Postharvest Pitting of 'Fallglo' Tangerine

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ABSTRACT. The morphology and etiology of postharvest pitting of 'Fallglo' [Bower citrus hybrid (*Citrus reticulata* Blanco x *C. reticulata* Blanco x *C. paradisi* Macf.) x Temple (*C. reticulata* Blanco x *C. sinensis* L.)] peel were determined. The disorder was characterized by scattered collapse of the flavedo that resulted from necrosis of cells within and enveloping the oil glands. In severe cases, damage occurred in epidermal and hypodermal cells above collapsed oil glands and surrounding vascular tissues, but cells between oil glands were often undamaged. Pitting was caused by storing waxed fruit at high temperature (≥ 15.5 °C), but was not affected by ethylene exposure during degreening. Fruit coated with commercially available shellac- and polyethylene-based waxes pitted more than fruit coated with carnauba-based waxes. Pitting was controlled by not coating the fruit with wax or storing the fruit at low temperature (4.5 °C) within hours after wax application.

'Fallglo' tangerine was released in 1987 and has since been marketed as an early season tangerine (Jackson, 1991). During the initial seasons of commercial production, we received reports that 'Fallglo' was unusually susceptible to postharvest decay and peel disorders. The susceptibility was attributed to a hypersensitivity of the peel to postharvest stress. Ethylene exposure at degreening, in particular, was suspected to be the critical factor in causing postharvest losses of 'Fallglo.' While ethylene stimulates chlorophyll degradation and carotenoid synthesis in citrus peel (Grierson et al., 1986; Stewart and Wheaton, 1972), ethylene also triggers the development of anthracnose [*Colletotrichum gleosporioides* (Penz.) Sacc.] (Brown, 1992; Smoot and Melvin, 1967) and stem end rot (*Diplodia natalensis* P. Evans) (Barmore and Brown, 1985) and promotes respiration of citrus fruit (Aharoni, 1968). However, the effects of ethylene on peel degradation are not well understood.

The reported sensitivity of 'Fallglo' to ethylene prompted us to examine degreening methods that minimize ethylene exposure. During these degreening studies, we observed severe cases of pitting of waxed fruit held at high temperature (≥ 15.5 °C). The pitting appeared to be similar to a peel disorder of 'Marsh' white grapefruit (*Citrus paradisi* Macf.) that was initially identified in March 1994 (Petracek et al., 1995). This disorder, termed postharvest pitting of grapefruit, is distinct from other peel disorders including chilling injury and has reportedly led to substantial postharvest losses of fresh grapefruit. Since postharvest pitting had not been previously identified in varieties other than grapefruit, citrus handlers considered this disorder to be species specific.

We examined the morphological development of postharvest pitting of 'Fallglo' tangerines and the effect of this disorder on peel anatomy. We also determined which postharvest handling strategies caused this disorder and related the cause to wax formulation and internal gas levels.

Materials and Methods

PLANT MATERIAL. Mature 'Fallglo' fruit were harvested at commercial groves near Haines City and Punta Gorda, Fla., for the second (effect of storage temperature and time of wax application) and fifth (effect of wax formulation) studies, respectively. All other fruit were harvested at the Citrus Research and Education Center (CREC) in Lake Alfred, Fla. Fruit were treated on the day of harvest unless otherwise noted. Average fruit mass was 225 ± 4 g (range: 150 to 310 g) and diameter was 8.0 ± 0.1 cm at the midsection.

