Efficacy of It's Fresh! Palladium ethylene scrubber in reducing ethylene and extending strawberry quality

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Background

- Approached by the Florida Strawberry Growers Association to evaluate It's Fresh!, a novel method for removing ethylene gas in consumer packages of strawberries and other produce.
- It's Fresh! has been reported to show potential for extending postharvest life of strawberry by reducing softening, darkening and decay (Elmi et al., 2013*).
- Since 2012, It's Fresh! package inserts have been used in multiple fruits, including: strawberries, stone fruit, tomatoes, avocados, pears, and cherries in both the U.K., and in the Americas.

*Elmi, F., K. Cools, and L.A. Terry. 2013. The use of It's Fresh! ethylene remover technology with e+® Active as a practical means for preserving postharvest fruit quality. Acta Hort. 1012:1205-1210.

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A New Palladium-Based Ethylene Scavenger to Control Ethylene-Induced Ripening of Climacteric Fruit

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A novel palladium-promoted zeolite material with a significant ethylene adsorption capacity at room temperature is described. It was characterised by diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) and transmission electron microscopy (TEM) to show palladium particles dispersed over the support. Initial measurements of the ethylene adsorption capacity were conducted with a synthetic gas stream at a higher ethylene concentration than would normally be encountered in fruit/vegetable storage, in order to obtain an accelerated testing protocol. Further laboratory-based trials on fruit samples show that the palladium-promoted zeolite material can be effective as an ethylene scavenger to prolong the shelf-life of fresh fruits.

Platinum Metals Rev., 2009, 53, (3), 112–122

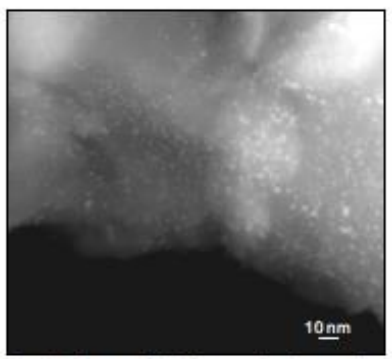

Fig. 3 TEM image of the Pd-promoted zeolite material showing nanometre size palladium particles (bright areas) on the zeolite support

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Development of new palladium-promoted ethylene scavenger

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Abstract

The control of ethylene in stored environments plays a key role in prolonging the postharvest life of many fresh produce types. However, there has been a paucity of research in recent years on developing novel and more effective ethylene scavenging materials. In this study a palladium (Pd)-promoted powdered material that has significant ethylene adsorption capacity (4162 $\mu L.g^{-1}$ material) at 20 °C and approximately 100% RH was identified and was shown to be far superior to $KMnO_4$-based scavengers when used in low amounts and in conditions of high relative humidity (RH).

Initial screening was carried out in a plug flow reactor with 200 $\mu L.L^{-1}$ ethylene, 10% (v/v) O_2 balanced with He at approximately 100% RH. Further work demonstrated that the Pd-promoted material at either 0.01 or 0.03 $g.L^{-1}$ effectively scavenged both exogenously administered (100 $\mu L.L^{-1}$) and/or endogenously produced ethylene by banana or avocado, respectively, to sub-$\mu L.L^{-1}$ concentrations within a 24 h period. Optimum ethylene adsorption capacity was calculated as approximately 10,000 $\mu L.g^{-1}$. Accordingly, corresponding inhibition of ethylene-induced ripening was observed. When removed, Pd-material did not disrupt subsequent ripening. The results from this study demonstrate that Pd-promoted material has commercial potential.

Keywords: Avocado; Banana; Ethylene adsorption capacity; Strawberry

The material is a palladium-impregnated zeolite giving finely dispersed palladium particles.

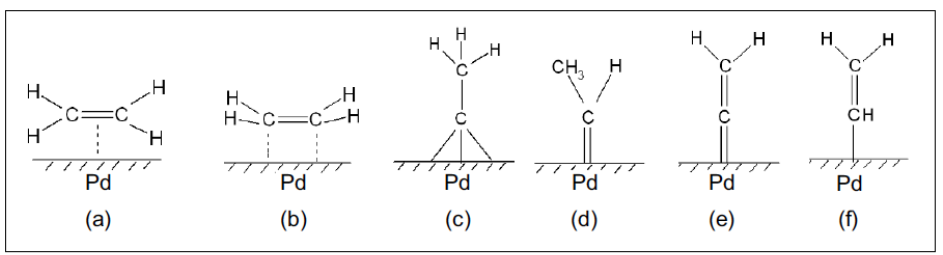

Fig. 8 Potential adsorbed species following exposure of the Pd-containing scavenger to ethylene: (a) π-bonded, (b) di-σ bonded, (c) ethylidyne, (d) ethylidene, (e) vinylidene and (f) vinyl

Wills & Kim from 1995: shelf life of strawberries at 0 or 20°C was doubled by reducing ethylene from 0.1 to <0.005 ppm

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Postharvest Biology and Technology

Effect of ethylene on postharvest life of strawberries

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Accepted 13 January 1995

Abstract

Strawberries are non-climacteric fruit and therefore regarded as independent of ethylene for ripening. The concentration of ethylene in punnets of strawberries in wholesale markets was found to be in the range 0.03–0.36 $\mu l\ l^{-1}$ per punnet. Experiments at 20 and 0°C, where the ethylene concentration was controlled, showed that the storage life of strawberries was extended by reducing the ethylene level. Maximum storage was obtained at the lowest ethylene levels used of 0.05 $\mu l\ l^{-1}$ at 20°C and 0.005 $\mu l\ l^{-1}$ at 0°C. The addition of potassium permanganate to punnets held at either of the above temperatures significantly extended storage life of the fruit and this may be capable of commercial exploitation.

