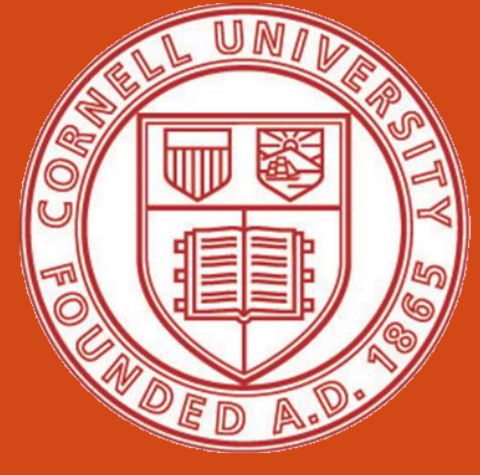


# CA and Dynamic CA-Chlorophyll Fluorescence Storage of 'McIntosh' and 'Delicious'

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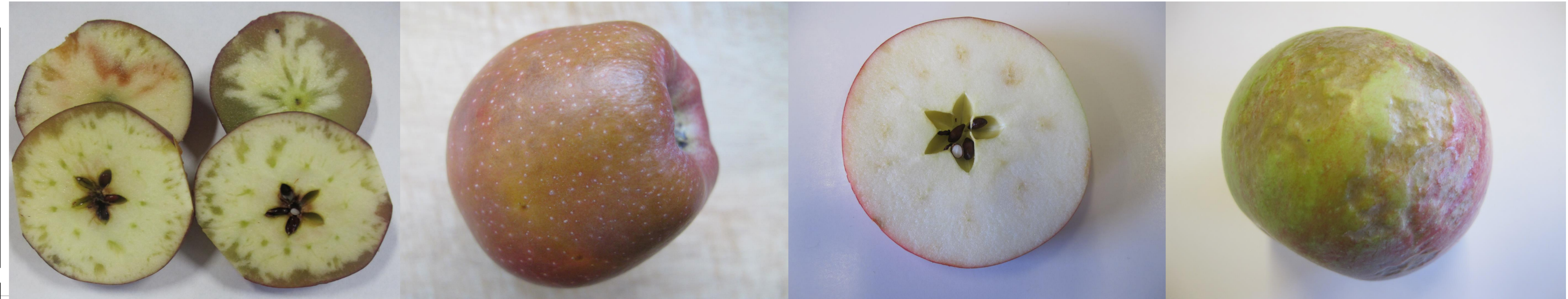
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## Introduction

Controlled atmosphere (CA) storage is used to extend the storage life of apples by slowing down cell metabolism, thereby maintaining firmness and other quality characteristics, and reducing susceptibility to disorders such as superficial scald. This can be optimized by further lowering O<sub>2</sub> levels and monitoring for anaerobic stress using dynamic CA (DCA)-chlorophyll fluorescence (CF) (HarvestWatch™).

## Materials & Methods

In 2013, fruit from four orchards of 'Red Delicious' from western NY (WNY) and four orchards of 'McIntosh' from the Champlain region of NY were harvested, untreated or treated with 1-methylcyclopropene (1-MCP) and kept in CA (2% O<sub>2</sub>/2%CO<sub>2</sub>) or DCA-CF storage for up to 8 months. O<sub>2</sub> levels for 'Delicious' were kept 0.2% above the fluorescence-derived low O<sub>2</sub> limit levels detected at 0.4% (0.5 °C) and 0.9% for 'McIntosh' (2 °C). Fruit were assessed after 4 and 8 months plus 1 and 7 days at 20 °C. The experiment was repeated in 2014 with 4 orchards of 'Red Delicious' from WNY and 4 orchards of 'McIntosh' from the WNY and Champlain regions. Only 8 month, day 7 results are reported here.



'Delicious' watercore breakdown

'Delicious' superficial scald

'McIntosh' vascular browning

'McIntosh' external CO<sub>2</sub> injury

Table 2. 'Delicious' firmness (N) after 8 months plus 7 d at 20 °C.

Firmness (N)	2013 'Delicious'				2014 'Delicious'			
	Orchard	CA	CA + 1-MCP	DCA-CF	DCA-CF + 1-MCP	CA	CA + 1-MCP	DCA-CF
1	65.4	72.9	70.3	72.5	57.1	69.7	55.1	72.2
2	61.4	70.7	66.3	72.5	58.2	71.2	62.6	74.3
3	65.4	74.3	68.5	75.2	60.9	69.4	62.6	70.3
4	68.5	73.4	71.2	73.4	65.2	71.0	68.7	73.8
	LSD <sub>0.05</sub> = 1.98				LSD <sub>0.05</sub> = 2.99			

Table 3. 'McIntosh' firmness (N) after 8 months plus 7 d at 20 °C.

