

Fig. 3. Layout in packinghouse No. 3.

5. Change between TBZ and 2-AB on the same basis as at packinghouse No. 1.

6. Apply OPP to the fruit at the washer.

Packinghouse No. 3 (Fig. 3) had the least amount of decay in fruit from the degreening rooms but was experiencing more decay in shipment than Houses 1 and 2.

The fruit handling procedure here is basically the same as in the previously discussed packinghouses. Our survey found that when large doors in the north wall of the pack floor were open, air movement down aisle (A) was toward the pregrade line (E) and bin fillers (B). The packinghouse has a limited supply of bins so that as soon as they were emptied at the pack dump (F), it was necessary to return them to the groves for the picking crews.

At the pack dump, the fruit was dumped onto a belt for inspection by graders who picked off rotten fruit and dropped it into open garbage cans (C). The fruit then proceeds thru the pack line (G) where it is washed and waxed with a water emulsion wax. With no exhaust hood over the dump and the graders dropping rotted fruit approximately 2 meters (6 ft.) into open containers, this area was considered the point needing immediate attention. Spore counts taken here exceeded 400 spores per minute.

In order to reduce spore counts, prevent recycling of molds which could increase resistance and reduce decay in shipping, the following steps were initiated.

1. Doors on the north side of the building were kept closed as much as possible during packing operations.

2. Degreening rooms were periodically sprayed with a quaternary ammonium compound (Cleansan 537, 1000 ppm a.i.). Because of the proximity of offices (J) to the degreening rooms, formaldehyde fumigation was impractical.

3. As each bin is dumped it is sprayed inside and out with a 200 ppm quaternary solution.

4. Install a hood with exhaust over the dump. Raise rotten fruit receptacles to the level of graders and partially cover these to reduce the escape of spores.

5. At each break, lunch and end of shift, the dump belt was washed down with quaternary sanitizer, also any time a bin with many rots was dumped.

6. Fungicides at the pregrade were changed on the same basis as at houses 1 and 2.

7. The pack line wash was changed to a foam with 2% SOPP Tetrahydrate. The shipping wax was changed to a combination of two compatible fungicides; SOPP Tetrahydrate, (1%) and TBZ (3500 ppm).

Results and Discussion

While following the procedures outlined, each packinghouse experienced less decay in degreening and shipment for the balance of the 71-72 season. During the following season, neither packinghouse 1 nor 3 experienced a reoccurance of the previous seasons' decay problems.

Packinghouse 2 did have a reoccurance of its previous high rate of decay in degreened fruit. Investigation found that the exhaust hood on the pack dump was not functioning and that fumigation of the degreening rooms had not been done during the current season. These were corrected and decay problems were reduced.

From the experience in these three packinghouses, it is apparent that the original packinghouse layout did not take into account what was going to happen to mold spores from fruit that began to decay in degreening. With the introduction of selective fungicides (6), the problem of decay due to resistance becomes even more important in overall fruit handling.

The lessons that can be learned from these packinghouses could be of tremendous advantage in designing future packinghouses. We can summarize these as follows:

1. Separate operations such as dumping fruit and rot grading from fruit that is prepared for degreening.
2. Orient operations where handling decayed fruit will be down wind (either natural or artificial) from other operations. Check the direction of prevailing winds *during* the pack season.
3. Contain spores at dumps with exhaust hoods, sanitizing sprays and total enclosure, if possible.
4. Separate degreening rooms as much as possible from other operations, and provide for simplicity in fumigation and cleaning.
5. Have the final layout of the packinghouse reviewed by a qualified plant pathologist for any potential sources of resistant mold recycling. (9)
6. Assay airborne spores in the packinghouse regularly for resistant molds.

An examination of the layout and operation of the 3 houses studied shows that at least 1 of the above principles has been by-passed in each. Existing packinghouses should review their layout compared to these principles, especially if experiencing high amounts of decay despite the use of fungicides. If in some area a possibility exists for recycling mold spores, then an assay of airborne mold should be run.

Based on the results of this assay, packinghouse management should seek to eliminate or minimize these sources of contamination by:

1. Isolating operations handling decayed fruit.
2. Regularly sanitizing surfaces susceptible to contamination.
3. Assaying regularly for resistant mold and selecting appropriate fungicides.
4. Using a fungicide at the pack line with a mode of action different to the one used during degreening.

By adopting such procedures, losses from decay can be reduced to a minimum.

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DECAY CONTROL OF FLORIDA CITRUS FRUITS WITH IMAZALIL[1]

A. A. McCornack and G. Eldon Brown
*Florida Department of Citrus,
Agricultural Research and Education Center,
P. O. Box 1088, Lake Alfred, FL 33850*

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Abstract. **Postharvest decay control of Florida citrus fruit treated with imazalil is comparable to benomyl (Benlate) and thiabendazole (TBZ). Imazalil, 1-[2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl] -1H-imidazole, is an experimental fungicide which also controls molds resistant to the benzimidazole fungicides, Benlate and TBZ. Imazalil exhibits** in vitro **activity against all of the common postharvest citrus fungus diseases found in Florida except sour rot,** Geotrichum candidum. **When green mold,** Penicillium digitatum, **develops in citrus fruits treated with imazalil, spourlation is retarded. Consequently, few spores develop to "soil" other fruit in cartons. Imazalil controlled decay of 'Valencia' oranges stored for 11 weeks at 40°F (4.5°C) as effectively as did Benlate. In a simulated marketing period of 1 week at 70°F (21°C) following this cold storage period, decay control from the imazalil and Benlate treatments continued.**

Decay control of Florida citrus fruits continues to be a problem because of the naturally high decay potential, which is frequently compounded by rough and/or delayed handling. Degreening with ethylene, a common commercial practice early in the packing season of many cultivars, adds to the decay problem (8, 9). With the approval of Benlate and TBZ as postharvest citrus fungicides, these problems were partially solved. It has since been found, however, that both green *(P. digitatum) and* blue *(P. italicum)* molds develop strains resistant to these benzimi-

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