DEGREENING AND CITRUS FRUIT QUALITY

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Introduction

The need for degreening citrus fruit is greatly influenced by climate. Citrus fruits grown in semitropical climates are very different from those grown in arid desert climates. Brazil, China, Florida, and Mexico are considered to have predominately humid subtropical climates. Some of the characteristics of fruit grown in humid subtropic and in arid desert climates are shown in Figure 1 (13). It is important to understand the differences in citrus grown in different climates before attempting to produce and market the fruit or juice. Citrus fruits grown in the subtropics have distinct characteristics: blemished and scarred peel, fruit with a tendency for pale or even green color (thus the need for degreening), thin peel, high sugar, and high juice content. Understanding the differences between citrus fruit from different climates makes it easy to understand why California grows a crop mainly for the fresh fruit market and why Florida markets about 15% fresh and 85% processed citrus.

Degreening is a very complex subject (10). Although we know a great deal, the recommended conditions may change in the future as more detailed research is completed. Degreening can affect fruit quality in several ways: color, wound healing, dehydration, and decay. These effects will vary with variety, fruit condition, and degreening conditions. Degreening is a process by which green color is removed from the peel to allow the yellow or orange color to show. In nature, citrus degreens when the weather is cool enough. In packinghouses, it is accomplished with the aid of ethylene gas in degreening rooms. Although citrus is easily degreened early in the season, fruit which regreens at the end of the season is much more difficult to degreen with ethylene (27). Apparently, at the end of the season there is a larger proportion of chlorophyll b which is more resistant than chlorophyll a to ethylene degreening (20).

Degreening Conditions

Ideal degreening conditions (23, 28, 30) for Florida citrus (except lemons) are simple:

Temperature:	82-85°F (28-29°C)
Humidity:	90-96% relative humidity
Ethylene:	5 ppm
Air Circulation:	10 cfm per Florida field box, or 100 cfm per pallet box capacity
Fresh Air:	one air change per hour

These conditions seem simple. However, they are not easily achieved and maintained. Degreening recommendations have evolved over the years as more detailed research was done and as the equipment and methods improved. The optimum ethylene level for fast degreening was determined to be 5 to 10 ppm (18). The ability of citrus packers to accurately maintain ethylene levels has narrowed the recommendation to an exact 5 ppm. Although high ethylene levels increase respiration and decay, ethylene levels as high as 20,000 ppm will not cause peel injury ("gas burn") (17).

The addition of artificial heat is limited to $85^{\circ}F$ by Florida Department of Citrus Rules, Chapter 20-31 (Figure 2). The reason for this rule is that degreening of Florida citrus is fastest at $85^{\circ}F$. This is illustrated (Figure 3) in a 1960 classic Bulletin by Grierson and Newhall (12).

Our suggested fresh air exchange is one air change per hour. In Australia (27) and Israel (6) as low as 1/2 air change per hour is recommended, and this rate is in use in Spain (personal communication, I. Sanchez, Pascual Hermanos, Valencia). Most Florida degreening rooms are not sealed tight enough to result in a carbon dioxide build up and slower degreening (6). Exceptions may be in dual purpose tomato/citrus coloring rooms because tomato rooms are traditionally built with little or no ventilation.

Keeping Records and Measuring Conditions

Routine record keeping is an important, but boring task. It is best to have a form with blank spaces for temperature, wet bulb temperature, and ethylene level (Figure 4). The top of the form should have a place for date, room number, fruit variety, grower or lot number, and any other information important to your records. With the large modern rooms there would be several varieties and lot numbers arriving and leaving each day. A separate page needs to be kept for each room or section. One person should be made responsible for record keeping during each work shift. Usually the night watchman is part of the record keeping team.

Wet and dry bulb thermometer units (hygrometers) placed in a position of strong air movement over 500 feet per minute (14) can be used to measure the temperature and humidity. Water evaporation from the wet bulb results in a lower reading -- the greater the difference, the lower the relative humidity. When degreening at 85°F a 1 to 2°F difference (Figure 5) is all that should be allowed (23, 30, 31). Too little air movement will result in less water evaporation and a false high humidity reading. The wet and dry bulb unit readings can be checked occasionally with a sling psychrometer (sling movement provides air flow) or a portable psychrometer battery operated fan.