Firmness (N)	2013 Champlain 'McIntosh'				2014 Champlain 'McIntosh'				2014 WNY 'McIntosh'			
	Orchard	CA	CA + 1-MCP	DCA-CF	DCA-CF + 1-MCP	CA	CA + 1-MCP	DCA-CF	DCA-CF + 1-MCP	CA	CA + 1-MCP	DCA-CF
1	39.0	62.8	43.2	69.0	42.4	61.0	44.0	64.3	37.4	58.7	44.0	60.1
2	43.6	67.2	45.0	67.0	43.9	67.6	47.0	70.3	32.5	57.6	36.3	55.4
3	36.4	71.2	47.3	72.2	45.3	64.3	42.0	66.6	44.4	67.0	46.1	65.9
4	37.7	58.5	45.0	63.1	46.7	62.4	50.8	63.9	51.2	68.4	58.0	71.1
	LSD <sub>0.05</sub> = 2.54				LSD <sub>0.05</sub> = 3.26				LSD <sub>0.05</sub> = 3.28			

Table 1. Maturity data at harvest.

Means that do not share a letter are significantly different at P=0.05.

Region	Orchard	IEC (μL L <sup>-1</sup> )	Firmness (N)	Starch index (1-8)	Watercore (%)
2013 'Delicious'	1	19.3 a	71.7 b	4.3 a	43 b
	2	19.3 a	72.9 b	3.8 ab	50 b
	3	1.0 b	77.6 a	4.3 a	87 a
	4	0.3 b	74.3 ab	3.3 b	0 c
	P value	0.002	0.005	0.012	<0.001
2014 'Delicious'	1	14.0 b	72.7 ab	3.3 b	47
	2	24.9 b	74.0 a	3.6 b	40
	3	58.2 a	67.7 b	5.3 a	60
	4	3.5 b	74.0 a	3.5 b	40
	P value	0.002	0.012	<0.001	0.498
2013 'McIntosh'	1	0.3	66.3 b	5.1 ab	0
	2	1.5	65.1 b	5.7 a	0
	3	0.1	71.5 a	3.9 b	0
	4	3.1	63.2 b	4.9 ab	0
	P value	0.538	<0.001	0.017	0
2014 'McIntosh'	1	0.3	68.3 a	6.6 a	0
	2	0.04	69.4 a	5.3 b	0
	3	5.1	66.8 a	6.8 a	0
	4	1.5	60.8 b	6.9 a	0
	P value	0.672	0.002	<0.001	0
2013 'Champlain'	1	0.07	67.2	5.6 a	0
	2	2.3	68.2	5.9 a	0
	3	0.07	69.9	5.3 a	0
	4	0.2	71.3	2.5 b	0
	P value	0.378	0.166	<0.001	0

Figure 1. Storage disorders in 2013 'Delicious' after 8 months plus 7 d at 20 °C.