POSTHARVEST TREATMENTS. All postharvest handling was performed at the CREC. Fruit were degreened only when noted and were not treated with fungicide. Fruit were washed on roller brushes with fruit cleaner (no. 395; FMC Corp., Lakeland, Fla.). Except for the fifth study, fruit were coated with a commercially available shellac-based water wax (FMC Corp.) In the fifth study, fruit were coated with commercially available shellac-based water waxes (FMC Corp.; EcoScience, Orlando, Fla.; or Elf Atochem, Monrovia, Calif.) (randomly labeled shellac-based 1, 2, or 3) or carnauba- or polyethylene-based water waxes containing no shellac. The liquid forms of carnauba- and polyethylene-based waxes were comprised of the same percentage of wax solids as the shellac-based wax from FMC Corp. All waxes were applied on roller brushes, and fruit were dried at 60 °C for ≈ 1 min. Fruit were packed in $10 \times 20 \times 40$ -cm cardboard boxes in all studies.

INTERNAL O₂ AND CO₂ LEVELS. Silicone, ≈ 1 cm in diameter and 0.3 cm thick (GE Silicon II; General Electric Co., Waterford, N.Y.), was applied to the stylar end of the fruit to create a gas sampling septum. Gas samples (0.5 mL) were taken through the septa by syringe from the inner core of the fruit. Samples were analyzed in a flow-through system consisting of O₂ (model 26112; Orbisphere Laboratories, Geneva, Switzerland) and CO₂ (LI-6251; LI-COR, Lincoln, Nebr.) gas analyzers connected in series with N₂ used as the carrier gas. Gas levels were calibrated by a standard consisting of 5.01% O₂ and 5.02% CO₂.

MORPHOLOGY. Pitting development was determined by visual inspection of 30 fruit coated with a commercially available shellac-based water wax and held at 15.5 °C and $93\% \pm 3\%$ relative humidity (RH). The numbers and clusters of sunken oil glands were counted upon development, and clusters were circled with a marking pen every 2 or 3 d after wax application.

Time-lapse video (VK-C350 video camera; Hitachi Instruments, San Jose, Calif., and AG-6720-P video recorder; Panasonic,

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Fig. 1. Postharvest pitting of 'Fallglo' tangerine. Bar = 1 cm.

Secaucus, N.J.) recorded changes in surface morphology of waxed fruit held at $23 \pm 2^\circ\text{C}$. The video recorder taped 480 h of real-time storage on a 2-h tape and thus reduced the recorded time by 240-fold. This reduction was reduced an additional 240-fold by playing the completed 2-h tape at normal speed on a video player (SV-771; Toshiba, Atlanta) and recording at slow speed on the AG-6720-P video recorder. The resulting 30-s tape, which consisted of one image for about every 16 min of real-time storage, was examined to determine times and patterns of collapse and discoloration.

Peel samples for light microscopy were excised by cork borer (6 mm in diameter) from pitted and nonpitted waxed fruit held at 26.5°C for 20 d. Additional samples were taken from waxed fruit held at 4.5°C for 20 d and nonwaxed fruit held at 4.5 or 26.5°C for

20 d. At least three fruit were sampled for each treatment. Tissue was fixed in 3% glutaraldehyde in 0.1 M phosphate buffer, rinsed with phosphate buffer, postfixed in 2% osmium tetroxide in phosphate buffer, and rinsed again with phosphate buffer. The tissue was dehydrated in an acetone series and embedded in Spurr's embedding resin (Spurr, 1969). Sections ($1\ \mu\text{m}$ thick) were taken on an ultramicrotome, stained with toluidine blue (O'Brien et al., 1964) or methylene blue-azure A/basic fuchsin, and examined under a light microscope.