The fresh air exchange is usually set at the time the room is built and as long as there are no changes such as expanding the room, changing the fans or motors, etc., the fresh air will remain constant. A velometer is used to measure the fresh air through an outside vent on the low pressure side of the fan and the vent opening is adjusted accordingly. Velometers are used to measure air flow in heating and cooling systems. We have one at the Citrus Research and Education Center, and the larger air conditioning contractors are likely to use them.

Lemons

Lemons have already been mentioned as an exception to normal degreening conditions. Lemons traditionally were cured with "zero" ethylene at 60°F for up to 3 weeks (26). Normal citrus degreening conditions resulted in excessive decay. Ethephon (Ethrel) was shown to reduce the degreening time for lemons with reasonable safety from decay (29). Finally, the use of predegreening fungicides and low levels of ethylene (0.5 to 1 ppm) was shown to be effective, reducing the 2 to 3 weeks time to 2 to 3 days (1).

Ethrel (Ethephon)

Ethrel is a chemical which releases low amounts of ethylene and can be applied before or after harvest. Ethrel was reported to have about the same effect over a wide range of concentrations (1000 to 12,000 ppm) and immersion times (1 to 10 minutes) (11). Ethrel is known to enhance degreening of lemons (16, 29) oranges (11) and grapefruit (11, 16).

Color

Maturity standards include something called color break. Many growers develop color blindness when they try to determine adequate color break. The Florida Department of Citrus Rule 20-34 bravely attempts to define color break. However, in Florida the practical determination of color break is presently: when the fruit can be degreened it has adequate color break. The reason for this liberal interpretation is that color is subjective, and this method approximates the rule. Although it is important, there are no simply determined standard numbers for color break. The obvious reason for degreening is to remove the green color and allow the yellow or orange to show.

Varietal color is dependent on chlorophyll and various carotenoid pigments. Whealon and Stewart reported (31) that for certain varieties orange and red pigments can be increased after harvest by holding citrus at various temperatures and ethylene levels. The best color was achieved at 59 to 77^{o}F and 1 to 10 ppm ethylene in 3 to 8 days. Washing reduces carotenoid synthesis (15) and the process is too slow for commercial application.

Wound Healing

Very high humidities of 90 to 96% have been shown to reduce mold development during degreening. This was explained (2, 7) as lignification wound healing of small injuries in the flavedo (colored portion of the peel). Wound healing occurs only at high relative humidities. Severe oleocellosis (oil spotting) was not overcome by wound healing.

Dehydration and Humidification

From the instant citrus fruit is harvested it looses moisture with no chance to replenish the supply. High relative humidities during degreening are needed to reduce moisture loss. Stem-end rind breakdown of oranges (22) is usually first seen in the markets, but is the result of earlier moisture loss. Of the five degreening conditions listed above, high humidity is the most difficult to achieve. Humidity can be added by steam which also adds heat (sometimes not needed), by high pressure water, and by air mist systems (24). Air mist systems are the most common type used in Florida citrus degreening rooms. Sonic atomizing nozzles have been used sucessfully in Spain (personal communication, I. Sanchez), but have a relatively high initial cost and have not been tried in Florida citrus degreening rooms. The idea that wet fruit should not be put in degreening rooms (12) is no longer important because of the high air movement in the modern rooms (8, 9). High air circulation quickly drys wet fruit and adds to humidity in the room. At the start of the season, dry wooden pallet boxes can absorb moisture from the degreening room humidity, so that wetting pallet boxes at the beginning of the season has proven to be helpful in some cases.

Decay

The most concise statement regarding the effect of degreening on decay was by Andy McCornack, "Ethylene increases decay." That statement says it all. Larger amounts of ethylene, or longer exposure to the same amount of ethylene will increase certain kinds of decay in citrus.

Stem-end rot which occurs early in the season, Diplodia natalensis, is increased by exposing the fruit to ethylene at 85^{o}F (3, 21). The affect of excessive ethylene is shown in Table 1.

