



# POSTHARVEST

## Oxygen Level Influences Storage Temperature Choice for 'Gala' Apples

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In recent years, varying storage temperatures ranging from 0 to 3°C have been recommended for controlled atmosphere (CA) storage of 'Gala' apples throughout different growing regions. Exact temperatures are dependent on several factors, such as use of plant growth regulators in the orchard or as postharvest treatments, and storage oxygen concentrations.

Past research in Ontario found 1-2°C to be optimum for long-term CA storage of 'Gala' apples treated with 1-methylcyclopropene (1-MCP). This conclusion was based on reduced internal browning in 1.5 or 2.5% oxygen regimes at those temperatures.

The objective of this current study was to evaluate 0.5 versus 3°C for storage of 1-MCP-treated 'Gala' apples in lower oxygen levels, 1.2 or 0.6%. These temperatures were chosen due to recommendations for their use outside of Ontario. In addition, slow cooling to 0.5°C was evaluated, due to positive results we found several years ago while using the higher oxygen levels in Ontario.

'Gala' apples (Brookfield strain) were collected from a ReTain-treated orchard during the commercial harvest period in Norfolk County, Ontario (Figure 1). Internal ethylene concentration was less than 0.5 ppm at harvest and firmness averaged 20.8 lbs, soluble solids concentration (Brix) 10.6%, and starch 2.0 on the Cornell chart. Boxes of 'Gala' were placed into 0.5 or 3°C, or 9°C and slow cooled down to 0.5°C over 5 days. CA storage was then established with 1.2 or 0.6% oxygen. All apples put into storage were considered marketable, free of disorders and disease. Apples were stored for 8 months and then evaluated for quality after 1, 7, and 14 days at room temperature.

Storage temperature had a significant effect on the percentage of clean marketable 'Gala' apples after 8 months in 1.2% oxygen (Table 1). Slow cooling to 0.5°C with 1.2% oxygen resulted in the highest percentage of clean apples (91%), followed by immediate storage at 0.5°C (73%) and 3°C with the least (54%). This effect of temperature was not found in 0.6% oxygen, where 80-86% of the apples remained clean.

Stem-end browning and internal browning were the major storage disorders (Figure 2), with significantly more developing in 1.2% than 0.6% oxygen and temperature having an effect. Slow cooling to 0.5°C in 1.2% oxygen reduced the amount of browning to 8%, compared to 23 and 42% incidence with immediate cooling to 0.5 or 3°C, respectively. This effect of temperature was not found in 0.6% oxygen, where only 11 to 17% of the apples had browning regardless of temperature.

Some stem-end cracking also developed in storage (Figure 3) and the highest incidence of 9% was found in 1.2% oxygen with immediate cooling to 0.5°C. Regardless of oxygen concentration, apples cooled immediately to 3°C had 5 to 6% cracking, while slow cooling to 0.5°C significantly reduced cracking to 1%.

There was no main effect of low oxygen on firmness, however apples stored at 3°C were almost 1 lb softer than those at 0.5°C regardless of cooling rate in 1.2% oxygen (Table 2). There was no effect of days at room temperature on firmness, indicating no firmness loss after removal from storage. This was likely due to the 1-MCP treatment at harvest treatment.

Internal ethylene concentration remained low (<0.5 ppm) throughout storage and subsequent shelf-life at room temperature. There was significantly higher soluble solids concentration in apples slow cooled to 0.5°C and stored in 0.6% oxygen, compared to those in 1.2% oxygen at 3°C (Table 2). Malic acid was significantly lower in apples held in 1.2% oxygen at 3°C than those at 0.5°C, but this effect was not found in 0.6% oxygen.



**Results demonstrate that oxygen concentration must be considered when deciding the best storage temperature for 1-MCP-treated 'Gala' apples. Firmness can be sacrificed and browning increased by storage at 3°C, especially as oxygen increases.**

Lower temperatures are always preferred for 'Gala' not treated with 1-MCP, to maintain fruit firmness and limit greasiness.



**Figure 1.** 'Gala' apples for this study at harvest time.



**Figure 2.** Internal browning (left) and stem-end browning (right) in 'Gala' apples after 8 months of storage in 1.2% oxygen.

**Table 1.** Percentage of clean marketable apples and disorders in 'Gala' apples after 8 months of storage in 0.6 or 1.2% oxygen at 0.5 or 3°C.

Oxygen (%)	Temperature (°C)	Clean (%)	Browning (%)	Cracking (%)
0.6	3	80 <sup>DE</sup>	17 <sup>BC</sup>	6 <sup>B</sup>
	0.5	83 <sup>CDE</sup>	13 <sup>BCD</sup>	2 <sup>CD</sup>
	Slow to 0.5	86 <sup>BCD</sup>	11 <sup>CDE</sup>	1 <sup>D</sup>
1.2	3	54 <sup>F</sup>	42 <sup>A</sup>	5 <sup>BC</sup>
	0.5	73 <sup>E</sup>	23 <sup>B</sup>	9 <sup>A</sup>
	Slow to 0.5	91 <sup>ABCD</sup>	8 <sup>CDE</sup>	1 <sup>D</sup>

Values within a column with the same letter are not significantly different at  $P < 0.05$ .

## Acknowledgements

Thanks to the Ontario Apple Growers, Norfolk Fruit Growers' Association, Apple Marketers' Association of Ontario, AgroFresh Inc., Pommes Philip Cassidy Inc., GRB Ag. Technologies Inc., and Storage Control Systems Inc., for their continuous support.



**Figure 3.** Stem-end cracking in 'Gala' apple after 8 months in CA storage.

**Table 2.** Quality of 'Gala' apples after 8 months of storage in 0.6 or 1.2% oxygen at 0.5 or 3°C.

Oxygen (%)	Temperature (°C)	Firmness (lb)	Soluble solids (%)	Malic acid (mg/100 ml)
0.6	3	18.8 <sup>B</sup>	12.3 <sup>AB</sup>	427 <sup>B</sup>
	0.5	18.9 <sup>AB</sup>	12.5 <sup>AB</sup>	439 <sup>B</sup>
	Slow to 0.5	18.8 <sup>B</sup>	13.0 <sup>A</sup>	436 <sup>B</sup>
1.2	3	18.3 <sup>C</sup>	12.2 <sup>B</sup>	396 <sup>C</sup>
	0.5	19.0 <sup>AB</sup>	12.6 <sup>AB</sup>	482 <sup>A</sup>
	Slow to 0.5	19.2 <sup>A</sup>	12.8 <sup>AB</sup>	494 <sup>A</sup>

Values within a column with the same letter are not significantly different at  $P < 0.05$ .