



Chapter 6

Recommended temperature and gas regimes for cold storage of South African commercial apple and pear cultivars

Compiled by ARC Infruitec-Nietvoorbij in co-operation with SA Apple & Pear Producer's Association

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IDEAL STORAGE CONDITIONS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION
Temperature	RA-storage: core temperature must be -0,5 °C within 48 hours of harvest	Hold temperature at -0,5°C for duration of storage
	CA-storage: core temperature must be -0,5°C within 96 hours (4 days) from harvest.	Rapid removal of field heat to a core temperature of -0,5°C is more beneficial than rapid attainment of the required gas regime.
Relative humidity (RH)	Must be between 90% and 95%.	Applicable to both RA and CA-storage. It is difficult to measure relative humidity accurately, but most cold stores are designed to maintain a high relative humidity.
Gas Regime (see Appendix 1)	Nitrogen flushing: must reach 3% O ₂ + 1,5% CO ₂ (0% CO ₂ for Bon Chretien and Forelle) within 4 days of sealing the room.	The optimum gas regime for the specific cultivars must be reached as quickly as possible thereafter.
	Nitrogen generator: must reach 3% O ₂ + 3% CO ₂ (0% CO ₂ for Bon Chretien en Forelle) within 48 hours of sealing the room.	The optimum gas regime for the specific cultivars must be reached as quickly as possible thereafter.
Important notes	Bon Chretien: <ul style="list-style-type: none"> • Can be handled after extended CA-storage, provided that only fruit of optimum maturity is stored and that the cold chain immediately after storage is strictly maintained. • Must be stored at 0% CO₂ 	
	Forelle: <ul style="list-style-type: none"> • Mature Forelle pears from certain areas are prone to CO₂ injury and should therefore be stored at 0% CO₂ if possible. 	

MINIMUM STORAGE CONDITIONS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION
Loading of CA room	<p>Orchard run fruit: loading should not exceed 7 days, during which effective cooling must take place.</p>	
	<p>Pre-sized fruit: loading may take up to 14 days from beginning of harvest. Minimum gas regimes must be reached within 7 days of sealing the room (total of 21 days from the beginning of harvest).</p>	<p>Effective cooling must take place during the loading period.</p>
	<p>Exception: where Packham's Triumph picked in week 7 is to be stored with Golden Delicious and/or the red cultivars picked in ± week 9. Under these conditions the total loading time of pears and apples should not exceed 21 days and minimum gas regimes (3% O₂) must be attained within 7 days of sealing the room.</p>	<p>The maximum number of days for the whole operation may therefore not exceed 28 days.</p>
Temperature	<p>RA and CA-storage: fruit must be placed under refrigeration within 24 hours from start of harvesting.</p>	<p>Core temperatures after sealing the room must be reached as follows: Bon Chretien: 2 days to 2°C + 2 days to -0,5°C (total 4 days) Other cultivars: 3 days to 2°C + 3 days to -0,5°C (total 6 days)</p> <p>To attain the above temperatures within the prescribed time limit, forced air cooling should be used.</p>
Gas regimes	<p>Prescribed gas regimes must be reached within 7 days of sealing the room.</p>	



IDEAL STORAGE CONDITIONS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION
Temperature	<p>Golden Delicious, Starking and other red cultivars to be cooled to a core temperature of -0,5°C within 48 hours of harvest and held at that temperature during storage.</p> <p>2 recommended methods for handling Granny Smith:</p> <ul style="list-style-type: none"> • cool to 3°C within 48 hours after harvest and hold at this temperature for 10 days. Then cool to -0,5°C as quickly as possible; or • cool to 0°C within 48 hours after harvest and then lift storage temperature to +0,5°C and hold at this temperature for the duration of storage. 	<p>These methods should prevent core flush without yellowing of the apples.</p>
Relative Humidity (RH)	<p>Must be between 90% and 95%.</p>	<p>Applicable to RA and CA storage. It is difficult to measure relative humidity accurately, but most cold stores are designed to maintain a high relative humidity.</p>
Gas Regimes (See Appendix 2)	<p>Nitrogen flushing: attain a gas regime of 3% O₂ + 1,5% CO₂ within 48 hours of sealing the room. The CO₂ concentration must not exceed 2,5% during the pull-down period, except in the case of Golden Delicious where the CO₂ concentration may not exceed 5%.</p>	<p>The optimum gas regime for the particular cultivar must be reached as quickly as possible thereafter.</p>
	<p>Nitrogen generator: attain a gas regime of 3% O₂ + 3% CO₂ within 48 hours of sealing the room. The CO₂ concentration must not exceed 2,5% during the pull-down period, except in the case of Golden Delicious where the CO₂ concentration may not exceed 5%.</p>	<p>The optimum gas regime for the particular cultivar must be reached as quickly as possible thereafter.</p>

