

Long-term controlled atmosphere storage techniques on 'Granny Smith' apples

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Reason for long-term storage

Image URL:

<https://www.hortgro.co.za/wp-content/uploads/docs/2018/07/key-deciduous-fruit-statistics-2017.pdf#page=7>

Image URL:

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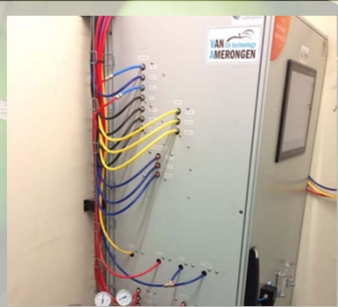
Edited figure, Source of original:
HORTGRO Key Statistics (2017)

Source: HORTGRO Key Statistics (2017)

Promising long-term storage systems



Dynamic control atmosphere - chlorophyll fluorescence (DCA-CF)



Dynamic control atmosphere - respiration quotient (DCA-RQ)



Extreme ultra low oxygen (XLO)

Dynamic Controlled Atmosphere (DCA)

- The gas composition of the storage environment is adapted according to sensors, enabling adaption in response to the fruit metabolism
 - Adjustments are achieved by pumping in O₂ rich air (atmospheric composition)
- 3 sensor types for monitoring
 1. Chlorophyll fluorescence (CF)
 2. Respiration quotient (RQ)
 3. Ethanol (ET)
- Benefit of DCA
 - Prohibits extended storage under anaerobic conditions



Aims

- I. Comparison of fruit quality maintenance between systems.
- II. Comparison of respiratory quotient reading and subsequent oxygen control between DCA-CF and DCA-RQ storage systems
- III. Determining the effect of ethylene scrubbing on the storability of fruit under DCA-CF storage.
- IV. Comparing biochemical data between fruit stored under different long term storage techniques.
- V. Evaluate the effect of different low oxygen storage techniques on the overall sensory sensation of fruit.

How does XLO work?

“Static” CA,

No in situ sensors to monitor fruit response to the modified atmosphere

LOW TOLERANCE TOWARDS DEVIATIONS FROM SET GAS LEVELS

- **Benefit of XLO (O_2 : 1.2 - 1.5 %, CO_2 : 0.6 - 1.0 %)**

- Better quality maintenance, compared to standard CA storage
- Extremely sensitive ethylene sensors (0,001 ppm)

Image URL:

https://www.researchgate.net/figure/Planning-used-for-Royal-Gala-apple-conditioning-to-ultralow-oxygen-partial-pressures_fig1_304628697

Source: Both et al., (2016)

How does DCA-CF work?

- Sensors measure chlorophyll fluorescence, a peak/sharp increase shows O₂ stress
- **Benefit of DCA-CF**
(O₂: 0.3 - 0.8%, CO₂: 0.3 - 0.8 %)
 - Better quality maintenance, compared to standard CA storage (O₂: 1.5%, CO₂: 1.0 %)
 - Reduced incidence of O₂ related disorders

Source: Wright et al., (2012)

Image URL:

<https://ars-els-cdn-com.ez.sun.ac.za/content/image/1-s2.0-S0925521411002298-gr2.jpg>

How does DCA-RQ work?

- **Sensors measure the CO₂ produced and O₂ consumed during storage, respiratory quotient (RQ) is calculated**
 - $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{energy}$
 - $RQ = CO_2 \text{ produced} / O_2 \text{ consumed}$ (1 = aerobic, > 1 anaerobic).
 - When RQ value is above the set-point RQ value the oxygen partial pressure is raised
- **Benefit of DCA-RQ**
 - Better quality maintenance, compared to standard CA storage
 - Measures the overall metabolic response

Image URL:

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Source: Bessemans et al., (2016)

Aim 1

**Fruit quality maintenance
comparison between
different
low oxygen storage techniques**

Image URL:

<https://ars.els-cdn.com/content/image/1-s2.0-S0308814616312390-gr4.jpg>

Source: Both et al., (2016)

Aim 1 - Methodology

- **Evaluation times**

- At Harvest
(obtaining a baseline)
- After 30 weeks of storage
at 0 °C
- + 6 weeks RA at -0.5 °C
- + 10 days shelf-life at 20 °C.

