Proc. Fla. State Hort. Soc. 117:392-395. 2004.

ALTERNATIVE DEGREENING OF 'FALLGLO' TANGERINES

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Additional index words. peel disorder, fruit color, citrus postharvest

Abstract. **Influence of degreening temperature, duration, and humidity were evaluated to optimize degreening regimens for 'Fallglo' tangerines. In most studies, fruit decay incidence was significantly reduced if fruit were degreened between 18 and 21 °C in comparison to the current commercial degreening temperature of 29 °C, both with 92% to 96% RH for the same length of time. Peel color development was slightly delayed in only one case when fruit were degreened at 18 °C. The degreening temperatures did not consistently influence pitting and chilling injury. Degreening for 6 hours resulted in better fruit color development in comparison to degreening for 18 hours. Overall, 'Fallglo' tangerines responded best to lower temperature degreening for maintaining all postharvest quality parameters. Commercially tangerines should be degreened at 21 °C for less than 12 hours at 92% to 96% RH.**

At harvest, citrus grown in Florida's climatic conditions often develop internal maturity while the external peel color still appears immature. External immaturity (green coloration) results from high chlorophyll content in the peel. Therefore, the majority of early season citrus varieties are degreened to improve fruit color in order to meet the USDA color standards for market acceptability. Ethylene, a plant growth regulator, has been used to break down chlorophyll, and to enhance the development of orange/yellow carotenoids in the citrus flavedo (Stewart and Wheaton, 1972). The degreening recommendation of Wardowski and McCornack (1979), modified by Ritenour and Miller (1999), is currently used in the Florida citrus industry. Typically, they recommend degreening of citrus fruit as follows: temperature of 29 °C, 5 ppm ethylene, and 92% to 96% RH. The length of fruit degreening is dependent on the external fruit maturity.

'Fallglo' tangerines, released in 1987, are early season tangerines. The fruit size is large, and fruit rind is thin with a smooth, leathery texture. The commercial harvest season extends from September to November. Generally, tangerines are susceptible to peel disorders and decay (Grierson et al., 1965). In particular, 'Fallglo' fruit are vulnerable to the development of postharvest pitting and anthracnose (Dou et al., 1999; Petracek et al., 1998). Ethylene degreening increases the severity of these decays primarily because ethylene stimulates pathogen infections and reduces natural fruit resistance to the pathogens (Brown, 1992). To reduce both decay and peel disorders of 'Fallglo' tangerine during the postharvest and market stages, an optimal degreening regimen is needed. Recently Dou (2002) suggested a specific degreening regimen for tangerines because the degreening recommendation of Wardowski and McCornack (1979) was established before 'Fallglo's' release. The only other paper on degreening of 'Fallglo' was published by Petracek and Montalvo (1997) who reported that degreening 'Fallglo' more than 24 h hastened fruit color development. Due to the severe postharvest losses of 'Fallglo' in recent years, a systematic study of 'Fallglo' degreening is necessary. The objective of the current paper was to evaluate a short time and low temperature degreening regimen for 'Fallglo' tangerines.

Materials and Methods

Study 1. 'Fallglo' tangerines were harvested commercially on 2 Oct. 1999 and transported to the Citrus Research and Education Center (CREC). The treatments were set up as follows; treatment 1 (no degreening): fruit were stored at 29 °C for 16 h with 0 ppm ethylene, and then stored at 21 °C and 92 ± 3% RH. Treatment 2 was degreened at 24 °C for 16 h at 5 ppm ethylene. After degreening, fruit were stored at 21 °C and 70 ± 3% RH. Treatment 3 was degreened as in treatment 2, but was stored at 92 ± 3% RH after packing. Treatment 4 was degreened at 29 °C for 16 h at 5 ppm and stored at 21 °C and 92 ± 3% RH. Treatment 5 was degreened for 12 h at 2 ppm ethylene at 29 °C to simulate commercial conditions and was stored at 21 °C and 92 ± 3% RH. All fruit were waxed with shellac wax (FMC Corporation, Lakeland, Fla.) 6 h after degreening before the fruit were stored at the respective storage conditions as described above. Each treatment consisted of three replications (boxes) with approximately 33 fruit in each box. Evaluations for fruit decay were done on 16 Oct. 1999 and 1 Nov. 1999, which correspond to 2 and 4 weeks after packing.

