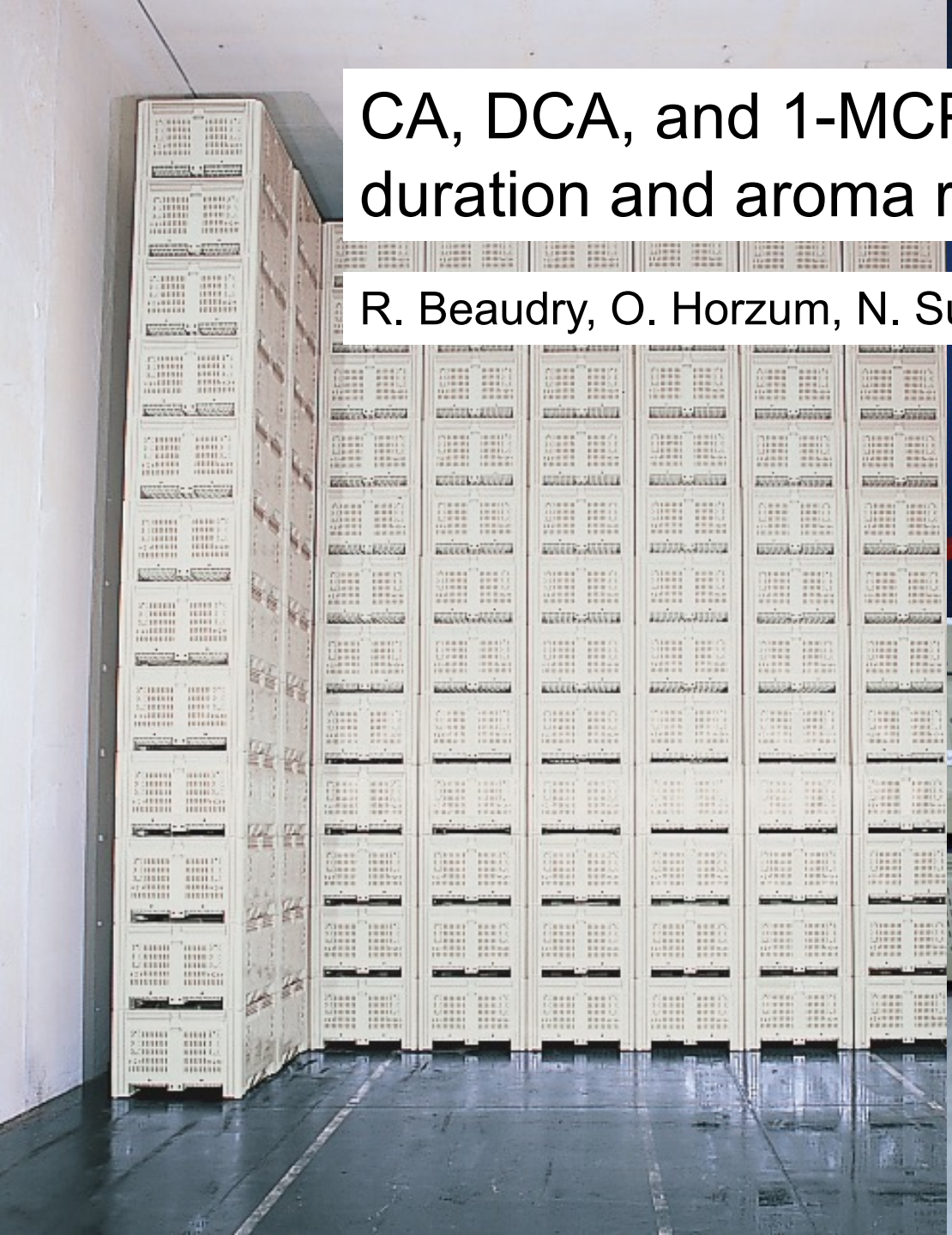
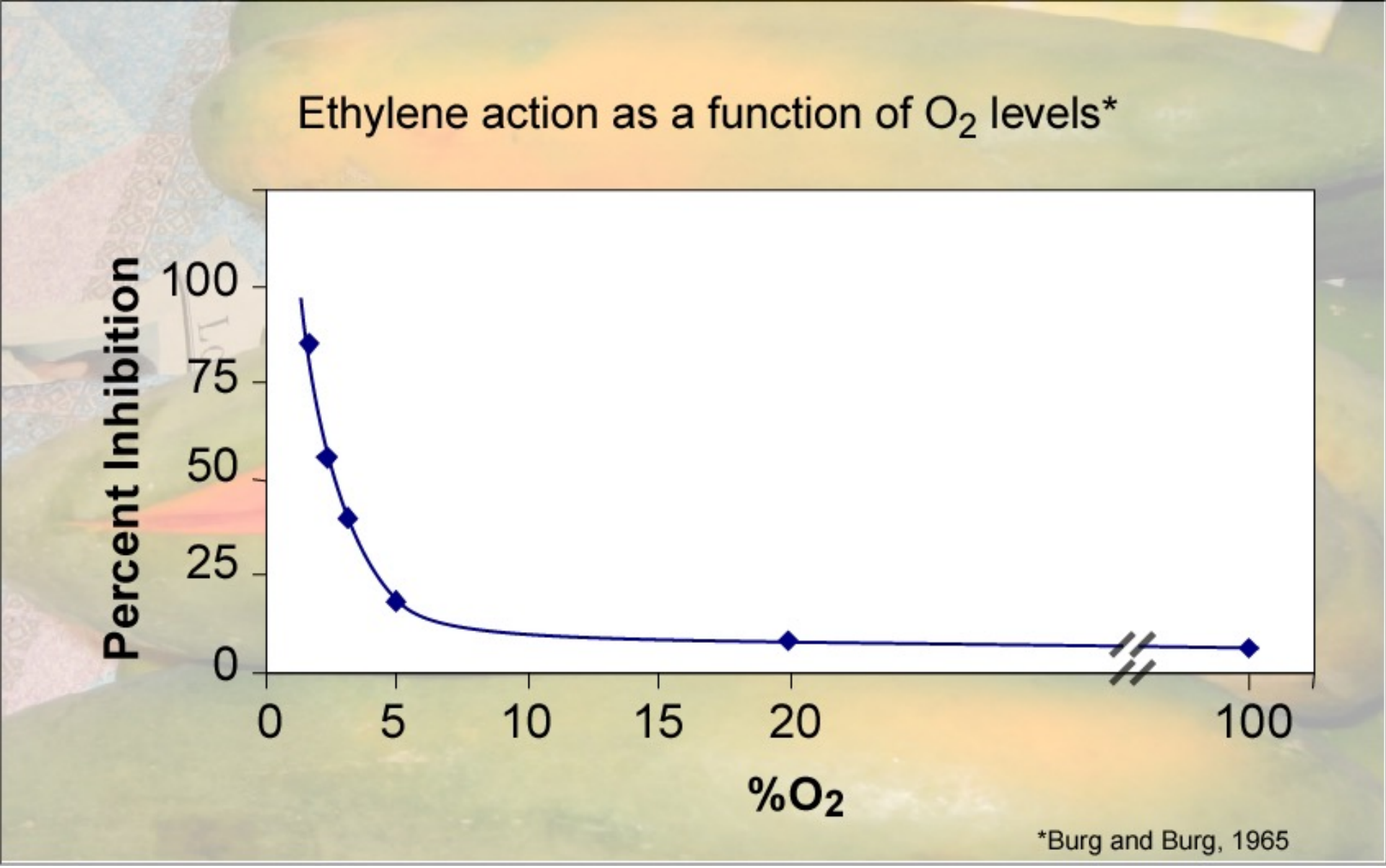
CA, DCA, and 1-MCP: Storage duration and aroma recovery