EFFECTS OF POSTHARVEST TREATMENTS. Five studies were conducted. In the first study, the effects of degreening, wax application, and storage temperature were investigated. Fruit were harvested and treated on 28 Sept., 3 Oct., or 21 Oct. 1995 ($n = 3$ boxes of 10 fruit per treatment with one box from each harvest date). Degreened fruit were exposed to $5\ \mu\text{L}\cdot\text{L}^{-1}$ ethylene for 24 h at $29.5 \pm 1.0^\circ\text{C}$ and $93\% \pm 3\%$ RH and held in air for an additional 24 h at $29.5 \pm 1.0^\circ\text{C}$ and $93\% \pm 3\%$ RH. Nondegreened fruit were held 48 h at $29.5 \pm 1.0^\circ\text{C}$ and $93\% \pm 3\%$ RH. Waxed fruit were coated with shellac-based water wax. Ten fruit were packed and held at 4.5 or $15.5 \pm 1.0^\circ\text{C}$ and $93\% \pm 2\%$ RH. Fruit were rated visually (0 = no pits; 1 = 1 to 3 pits; 2 = 4 to 10 pits; 3 = 11 to 30 pits; 4 = 31 to 100 pits; and 5 = more than 100 pits) 20 d after packing.

In the second study, the effects of storage temperature and time of wax application were determined. Fruit were harvested on 21 Oct. 1995, transported to the CREC on 24 Oct. 1995, and treated ($n = 6$ boxes of 10 fruit per treatment). Waxed fruit were held 2 or 6 d at 26.5°C and $95\% \pm 2\%$ RH, waxed, and held at 4.5 , 15.5 , or $26.5 \pm 1^\circ\text{C}$ and $93\% \pm 2\%$ RH. Nonwaxed fruit were held 2 d at 26.5°C and $95\% \pm 2\%$ RH and then held at 4.5 , 15.5 , or $26.5 \pm 1^\circ\text{C}$ and $93\% \pm 2\%$ RH. Internal O_2 and CO_2 levels were measured 1 and 28 d after waxing. Fruit were rated visually for pitting as described above after 7, 14, 20, and 28 d in storage.

In the third study, the effects of altering temperature during

Fig. 2. The order of appearance of postharvest pit clusters as determined by time-lapse video of 'Fallglo' tangerines held 20 d at $23 \pm 3^\circ\text{C}$. The clusters of collapsed oil glands (left) are encircled and numbered sequentially according to the time required (days after waxing) for the initial visible sign of collapse (right): clusters 1–2, 3 d; clusters 3–4, 4 d; clusters 5–7, 9 d; clusters 8–11, 10 d; and cluster 12, 12 d.

storage and wax application were examined. Fruit were harvested and treated on 31 Oct. 1995 ($n = 3$ boxes of 19 fruit per treatment). Treatments of constant storage temperature consisted of waxed or nonwaxed fruit held at 4.5 or $26.5 \pm 1^\circ\text{C}$ and $93\% \pm 2\%$ RH. Treatments of varied storage temperature consisted of waxed fruit held at 4.5 or $26.5 \pm 1^\circ\text{C}$ for 3 d and transferred to 26.5 or $4.5 \pm 1^\circ\text{C}$, respectively. Fruit were rated visually for pitting as described above after 3, 8, 15, and 22 d in storage.

In the fourth study, internal gas levels and pitting of intact and punctured fruit were compared. Fruit were harvested and treated on 13 Nov. 1995 ($n = 3$ boxes of 10 fruit per treatment). A puncture was made by cutting a ring ≈ 2 mm into the albedo of the peel and 4 cm from the stylar end with a cork borer (14 mm in diameter). The circular plug created by the incision was not removed from the surface and no attempt was made to sterilize the incised region. Fruit without wax application or peel puncture were prepared as controls. Fruit were held at $15.5 \pm 1^\circ\text{C}$ and $93\% \pm 2\%$ RH. Internal gas levels were taken, and fruit were rated visually for pitting as described above 18 d after wax application.

In the fifth study, the effects of wax formulation were studied.

Fruit were harvested on 1 Oct. 1996, transported to the CREC the next day, and treated ($n = 3$ boxes of 16 fruit per treatment). Fruit were either not coated or coated with shellac-, carnauba-, or polyethylene-based waxes and were held 21 d at $21.0 \pm 1.0^\circ\text{C}$ and $93\% \pm 2\%$ RH. Internal O_2 and CO_2 levels were measured 7 and 14 d after wax application. Fruit were rated visually for pitting 14 and 21 d after wax application. Since similar results were obtained when the experiment was repeated with fruit harvested on 21 Oct. 1996, only the results from the first harvest are presented.