Study 2. 'Fallglo' tangerines were received from a local packinghouse in Polk County, Fla. on 23 Oct. 2000. Fruit were not drenched or degreened prior to arrival at the CREC and had 65% color break. Color measurements were taken before degreening. The study was set up with 5 treatments as follows: non-degreening, degreening at 92 ± 3% RH for either 6 or 18 h or at 70% RH for 6 or 18 h, respectively. All treatments were conducted at 24 °C and 5 ppm ethylene (Table 3). Fruit were washed with sodium orthophenylphenate (SOPP, FMC Corporation, Lakeland, Fla.), dried at approximately 55 °C for 2 min, and waxed with shellac wax (HS590, FMC Corporation, Lakeland, Fla.) following degreening treatments. Each treatment was replicated three times with 30 fruit per replication. Fruit were stored at 21 °C with 92 ± 3% RH or 4 °C with 92 ± 3% RH, respectively. Ten fruit from each treatment were randomly selected from storage and their color was measured as described below.

Study 3. 'Fallglo' tangerines were received from local commercial packinghouses on 5 Oct. 2001. Fruit were either non-degreened or degreened at 18, 24, or 29 °C at 5 ppm ethylene for 16 h. Each treatment was replicated three times with 35 fruit in each replication. Fruit were washed with commercial fruit cleaner (Sooty Mold Clean 278, Decco Inc., Monrovia, Calif.) and waxed with shellac wax (HS590, FMC Corpora-

tion, Lakeland, Fla.) 6 h after degreening. 'Fallglo' tangerines were stored at either 21 or 4 °C with 92 ± 3% RH.

Study 4. 'Fallglo' tangerines were received from a local packinghouse on 1 Oct. 2002; fruit were not drenched. Three hundred fruit were either non-degreened or degreened at 18, 24, or 29 °C, respectively, at 5 ppm ethylene for 6 h. After degreening, each treatment was packed in three boxes (50 fruit), and stored at 4 or 21 °C, respectively. Pitting and chilling injury (CI) was examined on day 20 in 21 °C, and on day 60 in 4 °C storage, respectively.

Study 5. 'Fallglo' tangerines were received from local commercial packinghouses on 2 Oct. 2003. Fruit were either non-degreened or degreened at 18, 24, or 29 °C at 5 ppm ethylene for only 6 h. All further handling was exactly as described in study 3.

Disorder evaluation. Chilling injury (CI) was rated by subjectively assigning each fruit a numerical rating of 0) no damage, 1) slight: <5% of fruit surface damaged, 2) moderate: 5% to 30% of fruit surface damaged, or 3) severe: >30% of fruit surface damaged. Likewise, postharvest pitting was rated subjectively by assigning each fruit a numerical rating of 0) no pitting, 1) 1-4 pits, 2) 5-10 pits, 3) 11-30 pits, 4) 31-100 pits or 5) >100 pits, according to Petracek et al. (1998). Total disorder incidence was calculated as a percentage of total fruit. Percentage of CI, pitting, and decay for each replication within a treatment was calculated and statistically analyzed.

Color. Peel color was measured at four regions along the mid-section spaced 90° apart using a CR-300 colorimeter (Minolta, Japan). For the color determination, tristimulus values (X, x, and y) were converted to hue angle (0° = red-purple, 90°= yellow, 180° = bluish-green, 270° = blue) according to McGuire (1992).

Statistical analysis. Studies were organized as completely randomized block design. Data were analyzed by ANOVA and means were separated by Duncan's new multiple range test ($P \leq 0.05$) using Plotit statistical software (Scientific Programming Enterprises, Haslett, Minn.).