MINIMUM STORAGE CONDITIONS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION						
Loading of CA room	<p>Orchard run fruit: loading should not take longer than 7 days, during which time effective cooling must take place.</p>							
	<p>Pre-sized fruit: loading may take up to 14 days from beginning of harvest, but it is required that the minimum gas regimes be reached within 7 days of sealing the room (total of 21 days from beginning of harvest).</p>	<p>Effective cooling must take place during the loading period.</p>						
	<p>Exception: where Packham's Triumph pears picked in week 7 are to be stored with Golden Delicious and/or the red cultivars picked in ± week 9, the total loading time of pears and apples may not exceed 21 days and the minimum gas regimes must be attained within 7 days of sealing the room. Total 28 days for the whole operation</p>	<p>The maximum number of days for the whole operation may therefore not exceed 28 days.</p>						
Temperature	<p>Place fruit under refrigeration within 24 hours from start of harvesting. Attain core temperatures after sealing the room as follows: Granny Smith: 4 days to 3°C + 10 days to -0,5°C or +0,5°C (minimum: -0,5°C, total 14 days) Other apples: 4 days to 2°C + 3 days to -0,5°C (total 7 days)</p>	<p>These guidelines are applicable to RA and CA storage.</p>						
Gas regimes	<p>The following gas regimes should be reached within 7 days of sealing the room (i.e. within 14 days from start of harvesting):</p> <table border="0"> <tr> <td>Granny Smith</td> <td>3,0% O₂</td> <td>1,0% CO₂</td> </tr> <tr> <td>Other cultivars</td> <td>3,0% O₂</td> <td>1.5% CO₂</td> </tr> </table>	Granny Smith	3,0% O ₂	1,0% CO ₂	Other cultivars	3,0% O ₂	1.5% CO ₂	<p>Note: CO₂ levels should never exceed 2,5% to prevent possible damage to the fruit. The exception is Golden Delicious where the maximum CO₂ level can be 5%.</p>
Granny Smith	3,0% O ₂	1,0% CO ₂						
Other cultivars	3,0% O ₂	1.5% CO ₂						

APPLES & PEARS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION				
Interruption of CA storage	<p>If CA conditions must be interrupted* a total period of 21 days (including pull-down period) above 2,5% O₂ may not be exceeded at any time. If this does occur, the fruit should not be regarded as CA-stored. Partially CA-stored fruit does not qualify as CA fruit, although the fruit will still benefit.</p>	<p>* e.g. due to partially packing a room for export or mechanical or other failures.</p> <p>** E.g. stored in RA for longer than 14 days prior to CA storage.</p>				
Measuring of oxygen concentrations with portable O₂ analyser	<p>Oxygen concentrations in CA rooms to be measured at least once weekly at the room itself with a portable analyser.</p> <p>This additional reading may be recorded on the log sheet or on a separate sheet.</p>	<p>This prevents the danger of alcohol formation because of faulty control equipment. This reading is additional to the existing control system where O₂ levels are measured at least twice daily and does not replace the traditional system.</p> <p>Record keeping of the measurements must form part of the existing record keeping process.</p>				
Tolerance	<p>The maximum tolerance for gas concentrations for pears and apples are:</p> <table border="0"> <tr> <td>Oxygen (O₂)</td> <td>+ or -0,5%</td> </tr> <tr> <td>Carbon dioxide (CO₂)</td> <td>+ or -0,5%</td> </tr> </table>	Oxygen (O ₂)	+ or -0,5%	Carbon dioxide (CO ₂)	+ or -0,5%	
Oxygen (O ₂)	+ or -0,5%					
Carbon dioxide (CO ₂)	+ or -0,5%					
Temperature range	<p>Temperature ranges for the storage of apples and pears are:</p> <table border="0"> <tr> <td>Minimum</td> <td>-0,5°C</td> </tr> <tr> <td>Maximum</td> <td>1,0°C</td> </tr> </table>	Minimum	-0,5°C	Maximum	1,0°C	
Minimum	-0,5°C					
Maximum	1,0°C					
Minimum storage period	<p>The minimum storage period under conventional CA conditions for pears and apples to quality to be CA fruit should be 60 days.</p>					

APPLES & PEARS	PRIMARY PRINCIPLE	ADDITIONAL INFORMATION
Log sheet (See Appendix 3)	Computer printouts and standard log sheets may be used. The following basic information is needed to be monitored: <ul style="list-style-type: none"> • Air delivery and return temperature • Fruit core temperatures in the front and back of the room • Oxygen and carbon dioxide readings 	All the information on the standard log sheet should also appear on the computer printout. This information should be recorded at least twice daily.
	The following important dates must be recorded: <ul style="list-style-type: none"> • Start harvesting • Start pre-cooling (if any) • Start of loading the room • Date of sealing the room 	
Export fruit in CA storage	Pears and apples stored under CA conditions for export must be treated in the same manner as fruit for the local market, except for the dipping and drenching treatments.	Producers should apply the recommendations supplied by ARC Infruitec-Nietvoorbij and comply with the directions of the various manufacturers of dipping and drenching material.
Safety precautions	CA operators should be aware of the content of the safety procedures applicable to CA rooms.	