Anthracnose is also increased by ethylene during degreening. This disease is common on Robinson tangerines and the severity of the infection is related to peel color (4, 5). Yellow fruit are easily infected while dark orange fruit are more resistant. This color relationship is so consistent that color sorting tangerines into three groups will frequently sort anthracnose into three levels of severity.

Table 1. Effects of two concentrations of ethylene during degreening on decay 4 weeks after picking (adopted from 21).

Treatment	Hamlin[z]	Valencia[y]	Temples[yx]
	% decay[w]		
Not Degreened	17.0 a	6.5 a	59.9 a
4 ppm Ethylene	23.6 ab	11.1 a	60.5 a
50 ppm Ethylene	32.5 b	21.1 b	81.3 b

[z] Average of 3 experiments.
[y] Average of 4 experiments.
[x] Freeze injured.
[w] Data followed by the same letter in each column do not differ at a probability level of 5%.

Washing before degreening has been reported to reduce anthracnose (19, 25) and stem-end rot (25). This process also slows the degreening process (15) so that the advantage of reducing decay is offset by longer and poorer degreening.

A more detailed discussion of stem-end rot and anthracnose by G. E. Brown is found in the decay control section of these proceedings.

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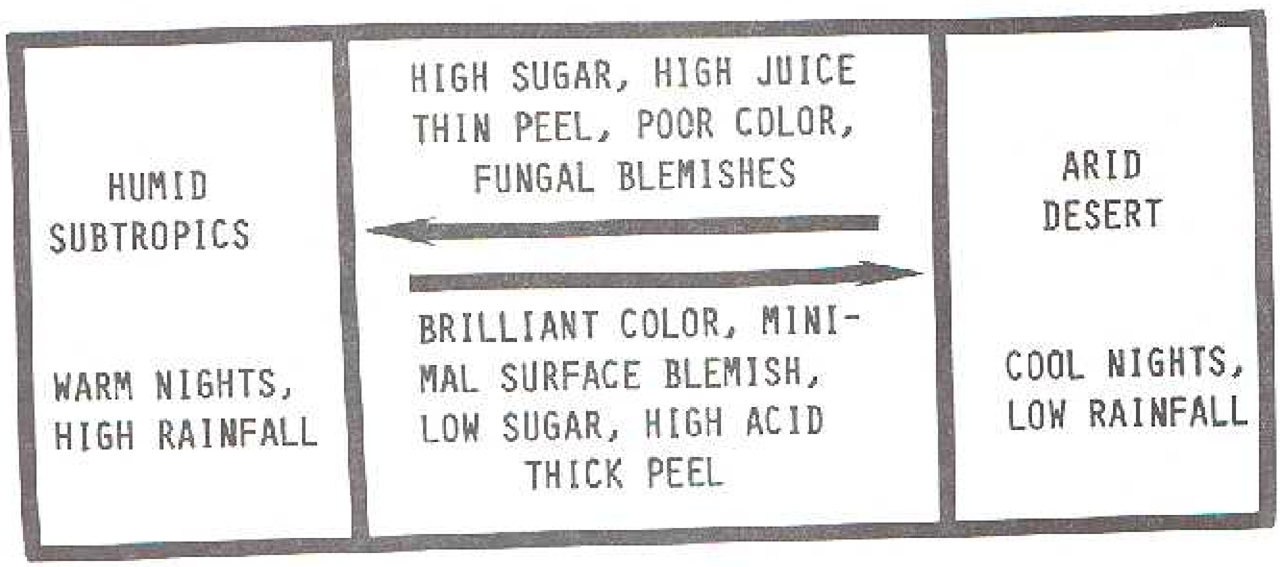

Figure 1. Effects of climatic extremes on citrus fruit quality (adopted from 13).

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CHAPTER 20-31

COLORING ROOM METHODS AND PRACTICES

20-31.001 Certain Heating Prohibited: No kerosene or other gas-generating heater shall be operated inside, or within 15 feet of, any coloring-room or enclosure where citrus fruits are being degreened.

Specific Authority: 601.10(1),(7), F.S. Law Implemented: 601.10(7), F.S. History: Formerly 105-1.13(1); Revised 1/1/75; Previously numbered 20-31.01.

20-31.002 Air Circulation: Sufficient air circulation shall be provided in every coloring-room or enclosure to maintain a reasonably uniform temperature throughout.