Source: Bessemans et al., (2016)

Image URL:

https://ars-els-cdn-com.ez.sun.ac.za/content/image/1-s2.0-S092552141530199X-gr8_lrg.jpg

Evaluation Parameters

- Flesh Firmness
- Total Soluble Solids
- Titratable Acidity
- Starch Breakdown
- Superficial Scald Incidence And Severity
- Colour Change (A.38 & H,L,C)
- External Defects e.g. Greasiness
- Internal Defects e.g. Core Flush, Browning



Aim 1

Treatment	Replicates (Janny ^{MT} bin)	Minimum fruit per replicate
DCA-CF	3	720
DCA-CF + ethylene scrubbing	3	720
DCA-RQ	3	720
XLO + ethylene scrubbing	3	720

**Evaluation per evaluation date (excluding at harvest),
per replicate, per treatment**

Maturity indexing	Scald development
20 fruit (60 Fruit – Biochemical, 10 Ethylene)	Remainder

Aim 2

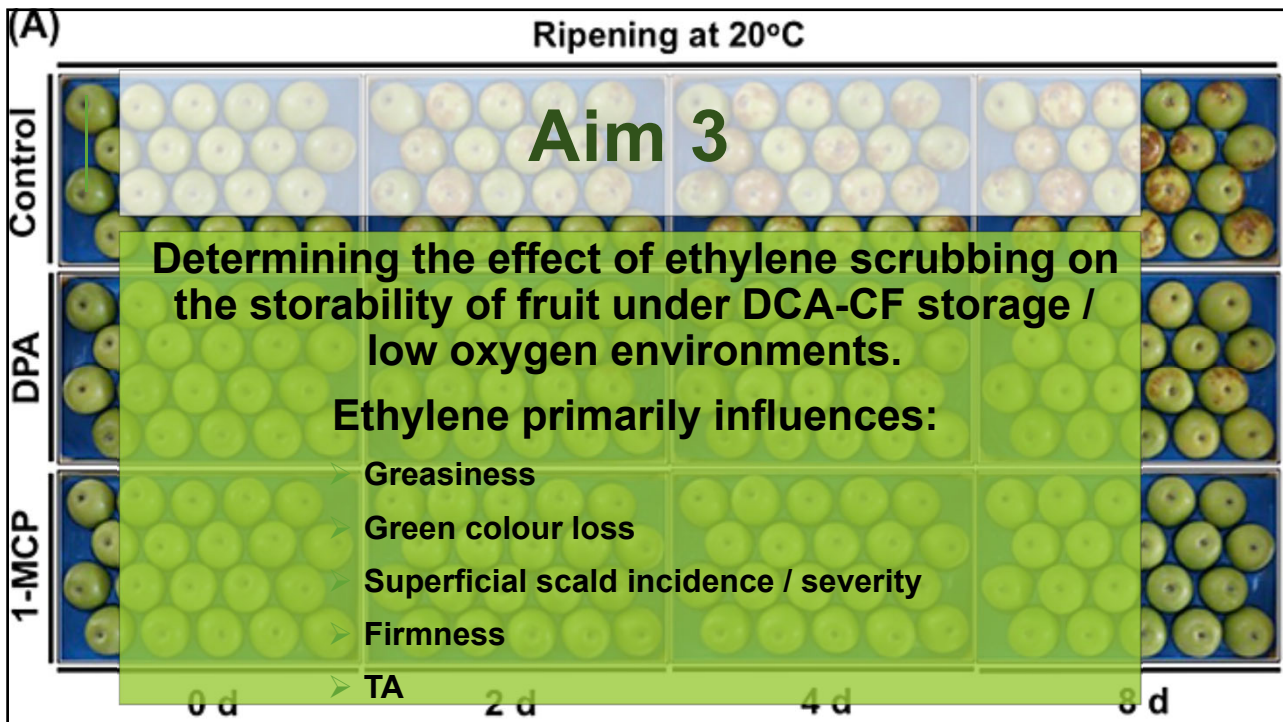
Comparison of RQ reading and subsequent O₂ control between DCA-CF and DCA-RQ storage systems

1. Compare the RQ readings obtained under both systems.
2. Determine which method is more prone to increase O₂ levels (which system maintains the lowest O₂ levels).