Results

Study 1. Decay in 'Fallglo' tangerines was significantly higher when degreened at 29 °C than 24 °C (Table 1). 'Fallglo' degreened at 29 °C had 14% to 28% decay incidence 2 weeks after packing, while fruit degreened at 24 °C had only 4% to 8% decay. Similarly, after 1 month in storage at 21 °C, nearly all 'Fallglo' degreened at the higher temperature were decayed compared to 60% to 71% decay for fruit degreened at the lower temperature of 24 °C. Degreening at 70% RH resulted the lowest decay in incidence among the treatments. No difference was found in fruit color development in this study (data not shown).

Study 2. In the Fall 2000, peel color was evaluated under different degreening conditions (Table 2) and high decay incidence was found in all treatments (data not shown). Fruit stored at 4 °C after degreening at 70% RH for 6 h developed the best fruit color in comparison to non-degreened fruit or fruit degreened at higher RH or for longer duration. Three days after fruit were stored at 21 °C, similar fruit color was developed. Higher RH (92%) and longer degreening duration (18 h) enhance fruit color development at 21 °C (Table 2).

Study 3. In the 2001-2002 season, the incidence of postharvest pitting and chilling injury in 'Fallglo' was high in all treatments (>73%). Decay was significantly lower in the non-degreened and 18 °C degreened treatments than in the treatment degreened at 29 °C, stored either at 21 °C for 2 weeks or 4 °C for 3 months, as shown in Table 3. Initial color (hue angle) before degreening, was >92 ° in all treatments (yellow to yellow-green). After 2 weeks in storage at 21 or 4 °C, fruit hue angle was greatly reduced. Fruit degreened at 24 °C developed similar fruit color to fruit that was degreened at 29 °C, as well as non-degreened fruit. However, degreening at 18 °C delayed color development in 'Fallglo' in this study (Table 3).

Study 4. No significant difference was found in fruit color and decay incidence among four degreening treatments when fruit were stored at 21 °C for 3 weeks. However, pitting was higher at 29 °C degreened than 24 °C or non-degreened fruit. In 4 °C storage, fruit developed higher CI as non-degreened than degreened fruit. Fruit color and decay were in similar order in all 4 treatments (Table 4).

Study 5. The repeat study in early Oct. 2003 found no difference in pitting development after 8 d storage at 21 °C and 92% RH. However, decay is lower in 24 °C degreened and non-degreened than degreened fruit either at 29 or 18 °C. Surprisingly, fruit color was better developed in fruit degreened at 18 °C than at 29 °C. No difference was found at degreening temperatures of 24 and 29 °C (Table 5).

Discussion

The major decay after ethylene degreening was anthracnose in 'Fallglo' tangerines as reported by Brown (1992) who mentioned that anthracnose and stem-end rot are the main decay diseases following degreening. Similar results were found by Wardowski and McCornack (1979). Most of

Table 1. Effect of degreening regimen on decay incidence of 'Fallglo' tangerines after 2 or 4 weeks in storage at 21 °C.[z]

Regimen	% Decay	
Deg T/Deg RH/Ethylene PPM/Deg h	2 wk	4 wk
No degreening	7.8 ab[y]	60.0 a
24 °C/70% RH/5 ppm/16 h	4.4 a	71.1 a
24 °C/92% RH/5 ppm/16 h	7.7 ab	65.6 a
29 °C/92% RH/5 ppm/16 h	27.8 c	95.6 b
29 °C/92% RH/2 ppm/12 h (commercial degreening)	14.4 b	90.0 b

[z]Study started on 2 Oct. 1999, decay measurements taken on 16 Oct. 1999 and 1 Nov. 1999, respectively.
[y]Mean separation within columns was by Duncan's new multiple range test at $p \leq 0.05$.