Specific Authority: 601.10(1),(7), F.S. Law Implemented: 601.10(7), F.S. History: Formerly 105-1.13(2); Revised 1/1/75; Previously numbered 20-31.02.

20-31.003 Maximum Temperature: The temperature of the coloring-room or enclosure containing citrus fruit in the process of being degreened, shall be so controlled that the temperature shall not exceed 85°F. due to application of heat, except when the added heat comes from steam released into the atmosphere to increase humidity.

Specific Authority: 601.10(1),(7), F.S. Law Implemented: 601.10(7), F.S. History: Formerly 105-1.13(3); Revised 1/1/75; Previously numbered 20-31.03.

Figure 2. Florida Department of Citrus Rules pertaining to degreening.

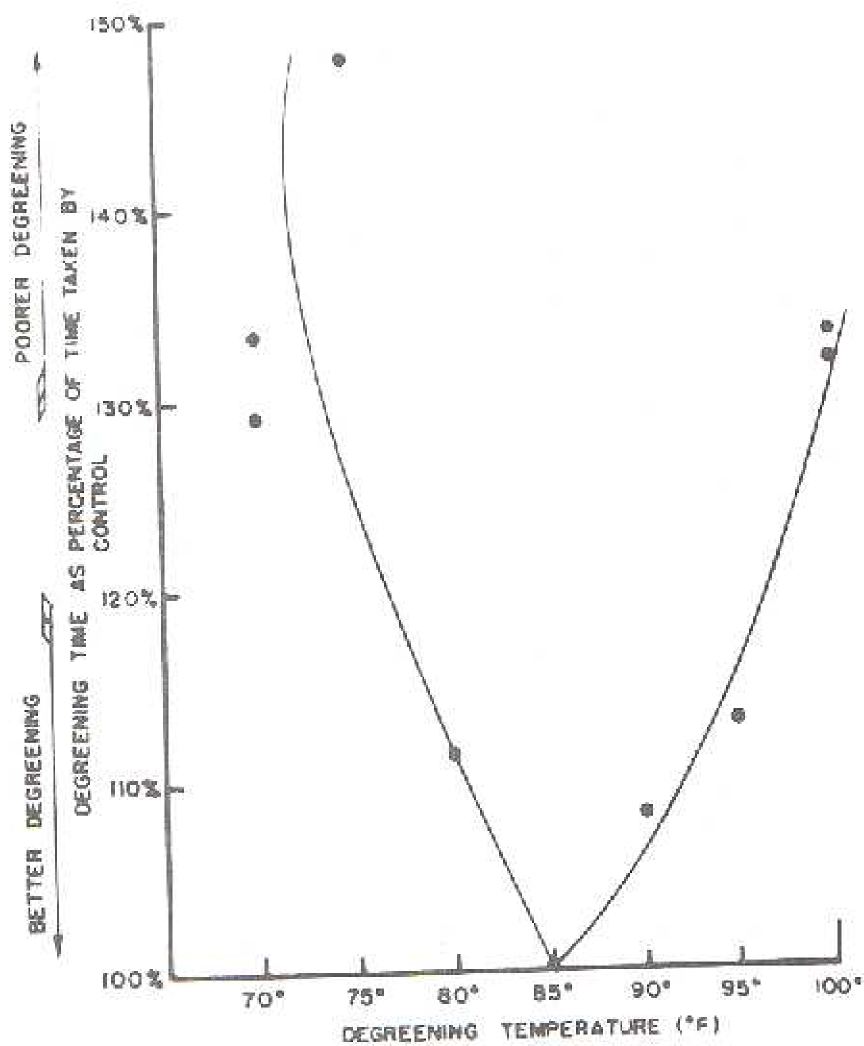

Figure 3. Effect of temperature on rate of degreening of Hamlin oranges (12).