Source: Both et al., (2016)

Image URL:

<https://ars.els-cdn.com/content/image/1-s2.0-S0308814616312390-gr1.jpg>



Effects of ethylene scrubbing:

Why ethylene matters:

1. The synthesis of α -farnesene is ethylene dependent (Watkins et al., 1993; Ju & Curry, 2000).
2. 1-MCP's efficiency in lowering scald in apples confirms that ethylene is the main inducer of scald (Fan et al., 1999; Zanella, 2003).
3. The main effect of initial low oxygen stress treatments is the reduction of ethylene production during cold storage, which results in a reduction in superficial scald development (Pesis et al., 2010).

Effects of ethylene scrubbing:

Practical implications:

1. The regulation of ethylene action or biosynthesis has a notable effect on volatile production in apple (Defilippi et al., 2005).
2. Ethylene level (averages of tested levels: 2440, 178, 0.231 ml/l) had no significant influence on fruit flesh firmness and TA retention in 'McIntosh' apples stored for 210 days under 1.5% CO₂ + 1.0% O₂ directly after storage (Lidster et al., 1983).
3. Malic acid degradation is suppressed under low ethylene conditions (Defilippi et al., 2004).

Effects of ethylene scrubbing:

Practical implications (continued):

4. In the case of 'Cox Orange Pippin' flesh firmness retention was extended by ethylene scrubbing from the store atmosphere, at the tested O₂ levels of 1.25, 1.0, and 0.75%, both after 153 days of storage and after 14 days of shelf life (Stow, 1990).
5. Ethylene scrubbing significantly reduced TA acidity loss under CA storage utilizing 0.75% O₂ in the case of 'Cox Orange Pippin' stored for 153 days (Stow, 1990).

Aim 4

**Biochemical parameters
under different low O₂ storage techniques**

**Biochemical parameters
per evaluation date per replicate, per treatment**

ROS	MHO & EtOH	ACC, α -farnesene, CTols (Frozen)	Internal gasses O ₂ ; CO ₂ ; C ₂ H ₄
10 fruit	10 fruit	20 fruit	10 fruit
			2 fruit per reading

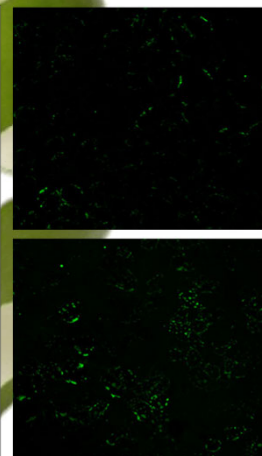
Aim 4

Headspace volatile analysis

- α -farnesene, MHO & ethanol
- 3 replicates, 10 fruit per replicate (in duplicate)
- GC-MS (Agilent technologies)

Reactive oxygen species (ROS) production

- 3 replicates, 10 fruit per replicate
- Fluorescent confocal microscopy



Aim 4

Conjugated trienols (CTols)

- 3 replicates, 20 fruit / rep
- HPLC
- UV Spectrophotometrically (α -farnesene & CTols)
- Fruit peel is frozen with liquid nitrogen
- Stored at -80 °C till analysis

Source: Wang (2016)

Image URL:

<https://journals.ashs.org/jashs/view/journals/jashs/141/2/177fig4.jpeg>

Aim 5

Effect of different low O₂ storage techniques on the overall sensory quality of fruit

Descriptive Sensory Analysis (DSA)

- A standard unstructured 100-point line scale
- Sensory profile per treatment
 - After long term storage
 - After simulated shipping
 - After shelf-life
 - 3 replicates per treatment - 2 fruits per replicate
 - Trained panel

Expected Outcomes

- I. Fruit quality storage profiling for different long term methods.
- II. Idea of the control of O₂ & CO₂ under different methods.
- III. Comparison of RQ value of DCA-CF and DCA-RQ storage methods
- IV. Does ethylene scrubbing influence long term DCA/CA storage quality?
- V. Biochemical data between fruit stored under different long term storage methods
 - a) Understand mechanisms e.g. α -farnesene vs. internal ethylene / ACC
 - b) How high is ethanol in DCA-RQ vs. DCA-CF vs. XLO?
- VI. Sensory experience between fruit stored under different long term storage methods