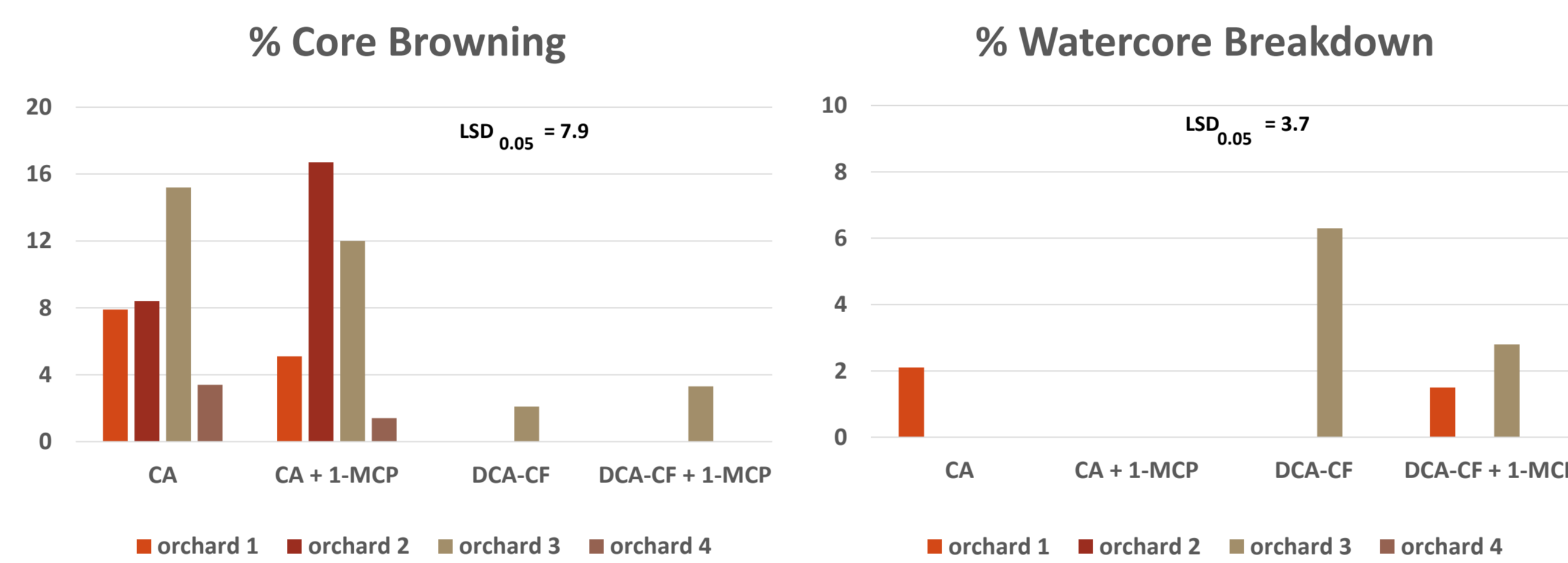


Figure 2. Storage disorders in 2014 'Delicious' after 8 months plus 7 d at 20 °C.

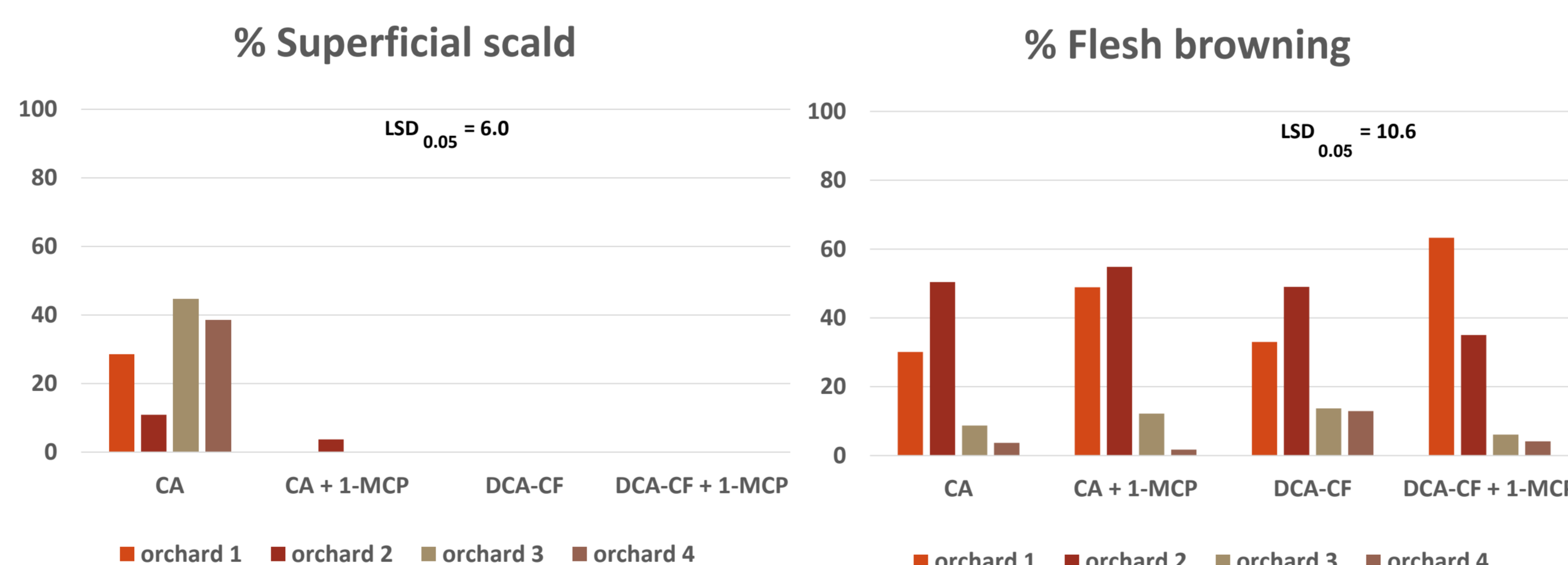


Figure 3. Storage disorders in 2013 'McIntosh' after 8 months plus 7 d at 20 °C.