Table 2. Effect of degreening regimen on color development of 'Fallglo' tangerines after 3 d storage at 4 or 21 °C.[z]

Regimen	Color (Hue Angle)	
Deg RH/Ethylene PPM/Deg h	21 °C	4 °C
No degreening	91.8 c[y]	91.8 d
70% RH/6 h	68.5 ab	63.6 a
92% RH/6 h	71.8 b	72.0 b
70% RH/18 h	70.6 b	75.5 c
92% RH/18 h	65.9 a	72.5 bc

[z]Study started on 23 Oct. 2000. Fruit were degreened at 24 °C with 5 ppm ethylene concentration.
[y]Mean separation within columns was by Duncan's new multiple range test at $p \leq 0.05$.

Table 3. Effect of degreening temperature on peel disorder, decay incidence, and color of 'Fallglo' tangerines.[z]

Stored at 21 °C Degreening temperature	% Pitting 2 wk	% Decay 2 wk	Hue Angle d 0	Hue Angle d 14
No degreening	81.5 a[y]	9.2 ab	105.3 b	74.6 a
18 °C	82.3 a	4.9 a	102.8 b	79.5 b
24 °C	73.6 a	17.5 ab	104.7 b	76.5 a
29 °C	83.3 a	23.0 b	92.9 a	75.9 a
Stored at 4 °C Degreening temperature	% CI 3 mo.	% Decay 3 mo.		
No degreening	78.5 a	15.0 a	105.3 b	85.4 a
18 °C	81.2 a	24.3 ab	102.8 b	92.1 b
24 °C	86.1 a	37.6 c	104.7 b	86.0 a
29 °C	68.8 a	28.3 bc	92.9 a	83.8 a

[z]Study was set up on 5 Oct. 2001. Color measurements are means of 10 fruit per treatment.
[y]Mean separation within four degreening temperatures was by Duncan's new multiple range test at $p \leq 0.05$. Column means followed by the same letter are not significantly different.

our studies showed that degreening at 18 to 24 °C, temperatures lower than the current commercial degreening temperature, significantly reduced the incidence of decay in 'Fallglo' tangerines (Tables 1 and 3). Over-degreening accelerates fruit external and internal quality decline in the form of decay, peel disorders, and deterioration. Decay in 4 °C storage was low for grapefruit (Dou and Ismail, 2000) where 'Fallglo' tangerine showed a high susceptibility to decay at either 4 or 21 °C in storage. Tangerines, such as 'Fallglo', are vulnerable to pitting and decay development, and produce ethylene after harvest (Petracek and Montalvo, 1997); therefore, degreening duration should be shorter for tangerines. The study confirmed that non-degreened fruit developed similar fruit color as degreened fruit either at 24 or 29 °C even though no ethylene was detected in the internal atmosphere of 'Fallglo' tangerine fruit during the postharvest storage and market period (Dou, unpublished data). The degreening duration was less than 18 h in the current studies. However, Petracek and Montalvo (1997) reported a higher fruit internal ethylene concentration after 24 to 48 h of degreening. Recent industry reports indicate high 'Fallglo' losses within 7 to 10 d during the marketing period. Obviously, a shorter degreening duration will extend 'Fallglo' marketing period from approximately 7-10 d to 2-3 weeks. Present study demonstrates that degreening for 6 h achieved even better fruit color development than 18 h, whether stored at 4 or 21 °C (Table 2). However, delayed hue angle development was found in the 2001 study (Table 3). The delay of fruit color development stored at 4 °C can be explained by the accumulation of temperature sensitive β-citraurin in citrus fruit peel (Wheaton and Stewart, 1973).

Stewart and Wheaton (1971) reported that fruit treated with ethylene and held at 29 °C, in most cases, had only slightly better color than untreated fruit. This is confirmed by the current study which indicated that low temperature degreened or non-degreened fruit developed color as good as that of fruit degreened at 29 °C, but decay is often lower in the former fruit than the latter. The authors further reported that 'Temple' oranges' color improved when degreened at 18 or 24 °C rather than at 29 °C. 'Fallglo' tangerines also developed better color with less decay in our studies. This is because 'Fallglo' is a new cultivar developed from Bower citrus hybrid and Temple orange (Jackson, 1991). Wheaton and Stewart (1973) found that fruit orientation on the tree (such as south vs. north or inside vs. outside of canopy) influences the degreening results. This report explains the inconsistence of degreening temperature in fruit color development. The big advantage of low temperature degreening as shown in this