Keywords: Strawberry; Ethylene; Storage life; Potassium permanganate

Found that scrubbing ethylene at either 0 or 20 °C (to 0.005 or 0.05 ul l^{-1}, respectively) significantly extended the storage life of strawberries due to decreased tissue softening, tissue collapse, color change to a translucent dark red, green color loss in the calyx and blackening in the stem-end.

Also stated,
"…the lack of of effect of ethylene reported by Siriphanich (1980) was probably due to his use of quite high ethylene levels of 1-100 ul^{-1} where fruit show little differential response."

Siriphanich, J. 1980. Postharvest deterioration of strawberries as influenced by ethylene and some other voaltiles. M.S. Thesis, University of California, Davis, Calif.

The Use of It's Fresh! Ethylene Remover Technology with e+® Active as a Practical Means for Preserving Postharvest Fruit Quality

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Keywords: photoacoustic laser ethylene sensor, pluot, strawberry

Abstract

The presence of ethylene in a storage environment can undermine both quality and postharvest life, often generating significant waste and associated economic losses. A demand for discovering alternative technologies capable of scavenging ethylene has led to the development of a new material, e+® active, which has significant ethylene adsorption capacity. The material has been shown to remove ethylene to below physiologically active levels during fruit storage at 0-20°C and consequently extend postharvest life for a variety of fresh produce types. Different formats have been evaluated. For example, "It'sFresh!" sheets containing e+® active were shown to be a highly efficacious format for suppressing ethylene and extending storage life of imported avocado and pluot plums in a series of trials. Indeed, It's Fresh! technology has also been shown to have profound effects on non-climacteric fruit types such as strawberry where quality-related attributes were affected. The mode of action of It'sFresh! technology with e+® active and the implications of scavenging ethylene in both non-climacteric and climacteric systems are discussed.

Proc. 7th International Postharvest Symposium
Eds.: H. Abdullah and M.N. Latifah
Acta Hort. 1012, ISHS 2013

Table 1. Effect of treatment on the colour of strawberries ('Elsanta' and 'Jubilee') stored for 7 days at 5°C with or without e+® (2.5 g powder).

Experiment	Hue angle (h°)		
	Control	E+	LSD (P<0.05)
1. Elsanta	31.67	33.52	0.709
2. Jubilee	34.77	35.70	0.862
3. Jubilee	34.28	35.19	0.827

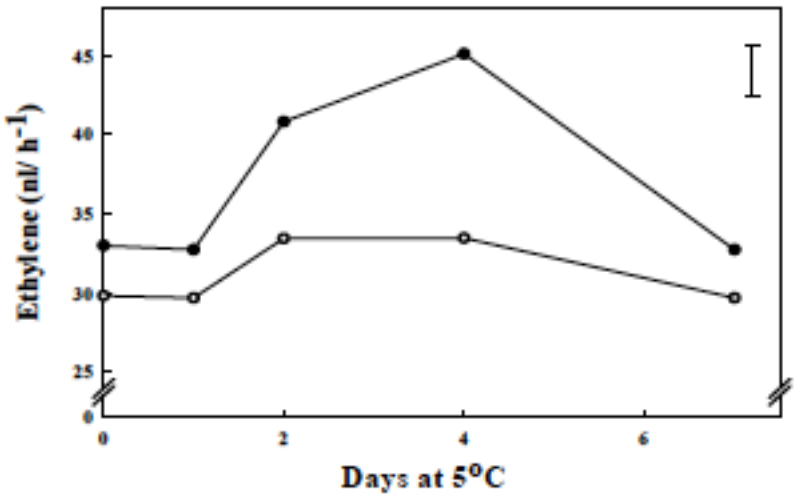

Fig. 2. Ethylene production (nl/h) of strawberry fruits ('Jubilee' Exp. 2.2) following storage at 5°C in 13 L boxes with (○, E+) or without (●, control) e+® powder (2.5 g). Ethylene production was measured at 18°C inside 1 L capacity jars (n=3 per treatment) connected to ETD-300. LSD bar (P<0.05).

"This study confirms the advantages of e+® in preserving postharvest fruit quality and has also demonstrated with the use of a highly sensitive ETD-300 ethylene detector, that ethylene may have a role in determining the postharvest quality of strawberry fruit."