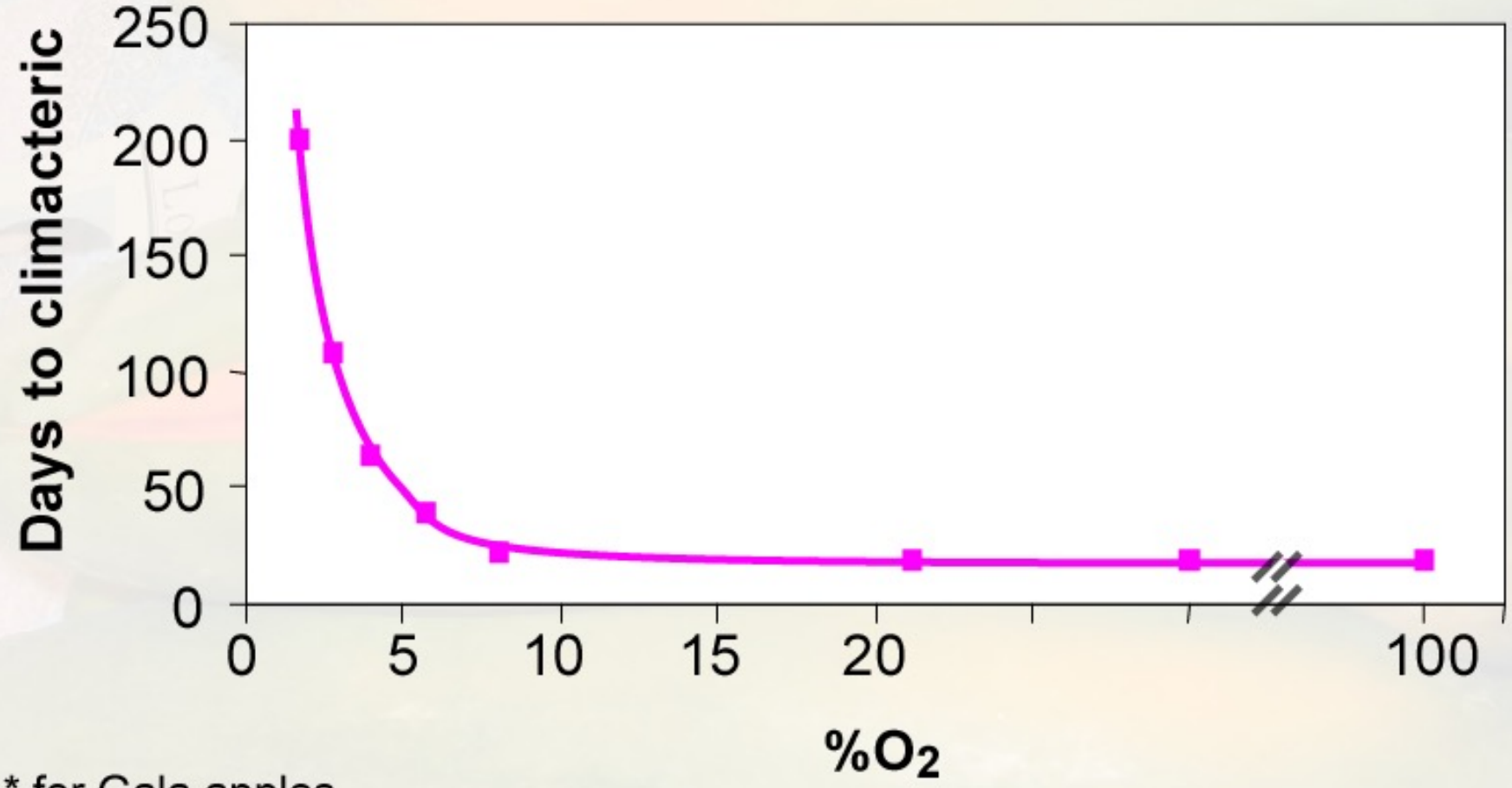
R. Beaudry, O. Horzum, N. Sugimoto