STATISTICAL ANALYSIS. In studies one and two, treatments were organized in completely randomized designs of factorial combinations of treatments, and data were analyzed by analysis of variance (ANOVA; $\alpha = 0.01$; Plotit, Scientific Programming Enterprises, Haslett, Mich.). In studies three, four, and five, treatments were organized in completely randomized designs, data were analyzed by ANOVA, and means were separated by Duncan's new multiple range ($\alpha = 0.01$).

Results

MORPHOLOGY. Postharvest pitting of 'Fallglo' was characterized by clusters of collapsed oil glands scattered over the surface of the fruit (Fig. 1). Pitting on 'Fallglo' appeared as early as 2 d after wax application. Although newly pitted areas continued to appear throughout storage, the development of new clusters

was greatest during the first 2 weeks after packing. There was an average of six oil glands per cluster (range: 1 to 125) and seven clusters per fruit (range: 1 to 24). In general, pitting developed initially at the stem end, but became more evenly distributed over the fruit surface during 28 d in storage at 15.5°C . Anthracnose and stem end rot, which developed during storage, did not appear to affect pitted regions or pitted fruit preferentially.

Time-lapse video showed that pitting within a cluster of damaged oil glands occurred in three phases: lag, rapid, and slow. During the lag phase, the outer surface of the peel located directly above the oil glands indented. Close examination of the time-lapse video suggested that the initial indentation occurred 12 to 24 h before collapse and could be observed by visual inspection. During the rapid phase of pitting, the indented regions collapsed quickly to form characteristic pits. In most cases, oil glands within a cluster collapsed within a 4- to 12-h period. However, for $\approx 5\%$ of the clusters, oil glands around the periphery of the cluster collapsed several days after the rapid phase. During the slow phase, oil gland indentation decelerated, but regions between oil glands continued to collapse for up to 7 d. After peel collapse, pitted regions became

Fig. 3. Light micrographs of sections of 'Fallglo' tangerine peel. (A) Waxed fruit held at 26.5°C . (B) Nonwaxed fruit held at 26.5°C . (C) Waxed fruit held at 4.5°C . (D) Nonwaxed fruit held at 4.5°C . (E) Collapsed oil gland during the early stages of pitting. (F) Epidermal cells injured from cold storage (4.5°C). O = oil gland, CO = collapsed oil gland, he = healthy epidermal cells, ie = chill injured epidermal cells, nh = necrotic hypodermal cells, v = vascular bundle. Bar = $200\ \mu\text{m}$.

Table 1. First study: effects of storage temperature, wax application, and degreening on pitting of 'Fallglo' tangerines.²

Storage temp (°C)	Wax	Pitting rating	
		Degreened	Nondegreened
4.5	+	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)
	–	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)
15.5	+	1.3 ± 0.4 (38)	1.8 ± 0.1 (54)
	–	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)

²Degreened fruit were exposed to 5 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene at 29.5 °C for 24 h. Waxed fruit were coated with a shellac-based water wax. Pitting represents the mean score ($\pm\text{SE}$) for $n = 3$ harvest dates (28 Sept., 3 Oct., and 24 Oct. 1995) with 10 fruit per harvest. Pitting was rated from 0 (none) to 5 (most severe) 20 d after wax application. Percentage of fruit with four or more collapsed oil glands is in parentheses. Main effects of storage temperature and wax application were significant ($\alpha = 0.01$).

bronze and then often turned dark brown several days later. In some clusters, only regions above the oil gland discolored. While adjacent clusters sometimes developed within hours of each other, cluster initiation did not spread progressively over the surface of the fruit (Fig. 2). Similarly, discoloration did not develop progressively over the fruit surface, but bronzing and eventual browning tended to spread across a given collapsed cluster. For example, cluster 2 (Fig. 2) began to discolor 3 d before cluster 4, but discoloration in both clusters occurred from left to right and over 4-d periods.