Another view…

Postharvest Biology and Technology 28 (2003) 417 -423

Effects of ethylene and 1-MCP on the quality and storage life of strawberries

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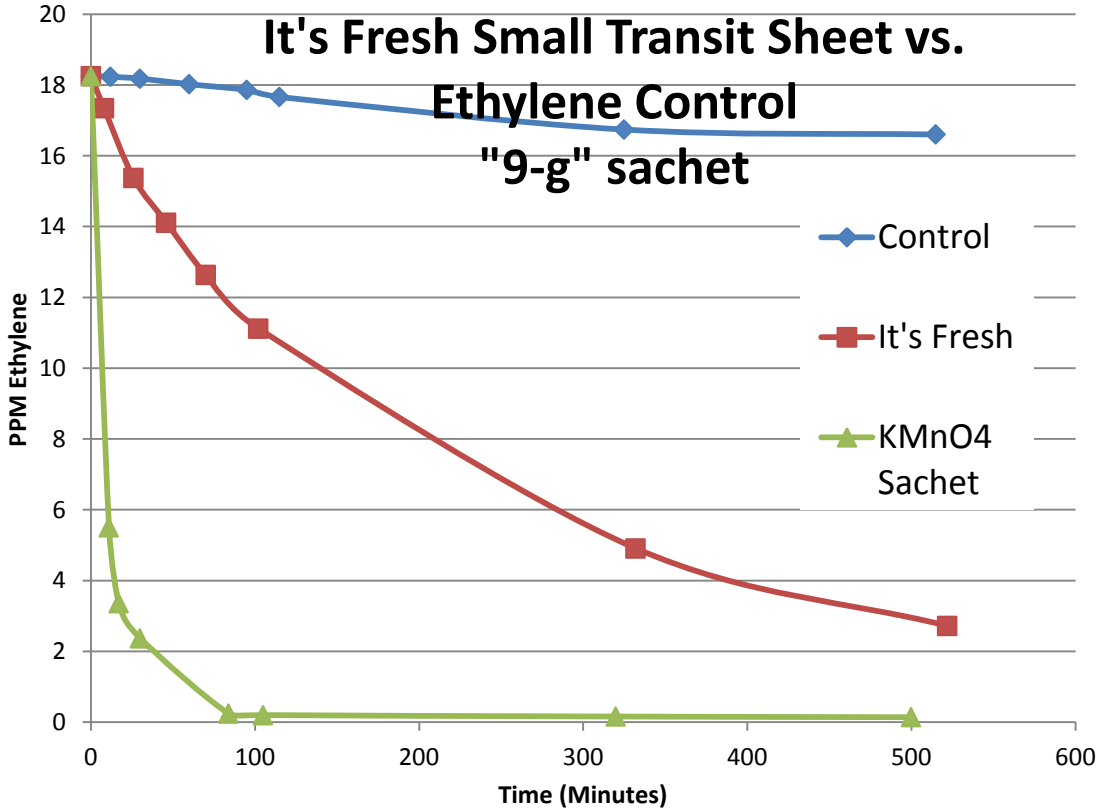
Abstract

Strawberry quality declines rapidly after harvest. Deterioration may be accelerated by ethylene and is potentially increased, decreased or unaffected by the ethylene inhibitor 1-MCP (1-methylcyclopropene). We have examined the effects of 0.01, 0.05, 0.1 and 1 ml l^{-1} of ethylene and 0.01, 0.1, and 1.0 ml l-1 1-MCP on the quality attributes and respiration rates of strawberries stored at 0 or 5 8C. Ethylene did not affect the rate of rot development. However, calyx quality was significantly reduced by exposure to 0.1 or 1.0 ml l-1 ethylene. Treatment with 1 ml l-1 1-MCP protected the calyx tissue from these effects. Exposure of strawberries to 0.01, 0.1 or 1.0 ml l-1 1-MCP did not affect overall fruit acceptability but did slightly increase the rate of rot development. 1-MCP treatment reduced ethylene production by the fruit. Increased production of CO2 by 1-MCP treated fruit was associated with the earlier onset of rots. Although the results suggest that blocking ethylene perception interferes with disease resistance in strawberries, there was only a small effect on total storage life. **It was concluded that neither the removal of low levels of ethylene from the storage environment nor the treatment with 1-MCP are likely to be cost effective methods of extending strawberry storage life.**