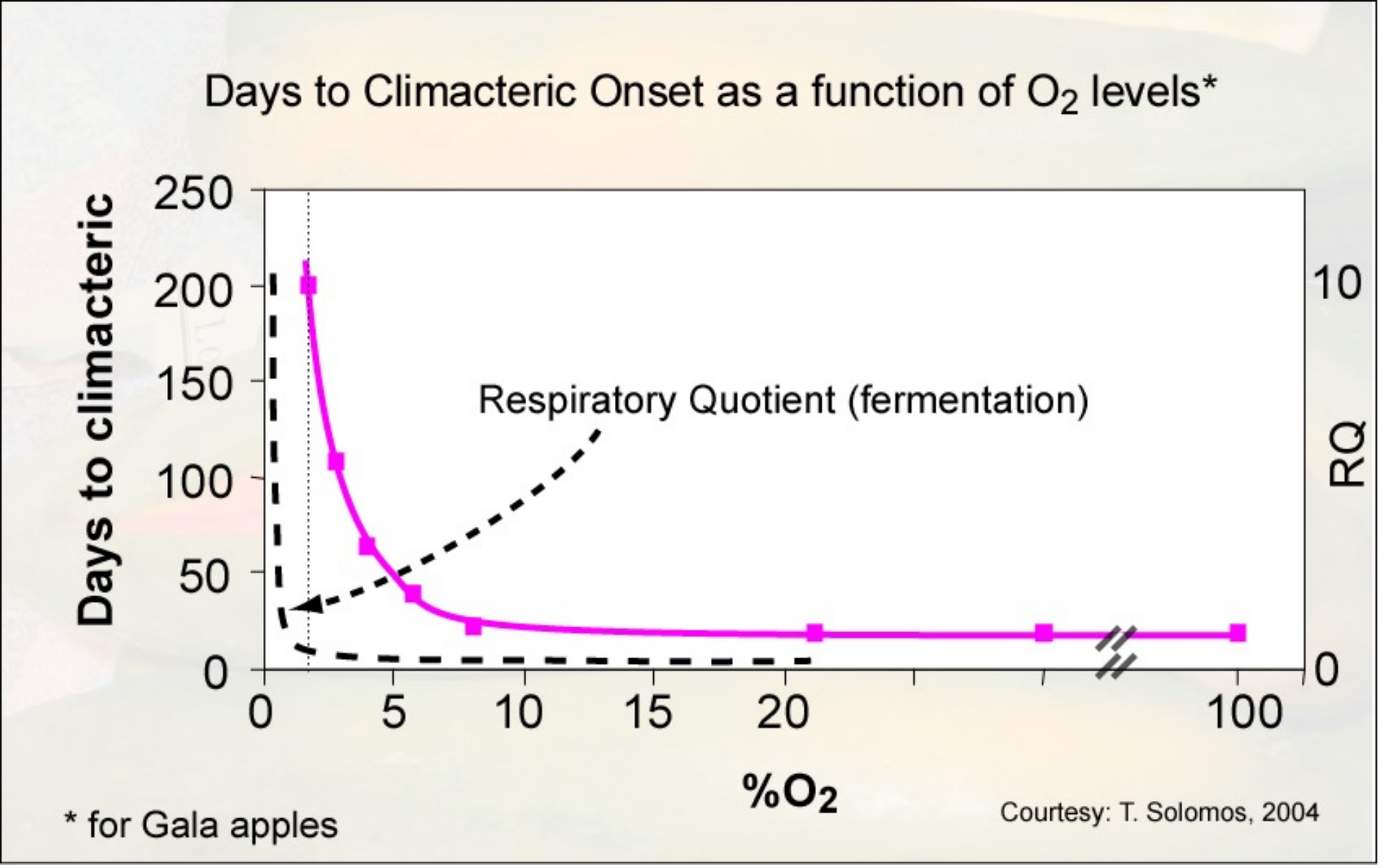
Why do we use low O_2 levels to store apples?