Points of interest:

1. Core flush incidence decreases with decreasing O₂ concentrations utilized in long term storage in the case of 'Granny Smith' (Zanella, 2003), however ethylene scrubbing under low oxygen storage (1.25, 1.0, and 0.75% O₂) has been shown to exacerbated core flush incidence in 'Cox Orange Pippin' stored for 153 days (Stow, 1990).
2. A modified atmosphere of 1.0% O₂ decreased ethylene accumulation during storage, as well as suppressed ethylene and CO₂ production at the end of storage compared to conventional CA (Lidster et al., 1983). Will additional ethylene scrubbing be economical?
3. Ethylene has been shown to be an important modulator in the biosynthesis of aroma compounds under normoxia (Defilippi et al., 2005).

THANK YOU

HORTGRO
Growing Fruit IQ
science



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Gas At Site
Isolcell
CONTROLLED ATMOSPHERE SINCE 1958

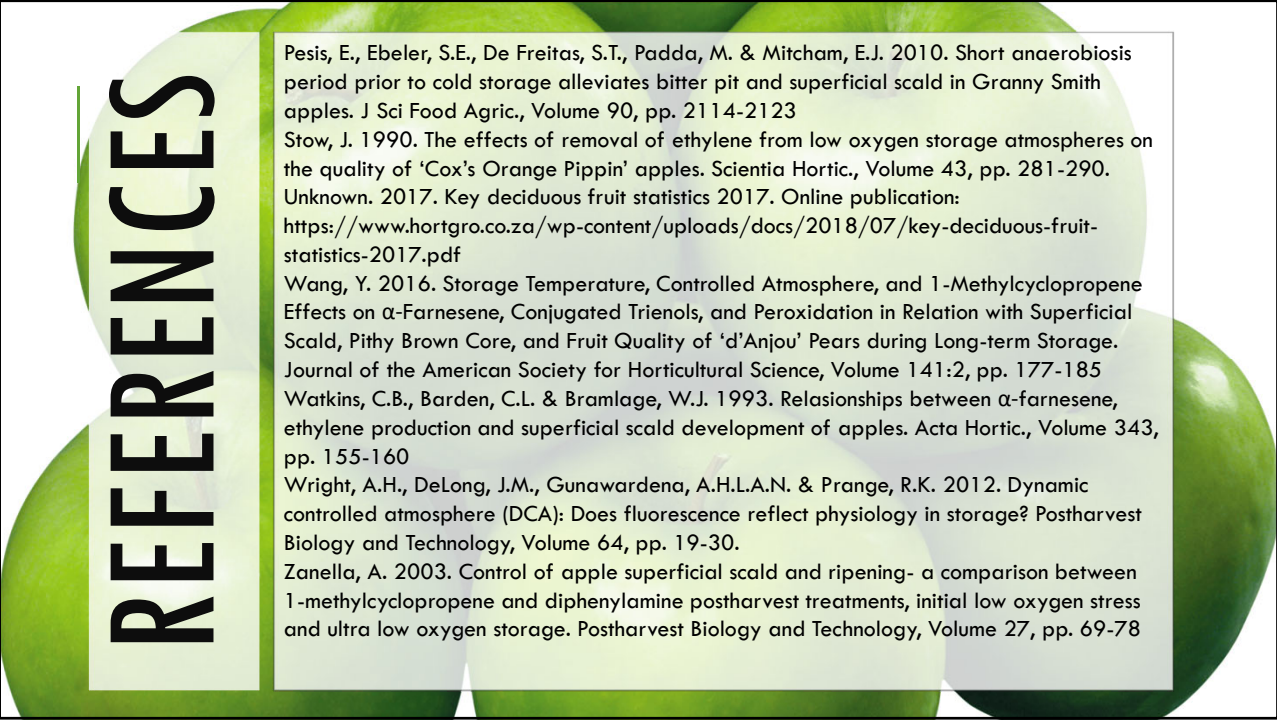


VAN CA technology
AMERONGEN

QUESTIONS?

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