RESULTS

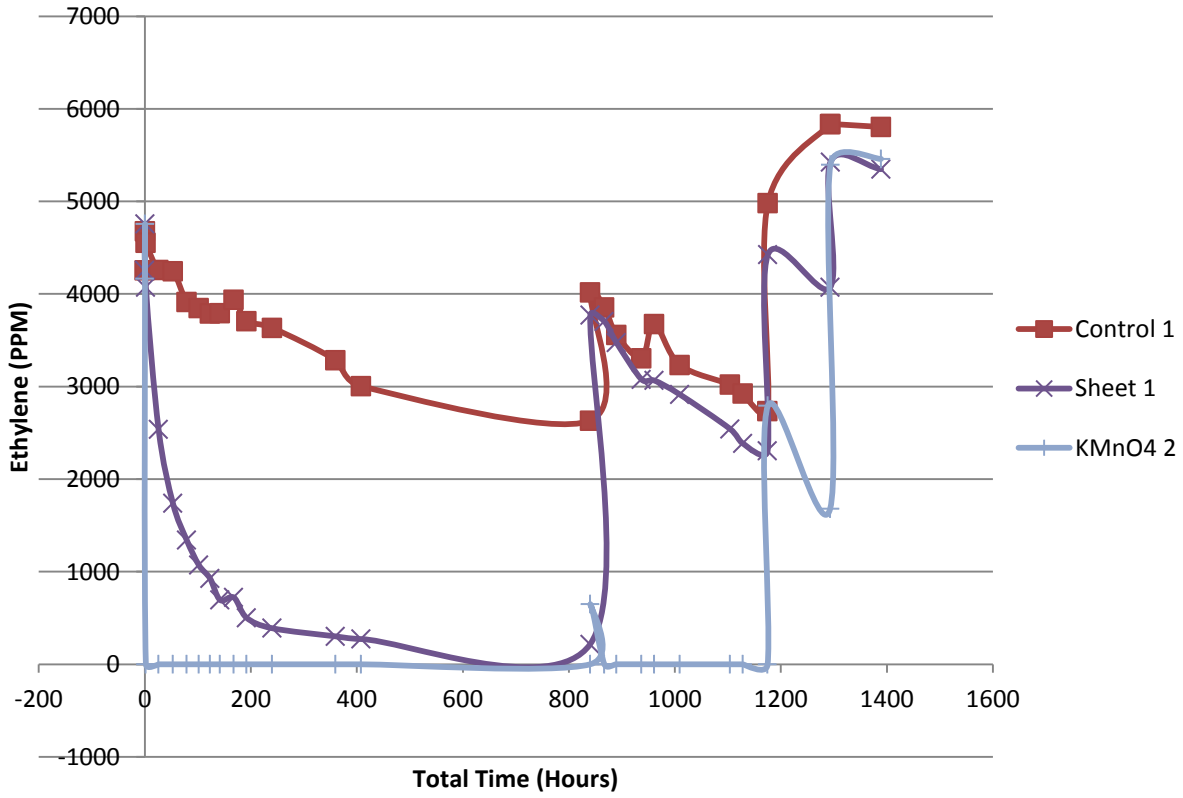
Comparison of It’s Fresh (palladium) and Ethylene Control (permanganate) ethylene adsorbers



- The initial rate of ethylene adsorption (reduction in concentration per minute) was almost 10 times greater for the $KMnO_4$ than for the It's Fresh! (0.52 uL min^{-1} versus 0.05 uL min^{-1}, respectively.
- However, the amount of active ingredient in the It's Fresh! sheets is less than 0.2% of the active ingredient in the sachets.
- Therefore, the rate of ethylene adsorption on a per weight basis (uL min^{-1} g^{-1} of active ingredient) was over 50 times greater for It's Fresh! than for $KMnO_4$.

Reduction in headspace ethylene concentration in sealed jars containing either a 4-in^2 (25.8 cm^2) It's Fresh! sheet or a 9-g Ethylene Control sachet at 77°F and 45% RH.
(The reduction in ethylene concentration in the control was due to leakage, which was corrected for in calculating the ethylene adsorption rates.)

- When ethylene adsorption was compared for low and high humidity it was found that the adsorption rate was about 25 to 30% lower in saturated humidity than in 45% RH for both the $KMnO_4$ sachets and the It's Fresh! sheets (data not shown).



- After repeated injections of ethylene, it was determined that the ethylene absorption capacity of the It's Fresh! sheets averaged 5,500 uL of ethylene per sheet and for the Ethylene Control sachets it was 8,000 uL of ethylene per sachet.

- However, the potential ethylene adsorption capacity for the It's Fresh! material is much greater than for $KMnO_4$ since the relative ethylene adsorption capacity on a per weight basis (uL g^{-1} of active ingredient) is almost 400 times greater for It's Fresh! than for $KMnO_4$.

Measurement of ethylene absorption capacity of a 4-in^2 (25.8 cm^2) It's Fresh! sheets and 9-g Ethylene Control sachets in sealed jars at 77°F and 45% RH.

(The reduction in ethylene concentration in the control was due to leakage, which was corrected for in calculating the ethylene adsorption rates.)

RESULTS

Strawberry shelf life evaluation in a simulated distribution system from farm to home

Sampling Procedure

- The strawberries were obtained from Wish Farms, Plant City, FL on the day of harvest and were collected immediately after forced-air cooling.
- A total of eight flats of strawberries with eight clamshells/flat (64 clamshells) were randomly divided into two sets at the cooling facility.
- It's Fresh! filter sheets (1 in^2) were attached to small fruit pads; one sheet per clamshell was placed inside one set of clamshells, and placebos (*i.e.*, inactive sheets) were placed inside the other set.
- The strawberry clamshells were placed into insulated coolers and transported by car to the Horticultural Sciences Department, University of Florida (approximately 2 hours).