Days to Climacteric Onset as a function of O_2 levels*



* for Gala apples

Courtesy: T. Solomos



The lower the O_2, the better, until you induce fermentation.
The lower O_2 limit will differ for each cultivar

CA Storage

- Standard CA (oxygen levels around 1.5%-3% and CO_2 levels around 2 to 3%) reduces the rate of apple fruit ripening, prolong storage duration, and improve fruit marketability.

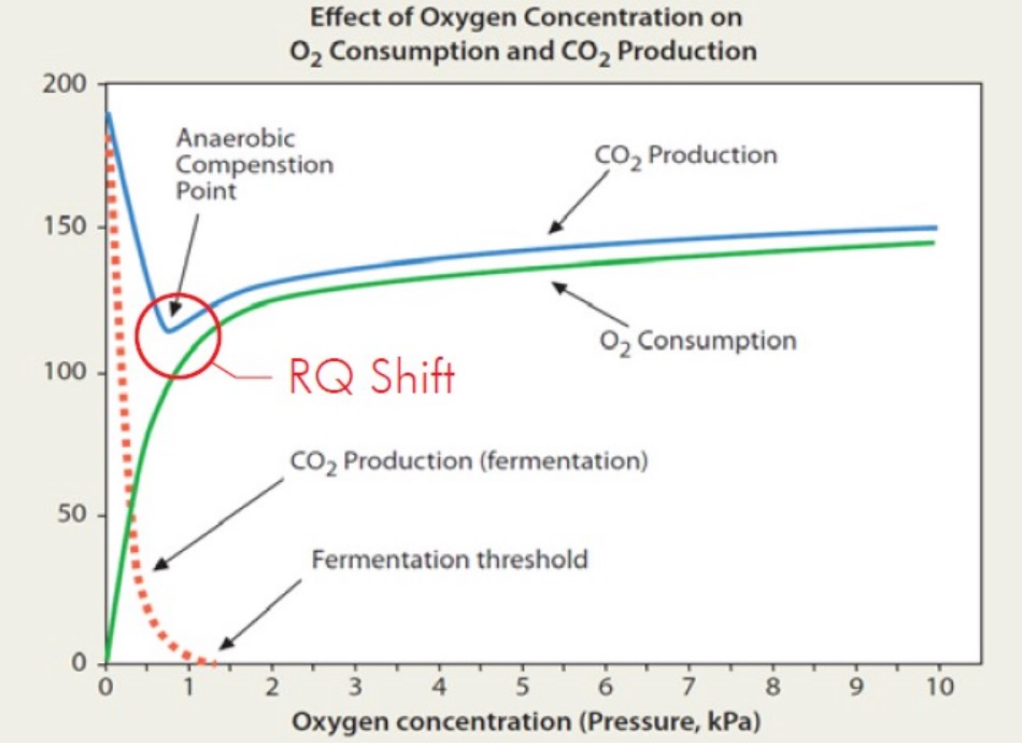
Dynamically Controlled Atmospheres

Systems have been developed to sense low oxygen stress by the product being stored and change the O_2 and/or CO_2 levels to reduce that stress. This allows the storage operator to come as close as possible to the storage threshold for that particular commodity.

Most (all?) DCA systems are dedicated to apple storage. Technologies include:

1. Chlorophyll fluorescence (Satlantic)
2. Ethanol detection (Devised by Wageningen Univ., STOREX)
3. RQ detection (Storage Control Systems, Van Amerongen)