Anatomical evaluation of pitting confirmed that oil glands were the primary sites of damage (Fig. 3 A and E). In severe cases of pitting, epidermal and hypodermal cells above collapsed oil glands and surrounding vascular tissues were damaged, but cells between oil glands and adjacent oil glands were sometimes undamaged (Fig. 3A). No cuticular damage or wound periderm was observed in pitted tissue. In less severe cases, damage occurred primarily in cells within or enveloping the oil glands (Fig. 3E). In contrast to pitting, low temperature (4.5 °C) storage damaged epidermal cells, but not oil glands (Fig. 3 C, D, and F). Underlying parenchyma cells of the albedo were densely stained for all treatments (waxed or nonwaxed, 4.5 or 26.5 °C storage).

EFFECTS OF POSTHARVEST TREATMENTS. Pitting occurred on waxed fruit held at 15.5 °C, but not on nonwaxed fruit at this temperature or fruit held at 4.5 °C (Table 1). Degreening the fruit for 24 h before wax application did not affect pitting. Pitting of fruit taken from three harvest dates (28 Sept., 3 Oct., and 21 Oct.) were not significantly different.

Pitting occurred on fruit that were waxed 2 or 6 d after harvest and held at 15.5 and 26.5 °C. Waxed and nonwaxed fruit held at 4.5 °C did not pit (Table 2). Pitting was less frequent and less severe on fruit held at 15.5 than at 26.5 °C. Mild cases of pitting (<10 pits per fruit) occurred on 3 of 60 nonwaxed fruit held at 26.5 °C.

The most severe pitting (>70 % incidence) occurred on waxed fruit held at 26.5 °C or waxed fruit transferred from 4.5 to 26.5 °C 3 d after wax application (Fig. 4). Less severe pitting occurred on

waxed fruit transferred from 26.5 to 4.5 °C ($\approx 20\%$ incidence) and nonwaxed fruit held at 26.5 °C ($\approx 10\%$ incidence). Waxed and nonwaxed fruit held at 4.5 °C did not pit.

Waxed fruit with punctures and nonwaxed fruit had significantly higher internal O_2 levels and lower CO_2 levels than waxed fruit without punctures (Table 3). Pitting was reduced by puncturing the peel of waxed fruit and eliminated by not applying wax.

Pitting was not observed on nonwaxed fruit, but was observed on fruit coated with carnauba- or polyethylene-based waxes or any of the three shellac-based waxes (Table 4). Pitting incidence was less on fruit coated with carnauba-based wax than on fruit coated with the shellac-based waxes, but not less than fruit coated with polyethylene-based wax or nonwaxed fruit. Internal O_2 levels were lower for fruit coated with shellac- or polyethylene-based wax than fruit coated with carnauba-based or nonwaxed fruit. Internal CO_2 levels were greater for fruit coated with carnauba-based wax or two of the shellac based waxes than nonwaxed fruit, but less than fruit coated with polyethylene-based wax or the third shellac-based wax. The correlation coefficients for internal O_2 and pitting score and internal CO_2 and pitting score for all treatments were -0.75 and 0.50 , respectively.

Discussion

Postharvest pitting of 'Fallglo' may have been previously observed but diagnosed as another disorder. In Oct. 1994, for example, we examined fruit waxed at a commercial packinghouse and held at ambient temperature for 5 d. Because of the severity of the disorder, the peels were described to have melted during storage. The oil glands had collapsed thus causing the surface to develop deep pits. Since the pitting was primarily around the stem end, the disorder was diagnosed as stem-end rind breakdown (SERB).

SERB and postharvest pitting are distinct in the following ways.

- 1) SERB results from general collapse of the tissue. Pitting occurs in clusters and results from collapse focused on the oil gland.