Shelf-life Procedure

- The shelf life test was conducted at the Postharvest Laboratory at UF.
- Replicating a retailers supply chain, strawberries were evaluated for quality daily.
  1. In-D.C., in-store
  2. In-Home
- The clamshells with and without It's Fresh! sheets were stored in identical, separate temperature- and humidity-controlled rooms (temperatures variable; humidity 95% RH).
- Fruit quality evaluations were conducted daily; the evaluators did not know which It's Fresh! sheets were active and which were the placebos (i.e., it was a blind test).

Shelf-life Scenario:

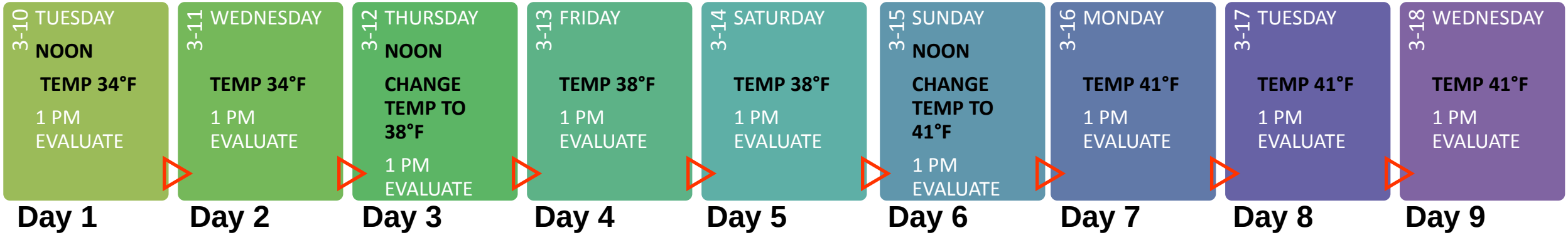
- **Day 1** – strawberries harvested and cooled to 38°F/3.3°C <4 hours after harvest; transported from Plant City to Gainesville and placed at 34°F/1.1°C

In-D.C., in-store

- **Days 1 to 3** – Simulated transport to and holding at Distribution Center (34°F/1.1°C)
- **Days 3 to 6** – Simulated retail store backroom and display (38°F/3.3°C)

In-Home

- **Days 6 to 9** – Simulated home refrigerator (41°F/5°C)



Quality evaluation schedule for shelf life test of ethylene scrubbing effect on strawberry quality.

Evaluation Procedure

64 clam shells per scenario x 2 (Control and It'sFresh!), evaluated from arrival at D.C. to in-home.

In-D.C., in-store

Clamshells scored as a "consumer" during the time in the D.C. and store, *i.e.,* "Would I buy this?"

1 = definitely would purchase, fruit is colorful, glossy and free of disease/damage,
2 = borderline purchase, fruit isn't looking fresh,
3 = definitely would not purchase, fruit is no longer colorful and glossy, signs of mold

In-Home

Clamshells scored as a "consumer" during the time in the home, *i.e.,* "Would I eat this?".

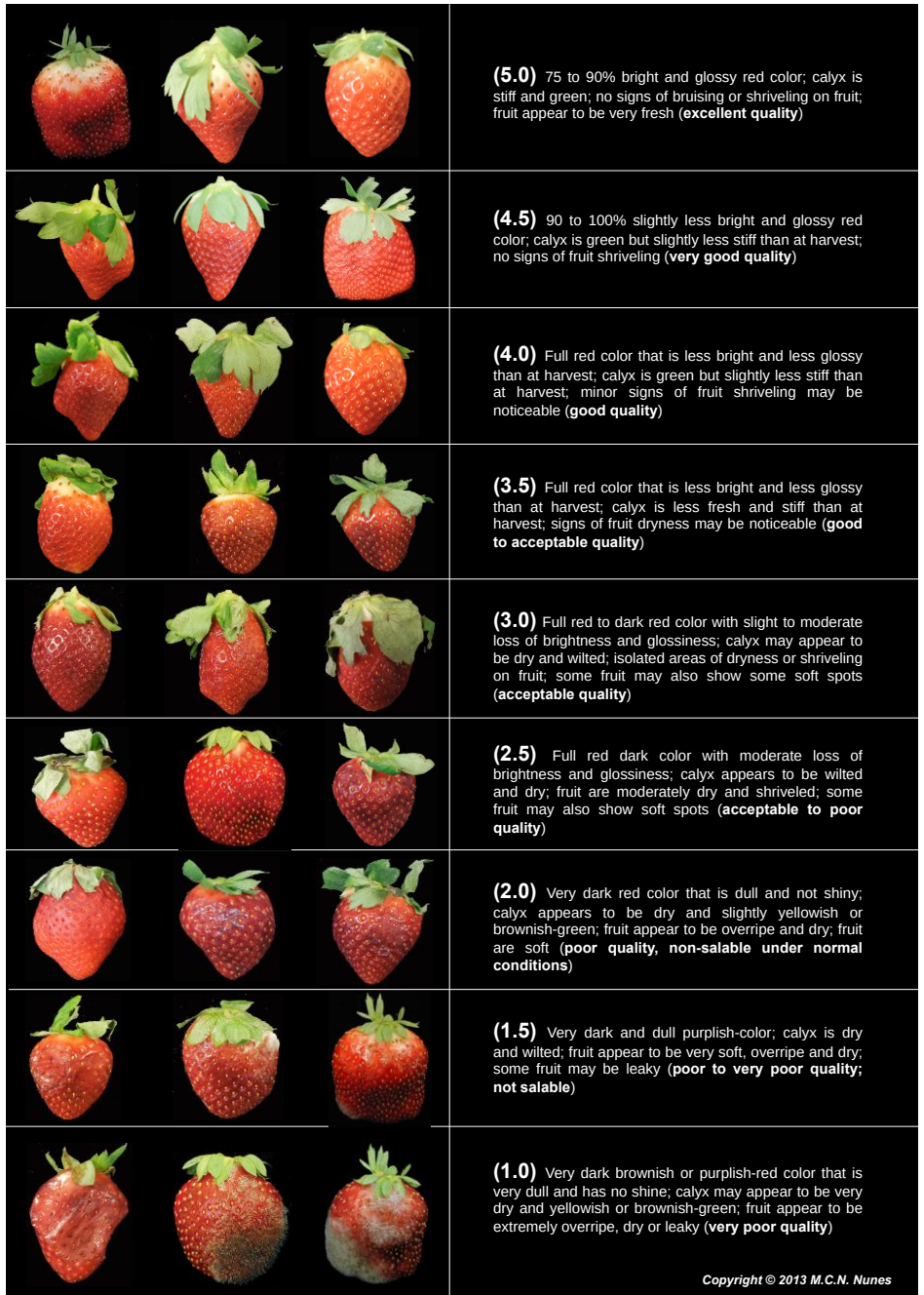
1 = definitely would eat/feed to my family,
2 = borderline, must eat immediately,
3 = definitely would not eat