Table 4. Effect of degreening regimen on peel disorder, decay incidence, and color of 'Fallglo' tangerines.[z]

Stored at 4 °C Degreening temperature	% Pitting 20 d	% Decay 20 d	Hue angle
No degreening	63.6 a[y]	19.7 a	81.7 a
18 °C	78.1 ab	19.3 a	81.3 a
24 °C	58.3 a	19.7 a	80.6 a
29 °C	86.9 b	16.1 a	81.1 a
Stored at 4 °C Degreening temperature	% CI 2 mo.	% Decay 2 mo.	
No degreening	35.5 b	9.3 a	85.8 a
18 °C	24.9 a	6.2 a	86.4 a
24 °C	24.5 a	3.8 a	84.5 a
29 °C	30.7 a	4.9 a	84.3 a

[z]Study was set up on 1 Oct. 2002. Color measurements are means of 10 fruit per treatment.
[y]Mean separation within four degreening temperatures was by Duncan's new multiple range test at $p \leq 0.05$. Column means followed by the same letter are not significantly different.

Table 5. Effect of degreening temperature on postharvest pitting, decay incidence, and color development of 'Fallglo' tangerines stored at 21 °C for eight days.[z]

Stored at 21 °C Degreening temperature	% Pitting d 8	% Decay d 8	Hue angle
No degreening	17.8 a[y]	0 a	68.2 a
18 °C	10.3 a	8.1 c	67.1 a
24 °C	20.7 a	2.5 ab	70.5 ab
29 °C	13.3 a	6.3 bc	71.2 b

[z]Study was set up on 2 Oct. 2003. Color measurements are means of 10 fruit per treatment.
[y]Mean separation within four degreening temperatures was by Duncan's new multiple range test at $p \leq 0.05$. Column means followed by the same letter are not significantly different.

paper is the reduced decay incidence of 'Fallglo' tangerines (Tables 1 and 3).

Additionally, little difference in fruit color development has been found in many studies regarding the ethylene concentration from 1 to 10 ppm (Miller et al., 2000; Wardowski and McCornack, 1979). Miller et al. (2000) demonstrated that ethylene concentrations higher than 20 ppm may cause peel damage of citrus fruit such as zebra skin (Brown, 1998). Surprisingly, degreening fruit at 70% RH reduced fruit decay during 21 °C storage and improved fruit color at 4 °C (Tables 1 and 2). No reports detailing this have been found. Generally, it is understood that low humidity inhibits decay fungi development as evidenced by the consistently high decay incidence found in the degreening room with 90% humidity. Another explanation is that cryptoxanthin and β-citraurin could be better accumulated at low temperature than at 29 °C (Stewart and Wheaton, 1971). This is why degreening at 70% RH resulted in slightly better fruit color than degreening at 90% RH.

Ethylene application in postharvest citrus resulted in substantial improvement of external citrus color associated with the synthesis of specific carotenoid pigments (Stewart and Wheaton, 1972). The exact biochemical process of 'Fallglo' degreening and the molecular details of the many diverse ethylene responses are still not well understood; it is now known that ethylene receptor proteins located on cell membranes mediate the signals for these responses (Brady and Speirs, 1991). Obviously, temperature and humidity influence these biochemical processes in fruit. Further studies in biochemical and physiological response of 'Fallglo' to ethylene exposure are needed.

In summary, a conservative/shortened degreening regimen ensures good fruit quality and longevity in the market. These new research findings and optimal handling practices are ensuring better fruit arrivals than are the degreening recommendations from the 1970's. The current optimal degreening regimen for 'Fallglo' tangerines is 21 °C with 92% RH at 2 ppm ethylene for 6 to 12 h. The degreening process should act as a primer to stimulate fruit maturation and packers should consider that 'Fallglo' tangerines continue to develop color after degreening.

Acknowledgments

Mr. Gary Coates is greatly appreciated for help with critical reading of this paper.

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