Proc. Fla. State Hort. Soc. 117:348-350. 2004.

EARLY DEGREENING RESEARCH: ESTABLISHING BASIC PRINCIPLES

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Additional index words. citrus degreening, packinghouse

Abstract. **On my arrival at the Citrus Experiment Station, Lake Alfred in July 1952, I was assigned a specific project, to find something better than ethylene, which "everybody knew" caused ugly fruit blemishes and horrendous decay. While apparently chasing this fantasy, I studied ethylene degreening. Ethylene was being used in incredible amounts, some packinghouses were weighing in several pounds of ethylene to start a room. Constant fear of losing ethylene led to sealed rooms with periodic ventilation schedules. A valuable clue to the amount of ethylene needed was that using kerosene fumes blown in from a "smokehouse" worked rather well. This was due, not to a magic component in the kerosene fumes, but to the large quantities of air blown into the rooms. Even without any analytical equipment it became apparent that very little ethylene was actually needed.**

Some basic principles became apparent. Adequate space MUST be left for air circulation. It is impossible to blow air through a stack of boxes. Airflow through stacks of fruit depends on establishing a slight pressure differential that will draw the air through. High humidity, just short of precipitation, was helpful, but hard to achieve. "Ethylene burn" was due to contaminants, usually fertilizer dust, on the fruit and boxes. Much peel injury blamed on degreening was due to the popular use of heated polisher brushes.

That much established, some solid facts with regard to the fruit itself became apparent. 85 °F was a sharp optimum for degreening oranges, but far less precise for grapefruit. Color change of Hamlin oranges ceased abruptly on leaving the degreening atmosphere, but Valencia oranges and Duncan grapefruit continued to degreen for up to 48 hours. Regreened areas on Valencia oranges were not "degreenable". Degreening could be impaired by ANY prior treatment, even manual handling. Payment of market claims for decay was costly. However, inappropriate accounting methods almost totally obscured other considerable financial losses due to poor degreening, thus providing little incentive for packers to spend money on needed improvement of degreening facilities.

When we arrived from Canada in July 1952, my wife wailed "You have brought me to a Third World country!" She was referring to shops, schools and such (there were still "strawberry schools" with vacation times set so the children would be available as pickers!). It wasn't much different in the fresh citrus industry. All harvesting was in mankiller field boxes weighing 105-110 lbs. gross. Over 100 packinghouses packed fresh fruit and all complained bitterly of the same problem: They could only ship in the Fall if they degreened, but immediately after the first degreened arrivals, the market collapsed, with numerous costly decay claims. Everyone KNEW that this was because ethylene caused ugly black "burns" on the fruit and horrendous increases in stem-end rot, stem-end rind breakdown and sundry other blemishes.

I was, therefore, assigned to take over an existing project "To find something better than ethylene for degreening". I dutifully continued with this project, testing a wide range of candidate chemicals (there was then no thought of Food and Drug approval!). Having a sound background in plant physiology, I had little hope for success and so unofficially studied and compared degreening practices among fresh fruit packers (with much criticism from my boss, Dr. A. F. Camp, for running up so much mileage at 8¢ per mile!). Obviously, some packers had less problems than others. Having no instrumentation other than thermometers, experimental work concentrated on temperature.

Temperature. The Citrus Code (Anonymous) set an upper limit of 85 °F (29.5 °C) for degreening, despite which I often found degreening rooms being run at 95 °F or higher, thinking to "hurry up degreening". We found 85 °F to be a sharply defined optimum for degreening oranges, but a very sloppy optimum for grapefruit (Grierson and Newhall, 1953a). Optimum degreening temperature is quite "district specific" and may vary between growing districts such as California where preferred degreening temperature is nearer 75 °F.

"Ethylene burn". Until the advent of modern fertilizer spreaders, grove fertilizing was done in a cloud of fertilizer dust that could be seen from miles away. Everything, fruit included, became coated with fertilizer dust. Any subsequent moisture on the surface of the fruit caused plasmolysis resulting in so-called "ethylene burns". It was easy to demonstrate that this ONLY occurred with dirty fruit and/or dirty boxes (another type of "ethylene burn" was traced to use of boxes treated with a popular wood preservative). Ethylene was innocent on all counts!

Handling effects, before and after degreening. ANY prior handling, especially washing, slowed up degreening, particularly of fruit without any color break. Waxing stopped degreening entirely.

Degreening was found to sensitize tender fruit to subsequent handling damage, particularly when the then popular heated "polisher driers" were used (Fig. 25 in Grierson and Newhall, 1960).