Would I Buy?

1
(definitely would)

2
(borderline)

3
(definitely wouldn't)



(5.0) 75 to 90% bright and glossy red color; calyx is stiff and green; no signs of bruising or shriveling on fruit; fruit appear to be very fresh (**excellent quality**)

(4.5) 90 to 100% slightly less bright and glossy red color; calyx is green but slightly less stiff than at harvest; no signs of fruit shriveling (**very good quality**)

(4.0) Full red color that is less bright and less glossy than at harvest; calyx is green but slightly less stiff than at harvest; minor signs of fruit shriveling may be noticeable (**good quality**)

(3.5) Full red color that is less bright and less glossy than at harvest; calyx is less fresh and stiff than at harvest; signs of fruit dryness may be noticeable (**good to acceptable quality**)

(3.0) Full red to dark red color with slight to moderate loss of brightness and glossiness; calyx may appear to be dry and wilted; isolated areas of dryness or shriveling on fruit; some fruit may also show some soft spots (**acceptable quality**)

(2.5) Full red dark color with moderate loss of brightness and glossiness; calyx appears to be wilted and dry; fruit are moderately dry and shriveled; some fruit may also show soft spots (**acceptable to poor quality**)

(2.0) Very dark red color that is dull and not shiny; calyx appears to be dry and slightly yellowish or brownish-green; fruit appear to be overripe and dry; fruit are soft (**poor quality, non-salable under normal conditions**)

(1.5) Very dark and dull purplish-color; calyx is dry and wilted; fruit appear to be very soft, overripe and dry; some fruit may be leaky (**poor to very poor quality; not salable**)

(1.0) Very dark brownish or purplish-red color that is very dull and has no shine; calyx may appear to be very dry and yellowish or brownish-green; fruit appear to be extremely overripe, dry or leaky (**very poor quality**)

Would I Eat?