Table 2. Second study: effects of storage temperature and time of wax application on pitting of 'Fallglo' tangerines.²

Storage temp (°C)	Pitting rating after harvest		
	2 d		6 d
	Control	Waxed	Waxed
4.5	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)
15.5	0.0 ± 0.0 (0)	0.9 ± 0.2 (33)	0.4 ± 0.2 (15)
26.5	0.1 ± 0.1 (5)	2.5 ± 0.2 (67)	1.6 ± 0.2 (53)

²Waxed fruit were held 2 or 6 d at 26.5 °C after harvest and coated with shellac-based water wax. Nonwaxed fruit were held 2 d at 26.5 °C before storage. Pitting represents the mean score ($\pm\text{SE}$) for $n = 6$ boxes of 10 fruit. Pitting was rated from 0 (none) to 5 (most severe) 20 d after harvest. Percentage of fruit with four or more collapsed oil glands is in parentheses. The interaction of storage temperature and wax application was significant ($\alpha = 0.01$).

Fig. 4. Third study: effects of altering storage temperature and shellac-based wax on percentage of pitted fruit for 'Fallglo' tangerines. Waxed fruit were held at 4.5 (did not pit) or 26.5 °C (●) or transferred from 4.5 to 26.5 °C (▲) or 26.5 to 4.5 °C (▼) 3 d after wax application (arrow). Nonwaxed fruit were held at 4.5 (did not pit) or 26.5 °C (○). Pitting was rated from 0 (none) to 5 (most severe) 3, 8, 15, and 22 d after wax application. Values represent percentage of fruit with pits (±SE) for n = 3 boxes of 19 fruit. Bars are not shown where symbol is larger than bar. Mean pitting score 22 d after application is in parentheses.

- 2) SERB develops at the stem end and usually does not spread to the midsection (Wardowski and Petrcek, 1995; Whiteside et al. 1988). Pitting appears primarily at the stem end and spreads to the midsection and stylar end.
- 3) SERB has a characteristic narrow band of unaffected peel surrounding the stem scar (Albrigo, 1972). Pitting develops in the region adjacent to the stem scar.

The potential misdiagnosis of 'Fallglo' pitting parallels that of grapefruit pitting (Petrcek et al., 1995), which was diagnosed initially as chilling injury (CI) because both disorders occur during storage and are characterized by collapse and discoloration of the peel. However, closer inspection of grapefruit pitting and CI revealed their differences. Pitting develops during high-temperature (≥ 15.5 °C) storage of waxed fruit (Petrcek et al., 1995), whereas CI occurs at low temperatures (≤ 10 °C) and is suppressed by wax application (Grierson, 1971). Pitting results primarily from oil gland collapse, whereas CI results from damage to epidermal and hypodermal cells (P.D. Petrcek and C. Davis, unpublished data).

Pitting of 'Fallglo' and grapefruit are similar in morphology. Pitting of both varieties is characterized by scattered clusters of collapsed oil glands (Figs. 1 and 2) (Petrcek et al., 1995). Wax application and high-temperature storage are required for pitting of both varieties, but ethylene exposure at degreening has no effect (Tables 1–3) (Petrcek et al., 1995). In contrast to 'Fallglo' in

which the stem end is the primary location of pitting, pitting of grapefruit is least prevalent at the stem end.

The anatomical evaluation of pitting showed that the oil gland was affected while epidermal cells above the damaged tissue were sometimes unaffected (Fig. 3 A and E). This is in contrast to disorders such as chilling injury (Fig. 3 C and D), oleocellosis, and physical damage in which epidermal and subepidermal cells are primarily affected.

Visual observation and time-lapse video illustrated that pit development was orderly, yet random. The collapse of oil glands occurred in clusters, but the shape and size of the clusters fit no apparent pattern. Pitting tended to develop first at the stem end, but pitting may develop anywhere on the fruit. Finally, discoloration of the pitted regions spread progressively across a given cluster, but discoloration among clusters was not simultaneous.