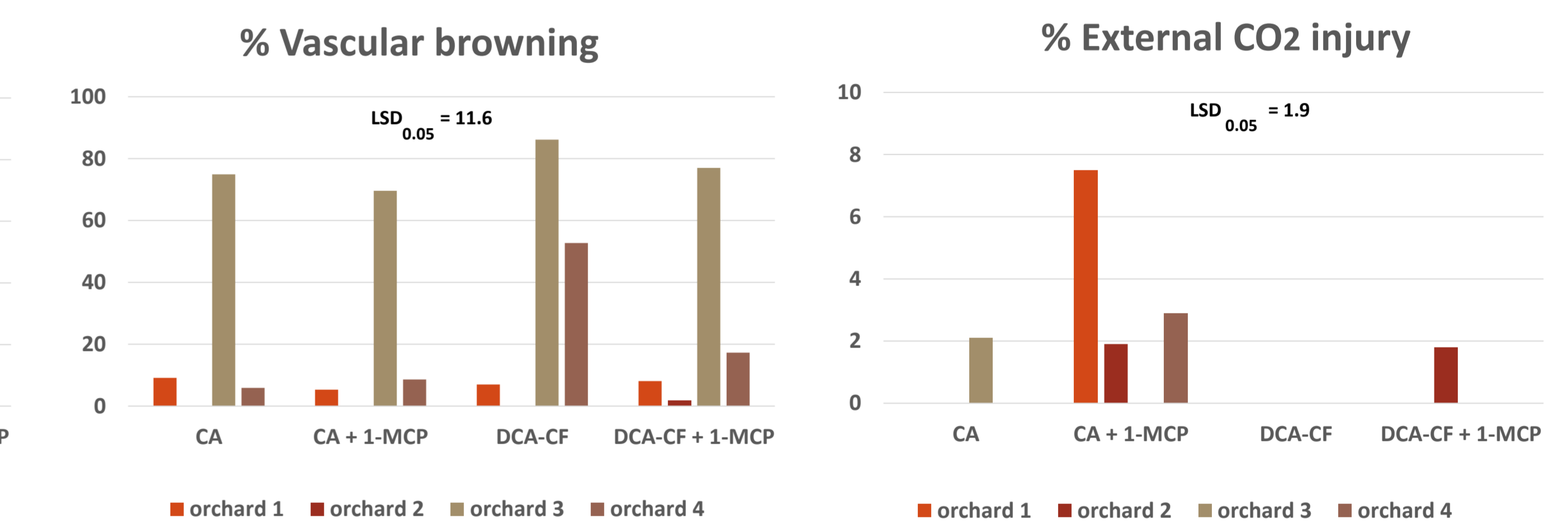
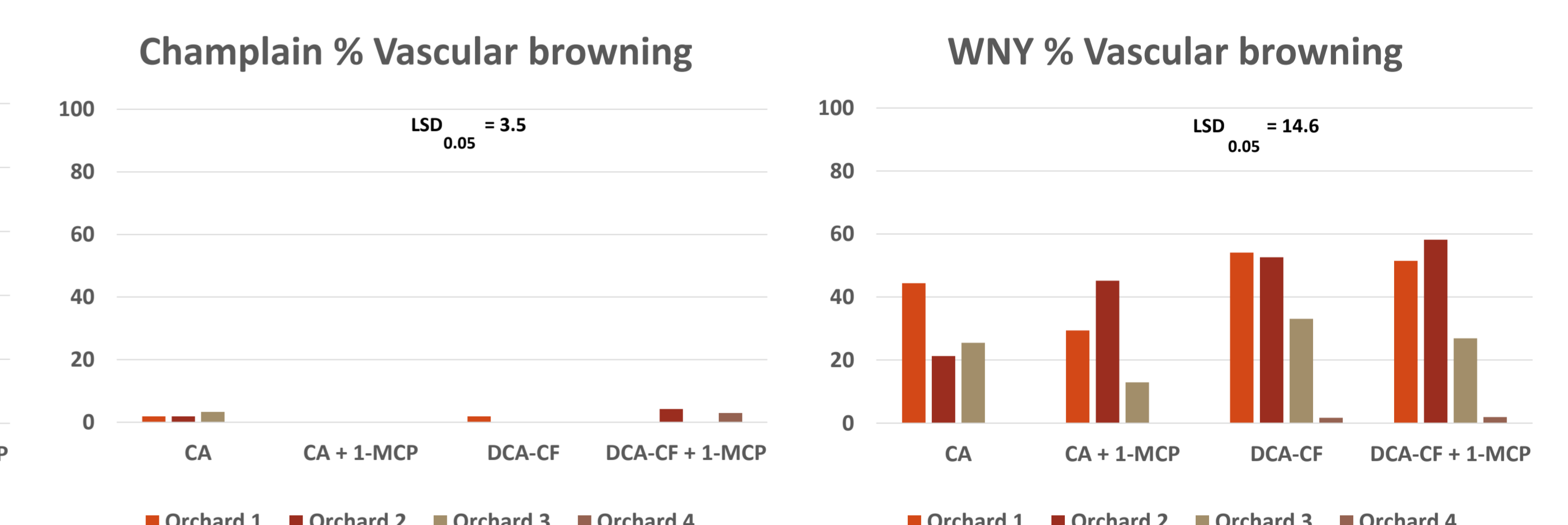