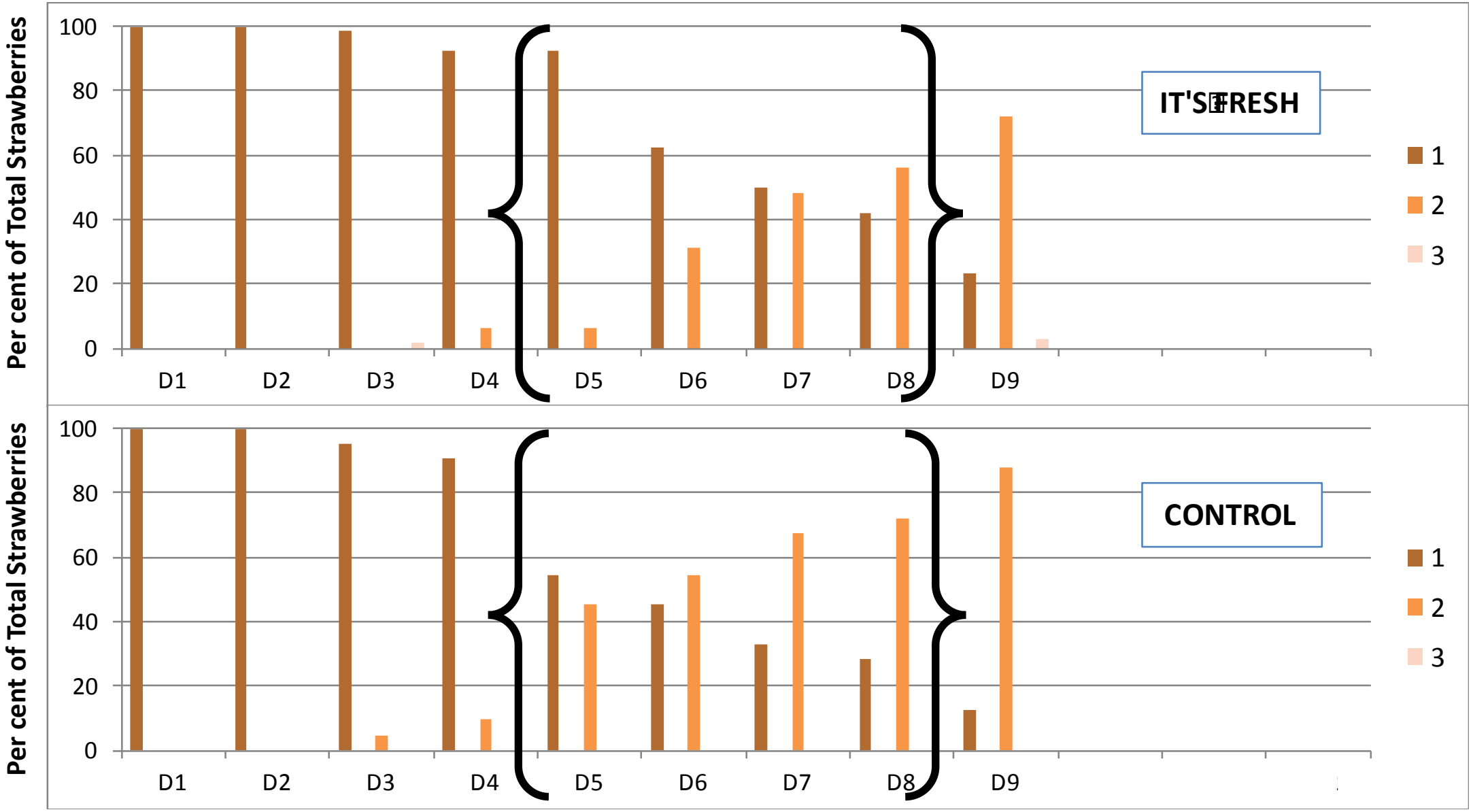
1
(definitely would)

2
(borderline)

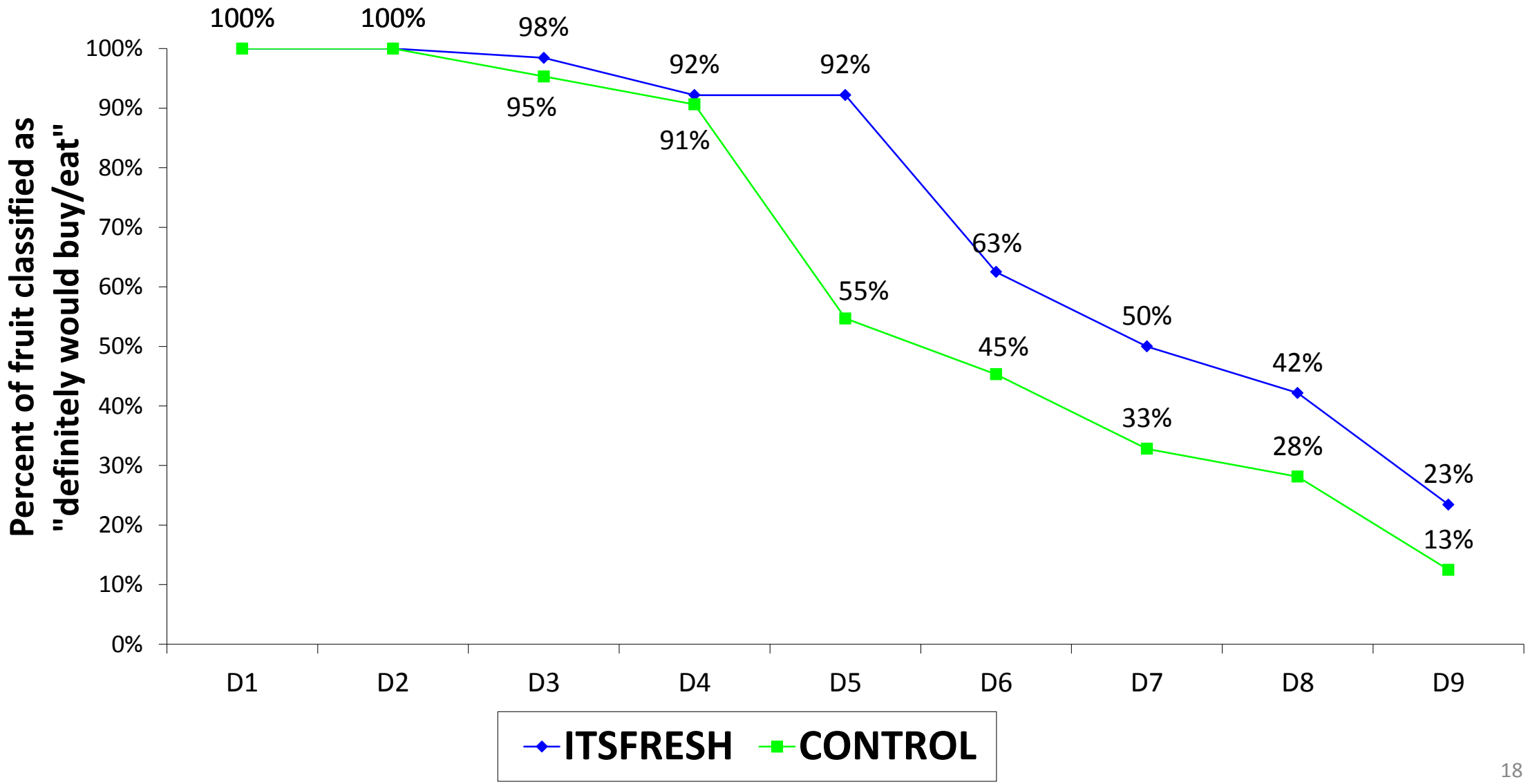
3
(definitely wouldn't)