Wax formulation studies showed that, while shellac- and polyethylene-based waxes caused more pitting than a carnauba-based wax, pitting may be stimulated by all waxes (Table 4). A single formulation therefore does not cause pitting. Also, pitting was reduced by puncturing the fruit (Table 3). If pitting was simply a phytotoxic response to wax constituents, puncturing would not have reduced pitting. Pitting therefore may be related to internal gas levels.

Wax application and high-temperature storage are physiologically related by their effects on internal gas levels. Wax application restricts gas exchange (Hagenmaier and Baker, 1994), while high-temperature storage increases the respiration at a rate greater than that of gas permeability of the film (Beaudry et al., 1992). We have seen previously that the application of shellac-based wax combined with high-temperature storage yielded low internal O_2 (2.5%) and high internal CO_2 (6.0%) levels in white grapefruit (Petrcek et al., 1995). By puncturing the sheet of applied wax and cuticular membrane, a path for gas exchange is created. Internal O_2 and CO_2 levels of punctured waxed fruit and nonwaxed fruit are consequently similar (Table 3).

Although the effect of O_2 and CO_2 was not established for 'Fallglo,' we have determined that low O_2 (4% in controlled atmosphere chambers) stimulated pitting of white grapefruit at 21.0 °C (P.D. Petrcek, unpublished data). Preliminary results showed that pitting of 'Fallglo' also was stimulated by exposure to low O_2 (4% in controlled-atmosphere chambers, not shown). Nelson (1933) showed that peel disorders such as storage spot and brown spot, characterized by collapse of the cells between oil glands, also could be stimulated by exposure to N_2 and that damage of the cells above the oil glands was stimulated by acetic acid and acetaldehyde, products of anaerobic respiration. Although post-harvest pitting occurs primarily to cells of the oil gland, the collapse caused by wax application and high-temperature storage may be related to the previously described disorders in that volatiles produced by anaerobiosis may stimulate cellular degradation.

Table 3. Fourth study: internal gas levels and pitting of punctured 'Fallglo' tangerines.^z

Treatment	Internal gas level (%)		Pitting rating
	O_2	CO_2	
Waxed, no puncture	4.8 a	9.8 b	2.0 b (55)
Waxed, puncture	18.3 b	4.5 a	0.4 a (19)
Nonwaxed, no puncture	18.7 b	3.2 a	0.0 a (0)

^zA peel puncture was made by a cork borer (14 mm in diameter) incision. Fruit were held at 15.5 °C. Internal gas levels and pitting (0 = none to 5 = most severe) represent the mean for n = 3 boxes of 10 fruit 18 d after wax application. Percentage of fruit with four or more collapsed oil glands is in parentheses after pitting score. Mean separation within each column is by Duncan's new multiple range test ($\alpha = 0.01$).

Table 4. Fifth study: effects of wax formulation on pitting, and internal gas level of 'Fallglo' tangerines.²

Wax applied	Pitting incidence (%)	Internal gas	
		O ₂ (%)	CO ₂ (%)
No wax	0 a	18.7 d	1.0 a
Carnauba-based	8 ab	13.6 c	4.6 b
Polyethylene-based	23 bc	7.7 ab	6.7 c
Shellac-based 1	36 cd	8.5 ab	5.5 b
Shellac-based 2	43 cd	10.8 b	5.5 b
Shellac-based 3	48 d	6.5 a	6.9 c

²Pitting incidence is the percentage of fruit (n = 3 boxes of 16 fruit) with four or more collapsed oil glands after 20 d of storage at 21.0 ± 1.0 °C and 93% ± 2% relative humidity. Internal gas levels are average values for 10 fruit per treatment after 7 d of storage. Mean separation within each column is by Duncan's new multiple range test ($\alpha = 0.01$).

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