European practices for storage of Pink Lady® apples

THE VISION FOR PINK LADY® APPLES
BEST PRACTICE TECHNICAL CONGRESS
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European practices for storage of Pink Lady® apples

- Good practice at harvest and during storage.
- Alternatives to SmartFreshSM:
  - Storage under 1% of O2 (like Dynamic Controlled Atmosphere)
  - Other alternatives: low ethylene, hot water...
- Current European practices in France, Spain, Italy...
How to obtain a good Pink Lady® apple?

- **Quality of the fruits**: Pink Lady® apples have a great potential regarding to this point.
- **Good Practices in orchard**, climatic conditions.
- **Maturity at harvest**, picking date and good practices around harvest.
- **Quality of the storage**, following the storage recommandations and good practices.
Harvest of Cripps Pink apples

How to estimate harvest date?
- Size, color (*Ctifl chart*), starch conversion (*Ctifl chart*), quality measurements (firmness, sugar, acidity).
- Following the “maturity network”
- APLE recommendations.
Optimum stage for harvest in France

For long term storage and good quality:
- **Starch index**: 4-5 on the 10 stages scale for 1st harvest.
- **Firmness**: 8-7 kg/cm²
- **Color**: Background color: B3-B4

*Source: Maturity network 2014 conducted by CEHM for APLE.*
More risks with a late harvest

- **Low Quality:** Low firmness at harvest and after storage; Bad texture; Greasy fruits; Yellow background color.

- **More disorders:** Internal browning; Rots; Stem end scald.

- **Bad impact on storage:** SmartFresh℠ treatment less effective; shorter storage life ...

*Apple is a climacteric fruit!*

**Risk with an early harvest:** Scald; Small size; Less sugar, Less color...
Good practices at harvest

- Good traceability and knowledge of the orchard: age, load, specific problems; climate accident...
- Good appreciation of fruit maturity.

Correct orientation of the fruits

<table>
<thead>
<tr>
<th>Long term storage:</th>
<th>Short term storage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} and 2\textsuperscript{nd} pick</td>
<td>Late harvest, over mature, less color</td>
</tr>
<tr>
<td>Homogenous pick</td>
<td>Heterogeneous pick</td>
</tr>
<tr>
<td>From well-balanced orchard</td>
<td>Young orchard (&lt; 3 years)</td>
</tr>
<tr>
<td>Less mature fruits</td>
<td>With a low fruit load</td>
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</table>
Good practices for storage

- **Before storage:**
  - Check the cooling facility & temperature probes.
  - Check the CA equipment & tightness of the rooms.

- **After harvest:**
  - Respect the cooling power of the cold room (tons/day),
  - Fill the room within a week; start the CA when all fruits are cold.
    - *Specific SmartFresh℠ or DCA Recommendations*

- **During storage:**
  - Respect the set temperature.
  - Monitor CA: Double check (portable analyzer), standard bottle.

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**Main risks during storage and grading**
- Low temperature, high CO₂ = internal browning
- Shocks = bruising / « carry with care »
Alternatives to SmartFresh™

- Storage under 1% of O₂:
  - Dynamic Controlled Atmosphere with Chlorophyll Fluorescence
  - Other DCA; “Extremely Low Oxygen”...
- Other alternatives: Low Ethylene storage, Hot Water dipping...
- Impacts on quality.
- Situation in Europe.
- Good practices for these storage methods.

- DCA-CF sensors - Isolcell
- Ethylene scrubber - Absoger
- Hot Water dipping - Xeda International
HarvestWatch system - Isolcell (Italy).

- Storage under very low O2 conditions dynamically adapted to the fruit reaction.
- By using chlorophyll fluorescence measurement, followed by FIRM sensors (Fluorescence Interactive Response Monitor).
- Decrease O2 rate until the acceptable limit:
  - Skin emits a stress signal detectable by measuring fluorescence (stress spike)
  - Then, increase the O2 rate (+0.2 %) to prevent fermentation (minimum 0.4-0.5 % O2).
- Impacts:
  - Low respiration; low ethylene production
  - Impact on quality: Scald control, firmness...

FIRM sensor

Spike : 0.1 % O2
ACR – Advanced Control Respiration

ACR system - Van Amerongen (the Netherlands) and AgroFresh: Advanced Control Respiration, by using O\textsubscript{2} and CO\textsubscript{2} sensors. ACR measures changes in the RQ (= CO\textsubscript{2}/O\textsubscript{2}) of the whole fruit load.

- When RQ values go up, the O\textsubscript{2} levels will be slightly increased automatically to avoid fermentation.
- Controls and adjusts automatically the O\textsubscript{2} level in the room. It brings and keeps the O\textsubscript{2} level to lower and safe levels, based on RQ.
Other DCA or Extremely Low Oxygen storage...

- **Swinglos™ - Fruit Control Equipments (Italy)**
  - Between ILOS (Initial Low Oxygen Stress) and DCA:
    - 0.5% O2 for 15 days at the start of storage; then storage under Extremely Low Oxygen (< 1%).
  - Repeating the “stress” (2-3 times) during storage
  - Monitoring the level of ethanol in juice
    - 50-100 ppm max. for Pink Lady®

- **Extremely Low Oxygen (XLO) – Absoger (France):** “Static” CA at very low O2 concentration (< 1%). Good results, no indicator during storage.