Rating scale with illustrations and definitions courtesy Cecilia Nunes, Univ. of South Florida

Quality Assessments – from 1, "Definitely Would Buy/Eat“ to 3, “Definitely Wouldn’t Buy/Eat”
Comparing Control versus It’sFresh! Strawberries



Quality Assessments – Per cent "Definitely Would Buy/Eat“ Comparing Control versus It’sFresh! Strawberries

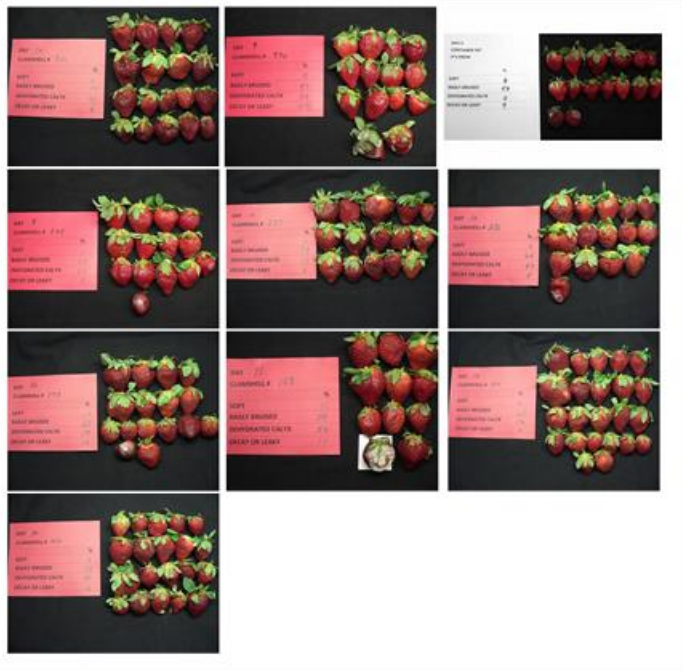


FLORIDA STRAWBERRY RESULTS – DAY 11
Categorized as #3, “definitely would not eat”

“…clear differences in bruising severity and also drying of sepals between control and It’sFresh!”

CONTROL – **28 clamshells out of 64 = 44%**
“definitely would not eat”

IT’SFRESH! – **10 clamshells out of 64 = 16%**
“definitely would not eat”



Conclusions

- On a per weight basis It's Fresh! adsorbed ethylene 50 times faster than $KMnO_4$ with an adsorption capacity 400 times greater.
- Ethylene adsorption rate was about 25 to 30% lower in saturated humidity than in 45% RH for both the $KMnO_4$ sachets and the It's Fresh! sheets.
- In the simulated handling test from post-forced-air cooling to the consumer, 1-in^2 It's Fresh! sheets extended strawberry quality both in-store and at home.
  - Shelf life was extended by about 1 day by slowing the development of dry calyx and sunken bruised areas starting on day 5 from harvest and continuing through simulated retail display and in the consumer's home (day 9).
  - Additionally, at the end of the simulation, 44% of clamshells in the control were rated "definitely would not eat" while only 16% of clamshells in the It's Fresh! treatment were similarly rated.
- This suggests that considerably more strawberries would likely be consumed and less fruit discarded by consumers in the home with the use of It's Fresh!

Acknowledgements

- These tests would not have been possible without the collaboration and contributions of time, resources, and materials from:
  - **Wish Farms**, Plant City, FL (Gary Wishnatzki)
  - **It's Fresh! Ltd.** (Greg Pavett)

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