Amount of ethylene. Horrendous amounts of ethylene were commonly used, some packinghouses were weighing in several pounds of ethylene when starting a room! Many packers used "FMC Trickle Units" (Fig. 17 in Grierson and Newhall, 1960), where one bubble per 10 boxes was being a common practice. Rooms were commonly closed as tightly as possible with highly variable ventilation schedules. A valuable clue that not much ethylene was needed was the surprisingly effective degreening with "smokehouse degreening" (Fig. 18 in Grierson and Newhall, 1960). This involved a small masonry building some distance from the packinghouse. In it were rows of kerosene burners with a fan and duct directing the fumes into the degreening room(s). Obviously, not much ethylene could be involved and it came with a lot of air and CO_2, a known ethylene inhibitor. Nevertheless, these rooms worked rather well. When, much later, we got little Kitagawa analyzers, it became apparent that even one ppm of ethylene was adequate. One ppm is very hard to regulate, so we made our recommendation 1-5 ppm, but no more.

Continuous ventilation. Such "smokehouse degreening" involved blowing a lot of air and a very little ethylene into the rooms. This observation, together with the advice of Orrin Thomas, the old packinghouse foreman at Lake Alfred, that "Degreening is easy, just give it lots of fresh air" led to a standard recommendation of continuous ventilation equal to one complete air change per hour. Despite the lack of any precise study, this recommendation still stands for no better reason than it always works very well.

Air circulation within the degreening room. Packers would commonly cram as much fruit into a degreening room as possible, even occasionally "manhandling" a fifth layer on top of the usual four-high stacks. Checking degreening performance in many packinghouses made it apparent that such overloading did little to slow up degreening in "slatted floor rooms" (Fig. 6 in Grierson and Newhall, 1960). These had a central stack drawing air from under a slatted floor and discharging it towards the ceiling. The tighter these rooms were stacked, the greater the pressure differential between the plenum area above the fruit and the vacuum area under the floor. This illustrates a very basic principle: it is impossible to blow air through even one stack of full boxes. It is easy to demonstrate with a smoke gun that air just bounces back. Fans should be used to create a pressure differential on either side of a stack of fruit. Air will then move through the boxes and around the fruit inside them (Grierson, 1966).

With solid floor rooms such overloading could be disastrous. When we acquired a velometer, it was easy to show that there was then virtually no air circulation only three or four feet from the stack. The solution was to install a "false ceiling" (Fig. 10 in Grierson and Newhall, 1960) thereby distributing the air to the sides of the room. However, if the boxes were stacked tight against the walls, as they often were, the air just returned over the top of the fruit and down the outside of the stack. A rail to prevent fruit from being stacked closer than six inches from the wall prevented this. But the reduced capacity was resented by some packers.

Let us pause here for another firm principle of fan performance: A fan (particularly an axial flow fan) pulling air through a coil delivers ca. 25% more air than when pushing air through that same coil. Nevertheless, a very high proportion of "package units" come with the fan pushing air through the coil with a consequent ca. 25% loss in efficiency. (A keen young engineer once sent me a page of calculus "proving" that I was wrong on this. Having forgotten any calculus I ever knew, I sent him experimental data from many years of studying fan performance in cold rooms, degreening rooms and reefer trucks in which fans pushing air through coils invariably lost ca. 25% efficiency.)

Humidity control. In the 1950s almost all degreening rooms had some form of added humidity. This typically consisted of a garden-type spray nozzle over the center stack fan with delivery controlled by a faucet. Humidity was supposedly "read" from a pair of wet and dry thermometers. "Supposedly" because the correlation of wet/dry temperatures with a hydronomic chart presumes an air flow of 400 feet per minute or more. This is achievable with a sling psychrometer, but these degreening room wet/dry thermometers were never exposed to any considerable air flow (Grierson, 1965).

A striking example of the importance of humidity control occurred when degreening Temples without added humidity. An ugly peel injury correlated with both amount and time of exposure to ethylene (Grierson and Newhall, 1953b). Repeated with ca. 85% RH there was no peel injury at all. A notable early advance in humidity control was an amendment to the Citrus Code (Anonymous) that allowed the use of steam for humidity control, even if that raised the temperature above the legal limit of 85 °F (McCornack, 1966).

When basic instrumentation became available for accurate measurement and control of humidity, there was much resistance to the necessary expenditure. One packer said that we should have a banker on our next program to explain how to pay for such fancy ideas! So we ran comparable rooms at 85% and 95% RH and compared shrinkage. 95% RH resulted in 2% more fruit to sell, which could pay for such instrumentation in a single season (Deason and Grierson, 1972).