- **Storex (the Netherlands):** DCS™ - Dynamic Control System; Monitoring the ethanol concentration in the air of a box placed in the CA room.

- **Besseling (the Netherlands):** DFR – Dynamic Fruit Respiration; Fruit Observer...

- **Storage Control System (USA):** Safepod system (based on RQ – Respiratory Quotient)...

*Swinglos™ Analysis kit*
Other alternatives

- **Low ethylene storage:**
  - Several techniques available:
    - chemical (with potassium permanganate);
    - physical (catalysis, photocatalysis ...).
  - **Target**: close to 1 ppm ethylene in the air during storage.
  - For an effect on scald, it has to be used in ULO.
  - Regular improvement of the equipment...

- **Hot Water dipping:**
  - 2-3 min à 48°C.
  - Effect on scald, interesting in combination with ULO.
  - **Main interest on rots** (especially for organic production).
  - Currently, the processing rate is the limiting factor.

Burg's Machinefabriek bv
Credit: G. Bompeix
Impact on apple disorders

Conclusions from 2010-2013 project

- **Good scalld control with “very low O2”**.
  - Low ethylene or Hot Water have to be associated with ULO for long storage.
- **Decay:**
  - Good effect of treatment with **Hot Water**. Gloeosporium rot often reduced with SmartFresh\textsuperscript{SM} and “**very low O2**”.
- **Greasy appearance:** may be observed after long storage in CA but rare or absent for other CA techniques.

**On Pink Lady\textsuperscript{®}:** with 6 trials, 1\textsuperscript{st} harvest, at 2\textdegree{}C, with long storage (6 months).
- **Scald:** Only in CA in 2 trials (50-80%). No scald in the others.
- **Internal browning:** Slight IB in 4 trials out of 6. Between 20-30 \% on avg. in CA, SmartFresh\textsuperscript{SM} or “very low O2”.
- **Stem end scald** reduced or stopped by “very low O2”.

Source: Mathieu-Hurtiger V., 2014
Impact on apple quality
Conclusions from 2010-2013 project

Firmness:
- **Very Low O2:**
  - Firmness higher than in CA (*XLO > CA in 5 trials out of 7 for Pink Lady®*)
  - DCA close to XLO (or slightly higher).
- **SmartFreshSM + CA:** significantly firmer than “Very Low O2” in 19 out of 28 tests (gap widens during shelf-life).
- **Hot Water:** slight decrease of firmness on some varieties (especially bicolor and Golden, but not Granny Smith).
- **Low Ethylene:** rather positive effect on firmness (sometimes significant).

Other parameters: *Color, Sugar, Acidity*

**Very low O2:**
- Limits the evolution of the background color (less than SmartFreshSM);
- Little effect on sugar; higher acidity (but slightly less than SmartFreshSM).

**Hot Water / Low Ethylene:** almost no effect.

*Source: Mathieu-Hurtiger V., 2014*
Rosy Glow: Long cold storage after CA

**2011-2012 - 4 months of CA + 2 months in cold + 10 days of shelf-life**

$T^\circ C$ 2°C - Harvest end of October: Starch 6.1 – Firmness: 7.5 kg/cm²

**2013-2014 – 5.5 months in CA + 2 months in cold + 9 days of shelf-life**

$T^\circ C$ 2°C - Harvest end of October: Starch 4.7 – Firmness: 8.6 kg/cm²
Impact on aromatic compounds & nutritional quality

Results on Pink Lady® 2010-2011 trial

- More flavors in cold storage.
- Reduction in CA, accentuated by DCA.
- Significant impact of SmartFresh℠
- Fall of the vitamin C content after harvest, no impact of atmosphere (Granny Smith, 2 years of study)
- Very small changes in the amount of polyphenol compounds after harvest, no impact of atmosphere (Granny Smith and Pink Lady®, 2 years of study)

Source: Aubert C., 2015
Impacts on the taste of Pink Lady® apples

2 trials with a panel on Pink Lady®:
- **Taste**: Lower overall taste: with 1-MCP and Very Low O2, increased green apple notes.
- **Texture**: Increased crunchiness (1-MCP and Very Low O2); lower effect on Pink Lady® (good texture in CA).

1 hedonic test on Pink Lady® (2012-2013):
- High overall satisfaction for CA, CA + 1-MCP or DCA,
- 1-MCP always lowest rated (not significant).
- Low incidence on texture.

Source: Mathieu-Hurtiger V., 2014
Specific recommendations

- **Room:**
  - Size: 300 tons maximum.
  - **Imperative** to have a tight room: 30 à 40 min / half pressure

- **Specific installation to regulate pressure:**
  - Air bag for small rooms, pressure sensor (with injection if loss of pressure)

- **New CA regulation and equipment:**
  - “New” **Nitrogen generator** with capacity to give “pure” N2 (over 99% of N2).
  - “New” **CO2 scrubber**: larger capacity (low efficiency at low oxygen), cleaning with N2 to avoid O2 reintroduction.
  - N2 storage tank.