Figure 4. Storage disorders in 2014 'McIntosh' after 8 months plus 7 d at 20 °C.



**After storage – (Table 2):** In 2013, 'Delicious' firmness was higher in DCA-CF without 1-MCP than CA without 1-MCP in orchards 1 and 2 with no firmness difference between CA + 1-MCP and DCA-CF + 1-MCP, all consistently high with 1-MCP use. The incidence of core browning (and greasiness, data not shown) were lower in DCA-CF than in CA (Fig. 1). Although low in numbers, watercore breakdown was more prevalent in DCA-CF (+/- 1-MCP) than in CA. 2014 'Delicious' stored in DCA-CF + 1-MCP maintained firmness near harvest levels. Superficial scald (Fig. 2) was not present in DCA-CF (+/- 1-MCP) (and core browning and senescent breakdown were lower, data not shown). Flesh browning incidence was similar in both years (and watercore breakdown, data not shown) and not reduced by DCA-CF use. In 2013, 'McIntosh' DCA-CF + 1-MCP had the highest firmness, higher than CA + 1-MCP in orchards 1 and 4. DCA-CF was often higher than CA but levels were low without 1-MCP. Internal browning in 'McIntosh', particularly vascular browning, became obvious in some orchards and was not always reduced by DCA-CF or 1-MCP (Fig. 3). External CO<sub>2</sub> injury (and senescent breakdown, data not shown) were minimized by DCA-CF (+/- 1-MCP). 2014 'McIntosh' firmness was higher in DCA-CF than in CA in orchards 1 and 4 in WNY but not in the Champlain fruit. DCA-CF + 1-MCP firmness was close to that found at harvest for Champlain fruit but only in orchard 4 from WNY fruit. 2014 'McIntosh' from 2 regions had different amounts of storage disorders, as illustrated by vascular browning (Fig. 4). Orchards with high vascular browning are not suitable for long term CA or DCA-CF storage.

## Results

**Harvest indices (Table 1): 'Delicious'** - In 2013, watercore incidence ranged from 0 to 87%. The high watercore orchard was most firm. In 2014, orchard 3 had the highest starch index, lowest firmness and highest IEC while all others were similar. 'McIntosh' - In 2013, Orchard 3 had the lowest starch index, along with the highest firmness. In 2014, Champlain 'McIntosh' was harvested at a higher starch index than in 2013 but firmness and IEC were comparable. WNY 'McIntosh' had one orchard with lower starch index and higher firmness. All regions had variable orchard quality at harvest.

## Conclusions

DCA-CF maintained firmness in long term storage, and usually better than normal CA. However, loss of firmness occurred in both CA technologies during the shelf life period. This loss could be prevented by 1-MCP treatment, which was sometimes but not consistently better in DCA-CF than CA stored fruit. DCA-CF eliminated or reduced the incidence of superficial scald, core browning, external CO<sub>2</sub> injury and greasiness, but not vascular browning and flesh browning. Different growing regions and orchards within a growing region had different responses to DCA-CF and these varied from season to season and were related to harvest quality. Some orchards may benefit from this technology while others show no benefit and maintain storage quality just as well with CA + 1-MCP storage. For 'Delicious', DCA-CF appears to provide a non-chemical method for scald control.