As available instrumentation improved, it became possible to run degreening rooms at 97-98% RH without precipitation. The benefits were appreciable, particular1y reduced darkening of blemishes such as oleocellosis. Decay was sometimes reduced, which FDOC's Eldon Brown showed was due to healing of minor flavedo-deep wounds.

Pallet box degreening. Credit for the advent of pallet box harvesting must be given to the late Sidney Chase. It became a personal campaign with me to do away with barbaric harvesting in manually handled field boxes weighing well over 100 lbs (ca. 45 kg). But my campaign was to no effect until Sidney Chase said: "Doc, will you show us?" So I drove with him and two of his staff to Pennsylvania to see Golden Delicious apples (a very frail variety) harvested in pallet boxes.

With a major packer volunteering his facilities, a University/U.S.D.A. project was set up to adapt pallet box handling to Florida citrus (Grierson et al., 1962). This project stalled because no forklift equipment was found that could handle pallet boxes consistently in soft Florida sands. The solution was to modify Johnny Petersen's Lightning Loader, which until then had been a fairly crude system suitable only for cannery fruit. Thus, the pallet boxes had to be suitable for lifting by the top in the grove and by the bottom in the packinghouses. Until it was realized that this called for an absolutely rigid base, much damage due to flexing of the pallet box bottoms was blamed on careless pickers, excessive fruit depth and/or poor degreening. Yet, no correlation was ever found with depth of fruit, despite which some packers still go to the considerable unnecessary expense of using shallow pallet boxes for tangerines.

Attempts to degreen pallet boxes in old style degreening rooms proved disastrous. Special degreening rooms had to be designed. The first of these kept to the center stack concept but with downward airflow from fans over a false ceiling. These worked fairly well, but with some uneven degreening traced to the pallet boxes adjacent to the stack getting about ten times as much airflow as at the corners of the room. Obviously, a whole new concept was needed for pallet box degreening.

But postharvest research is always an orphan stepchild in budget allocation. We could experiment with our tiny degreening rooms at CREC, Lake Alfred, but for any commercial scale trials we had to depend on some public minded packer letting us redesign one of his full sized degreening rooms until we found a solution. That was John Updike of Alcoma Packing who not only lent us a degreening room, but also the services of his very skilled mechanic, Felix, and much of the materials used.

The "Alcoma degreening room project" resulted in a horizontal airflow design, which the late Buford Gum of Lake Wales CGA agreed to use for their planned new degreening rooms. At that period, equipment for all degreening rooms

was supplied and installed by just three machinery companies, all of which refused to bid on anything so unorthodox.

This led to a very difficult meeting with the CGA's Board of Directors, but they eventually agreed to again call for bids, but from various air conditioning companies who had never before been involved in degreening. This worked out very well, as did the new degreening rooms, about which Lake Wales CGA members were soon boasting.

But a flaw was that with air delivery above the false ceiling from the back to the front, the canvas curtain billowed out and was difficult to secure. Also the new airflow pattern proved so efficient that it was apparent that only half as much radiator capacity was needed. So in our next design, air delivery was through the rows of pallet boxes, with return air flow over the false ceiling.

But this had to wait on the next packer again willing to wager many thousands of dollars on our next design. This was the late R. V. ("Red") Phillips of Haines City CGA. Reducing heating capacity by 50% seemed so drastic that his Superintendent, Cecil Chapman, installed two separate sets of radiators in each unit. The second radiators were never used, a major energy cost saving.

Studying the operation of the Haines City degreening rooms showed that, with air delivery now from the back of the room to the front, the rooms ran amazingly well with the curtain raised for long periods. This made "batch degreening" obsolete. Green fruit could be moved in and colored fruit moved out without disrupting the degreening process.

This led to the next logical step, a single large degreening room with fruit moving in and out as in a cold storage (Grierson, 1969). Again, this had to wait for some brave packer to gamble thousands of dollars on this radical new approach. This came with Carl Fetzer and Roy Schick of Blue Goose Growers, Vero Beach, who were delighted with the result.

Dual degreening/cold rooms. Unlike their California counterparts, Florida packinghouses seldom had much, if any, refrigeration capacity. By then, it was apparent that these pallet box degreening rooms could be suitable for fast cooling if vapor barriers and insulation were incorporated. Two Florida packinghouses did this, Golden Gem and Lake Placid Groves. This worked well.

Concerning lift trucks. A basic principle is that if a lift truck can smash something, it probably will do so. In the early days of lift trucks in packinghouses, degreening room controls proved particularly vulnerable. With these modem degreening rooms, all controls can be overhead, reached by a catwalk.

Conclusion. Our Florida degreening room designs are now being used worldwide, certainly in the Caribbean, South Africa and Australia. What a pity we could not charge royalties!

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