  + **Specific sensors, software depending on DCA method used**
Good practices for storage “<1% O₂”

**Before storage:**
- Imperative to have a automatic CA regulation, specific equipment.
- Special training for operators.
- All CA recommendations are true: Check the tightness of the room **every year**, good fruit quality, homogeneous maturity in the room...

**At the beginning of the storage:**
- Respect specific recommendations for each method
- Good air flow: be careful of the mix “wood/plastic” bins.
- Regular double check. It’s imperative!

**During storage:**
- Every day, check all parameters. Good traceability on computer, also on paper, with double check.

**DO NOT TRUST COMPUTER!**
### Situation in Europe (by company)

- **Isolcell**: 1494 rooms with DCA-CF in the world, 631 in Italy, 88 in France... *(Source: Isolcell, 2014-2015)*
- **Absoger**: 580 rooms with « Extremely Low Oxygen » mainly in France *(Source: Absoger 2015)*.
- **Storex**: 170 rooms mainly in the Netherlands *(source: Wright, 2015)*
- **Others**: no specific information.

#### Example of storage practices in South-Tyrol (1 million tons of apples):
- DCA-CF: 15 % - highest in the world
- SmartFresh<sup>SM</sup>: 15 %
- CA or ULO: 70 %

*(source: Zanella, CAMA 2013)*
## Recommendations in France

<table>
<thead>
<tr>
<th>Cold Storage</th>
<th>Controlled Atmosphere Storage*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T °C</td>
<td>Duration</td>
</tr>
<tr>
<td>1.5</td>
<td>2 months (January)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ULO Storage*</th>
<th>Extremely Low Oxygen Storage* (or DCA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T °C</td>
<td>% O₂</td>
</tr>
<tr>
<td>2 – 2.5*</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Specific recommendations for SmartFresh℠ fruits.  ** Depending on the technique used.

**Usually, cold rooms are filled within one week. CA is started when all fruits are cold, 2-3 days later.**
Other recommendations in Europe for CA storage

<table>
<thead>
<tr>
<th><strong>T°C</strong></th>
<th><strong>% O₂</strong></th>
<th><strong>% CO₂</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 °C</td>
<td>1.5 - 1.8</td>
<td>&lt; 1.3 (as low as possible)</td>
</tr>
</tbody>
</table>

*Stepwise cooling:* 4°C during the filling of the cold room (7 days); Cooling to 2.5°C in 15 days; then CA.

**Recommendations:** Spanish from IRTA; Italian from Laimburg; Swiss from Agroscope ACW

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<thead>
<tr>
<th><strong>T°C</strong></th>
<th><strong>O₂</strong></th>
<th><strong>CO₂</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 - 2°C</td>
<td>2.5 - 3 %</td>
<td>1.5</td>
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</table>

Lower temperature in Spain. Low risk for Internal browning.

**Stepwise cooling is used by SmartFresh℠ users.** (with a decrease in a week from 4°C to 2.5°C)

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<thead>
<tr>
<th><strong>T°C</strong></th>
<th><strong>ULO storage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 - 4°C</td>
<td>1% O₂ - 3% CO₂</td>
</tr>
</tbody>
</table>

Higher T°C and CO₂. **Main risks:** internal browning, scald.
This is a "general protocol", not a recommendation. Only local expert can provide DCA and T°C recommendations.

- LOL (Lower O2 Limit) is determined by a "stress spike", when the signal starts to increase.
- Stepwise cooling to 2.5°C
- Maintain CO2 < 1%; then follow the table.

<table>
<thead>
<tr>
<th>% O₂</th>
<th>% CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Zanella, Prange, August 2009 – DCA protocols for apples
Some references on Cripps Pink and DCA

- **Aubert C. et al., 2015**, Effects of Dynamic Atmosphere on Volatile Compounds, Polyphenolic Content, Overall Fruit Quality, and Sensory Evaluation of Pink Lady® Apples, Acta Hort. 1071, 275-280
- **Mathieu-Hurtiger V. et al., 2014**, Impact of post-harvest methods on apples quality, Infos Ctifl n°304, 33-40 *(in French)*
- **Siegrist et al., 2012**, Cold storage for Pink Lady® apples: influence of temperature, atmosphere and 1-MCP, Revue suisse Viticulture, Arboriculture, Horticulture I Vol. 44 (4) :258-265 *(in French)*
- **Jobling J. et al.,** Managing the flesh browning disorder of Cripps Pink Apples, AHR, 16p.
- ...

- **Prange & Zanella, 2009**, DCA protocols for apples (www.harvestwatch.net)
- ...


Thank you for your attention,

Thanks to:

- IPLA : International Pink Lady® Alliance
- APLE : Association Pink Lady® Europe
- APAL : Apple & Pear Australia LTD

- Angelo ZANELLA (Laimburg, Italy)
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Thank you for your attention,

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