DEGREENING RECORD

My Packing Company
1 Citrus Avenue
Orangeville, FL 33000

Date ____________________

Room Number ____________________

Variety ____________________

Lot Number ____________________

Time	Ethylene ppm
______	______
______	______

AM	Wet bulb	Dry bulb	PM	Wet bulb	Dry bulb
1	______	______	1	______	______
2	______	______	2	______	______
3	______	______	3	______	______
4	______	______	4	______	______
5	______	______	5	______	______
6	______	______	6	______	______
7	______	______	7	______	______
8	______	______	8	______	______
9	______	______	9	______	______
10	______	______	10	______	______
11	______	______	11	______	______
12	______	______	12	______	______

Figure 4. Example of degreening record sheet which should be made to suit the operation of the individual packinghouse.

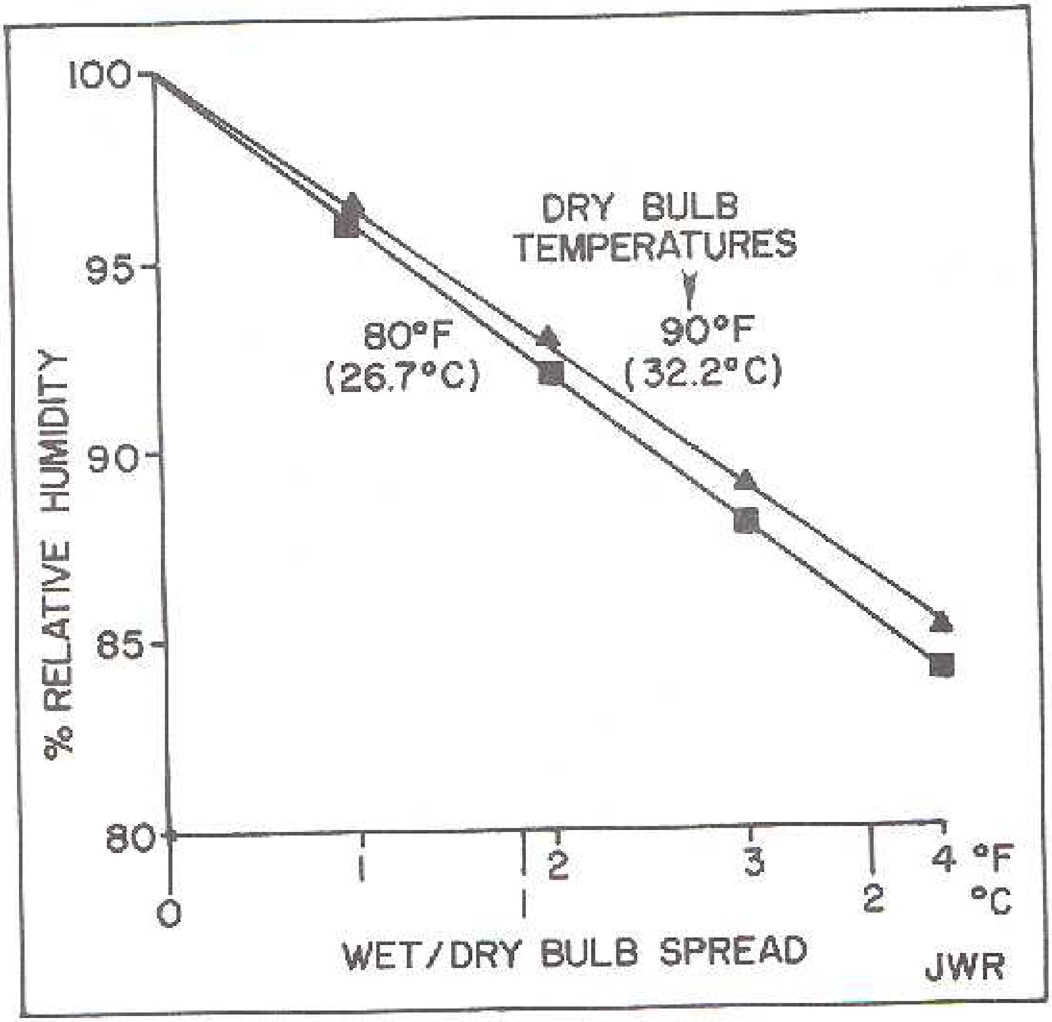

Figure 5. Temperature readings for wet and dry bulb thermometers at 80° to 90°F (26.7° to 32.2°C) dry bulb readings and 500 to 1000 feet per minute air flow over the wet bulb (31).