APPENDIX 1**RECOMMENDED GAS REGIMES AND STORAGE PERIODS FOR PEARS**

Cultivar		O ₂ (%)	CO ₂ (%)	Temperature (°C)	Storage Period (months)	Alternatives to DPA
Bon Chretien	Opt.	1,0	0,0	-0,5	4	No
	Max	1,5	0,0	0,0		
	Min	1,0	0,0	-0,5		
Beurre Bosc	Opt.	1,5	1,5	-0,5	4	No
	Max	2,0	2,0	0,0		
	Min	1,0	1,0	-0,5		
P. Triumph	Opt.	1,5	2,5 or 1,5	-0,5	9-10	DCA; RLOS; DCA+SF after 180 d DCA pre-shipment
	Max	2,0	3,0	0,0		
	Min	1,0	1,0	-0,5		
D. du Comice	Opt.	1,0	1,0	-0,5	6	No
	Max	1,5	1,5	0,0		
	Min	1,0	1,0	-0,5		
Forelle	Opt.	1,5	<1.0	-0,5	7	DCA or FEMA
	Max	2,0	1.0	0,0		
	Min	1,0	0,0	-0,5		
Josephine	Opt.	1,5	1,0	-0,5	8	No
	Max	2,0	1,5	0,0		
	Min	1,0	0,0	-0,5		
Rosemarie	Opt.	1,5	1,0	-0,5	5	No
	Max	2,0	1,5	0,0		
	Min	1,0	0,0	-0,5		
Flamingo	Opt.	1,5	1,0	-0,5	5	No
	Max	2,0	1,5	0,0		
	Min	1,0	0,0	-0,5		

RECOMMENDED GAS REGIMES AND STORAGE PERIODS FOR PEARS

Cultivar		O ₂ (%)	CO ₂ (%)	Temperature (°C)	Storage Period (months)	Alternatives to DPA
Abate Fetel	Opt. :	1,5	0,5	-0,5	4	No
	Max :	2,0	1,0	0,0		
	Min :	1,0	0,0	-0,5		

APPENDIX 2

RECOMMENDED GAS REGIMES AND STORAGE PERIODS FOR APPLES

Cultivar	O ₂ (%)	CO ₂ (%)	Temperature (°C)	Storage Period (months)	Alternatives to DPA
Golden Delicious Opt. : Max : Min :	1,5 2,0 1,0	2,5 or 1.5 3,0 1,0	-0,5 0,0 -0,5	7-9	Alt: SF/DCA
Granny Smith Opt. : Max : Min :	1,5 2,0 1,0	1,0 1,5 0,0	0.0 +0,5 0.0	11	Alt: SF/DCA
Red Delicious Opt. : Max : Min :	1,5 2,0 1,0	2,5 or 1.5 3,0 1,0	-0,5 0,0 -0,5	9	Alt: SF/DCA
Royal Gala Opt. : Max : Min :	1,5 2,0 1,0	1,5 3,0 1,0	-0,5 0,0 -0,5	Flavour: 3 months Quality: 7 months	Alt: SF/DCA
Cripps' Pink Rosy Glow Opt. : Max : Min :	1.5 2.0 1.0	0.5 1.0 0.0	1.0 1.5 1.0	6-8	Alt: SF/DCA
Carmine Opt. : Max : Min :	1,5 2,0 1,0	1,5 3,0 1,0	-0,5 0,0 -0,5	7	Alt: SF/DCA
Cripps' Red (Joya) Opt. : Max : Min :	1.5 2.0 1.0	0.5 1.0 0.0	1.0 1.5 1.0	9	Alt: SF/DCA
Braeburn Opt. : Max : Min :	1,5 2,0 1,0	1.0 1.5 0.5	-0,5 0,0 -0,5	8	No

Fuji	Opt. :	1,5	0.5	-0,5	7-8	Alt: SF/DCA
	Max :	2,0	1.0	0,0		
	Min :	1,0	0,0	-0,5		

DCA = Dynamic controlled atmosphere storage

SF = Smartfresh (1-MCP)

RLOS = Repeated low oxygen stress

LOG SHEET

APPENDIX 3

ROOM NO.:
Cultivar:

PICKING TIME: FROM TO

PRE-COOLING TIME: (DAYS)
LOADING TIME: (DAYS)

Date	Time	Gas mixture		Ambient Pressure (millibar)	Ambient temperature (°C)	Cold room air temperature		Fruit core temperature (°C)		Defrosting time (min)	Oxygen at Room (hand held) (%)	Signature	Remarks
		O ₂ (%)	CO ₂ (%)			Front	Back	Front	Back				