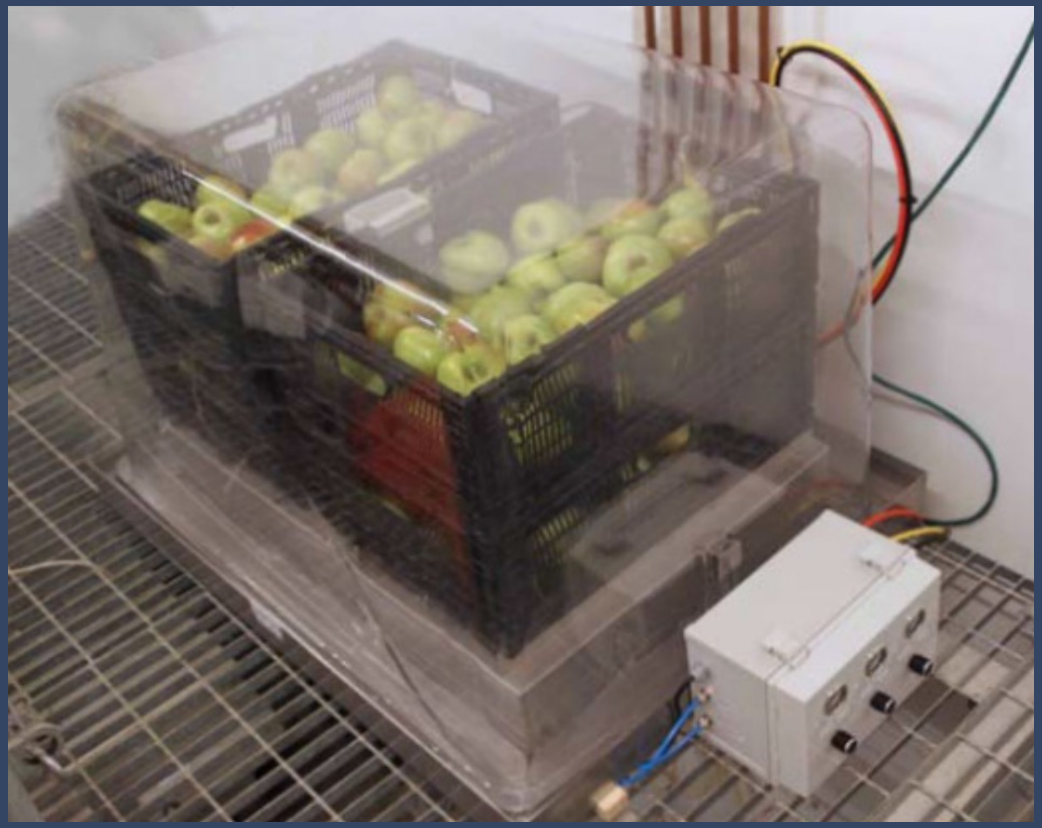
Respiratory quotient (RQ) measurement

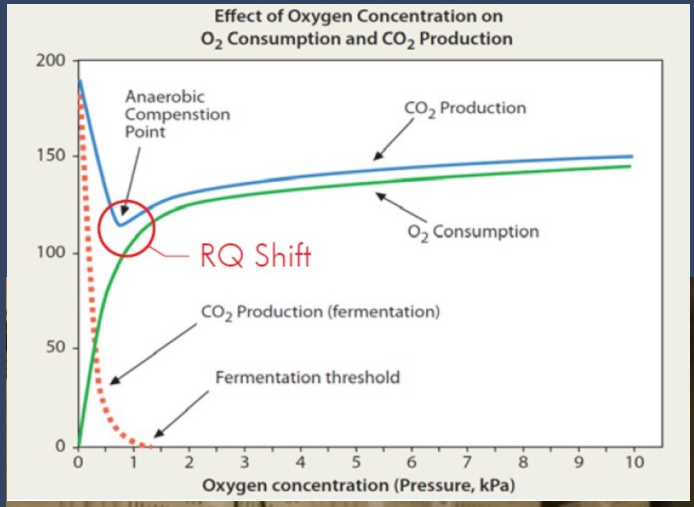


$$RQ = \frac{\text{Rate of } CO_2 \text{ production}}{\text{Rate of } O_2 \text{ uptake}}$$

As oxygen declines, a point is reached when the fruit is starved of oxygen such that fermentation is induced.

DCA technology: SafePod by Storage Control Systems





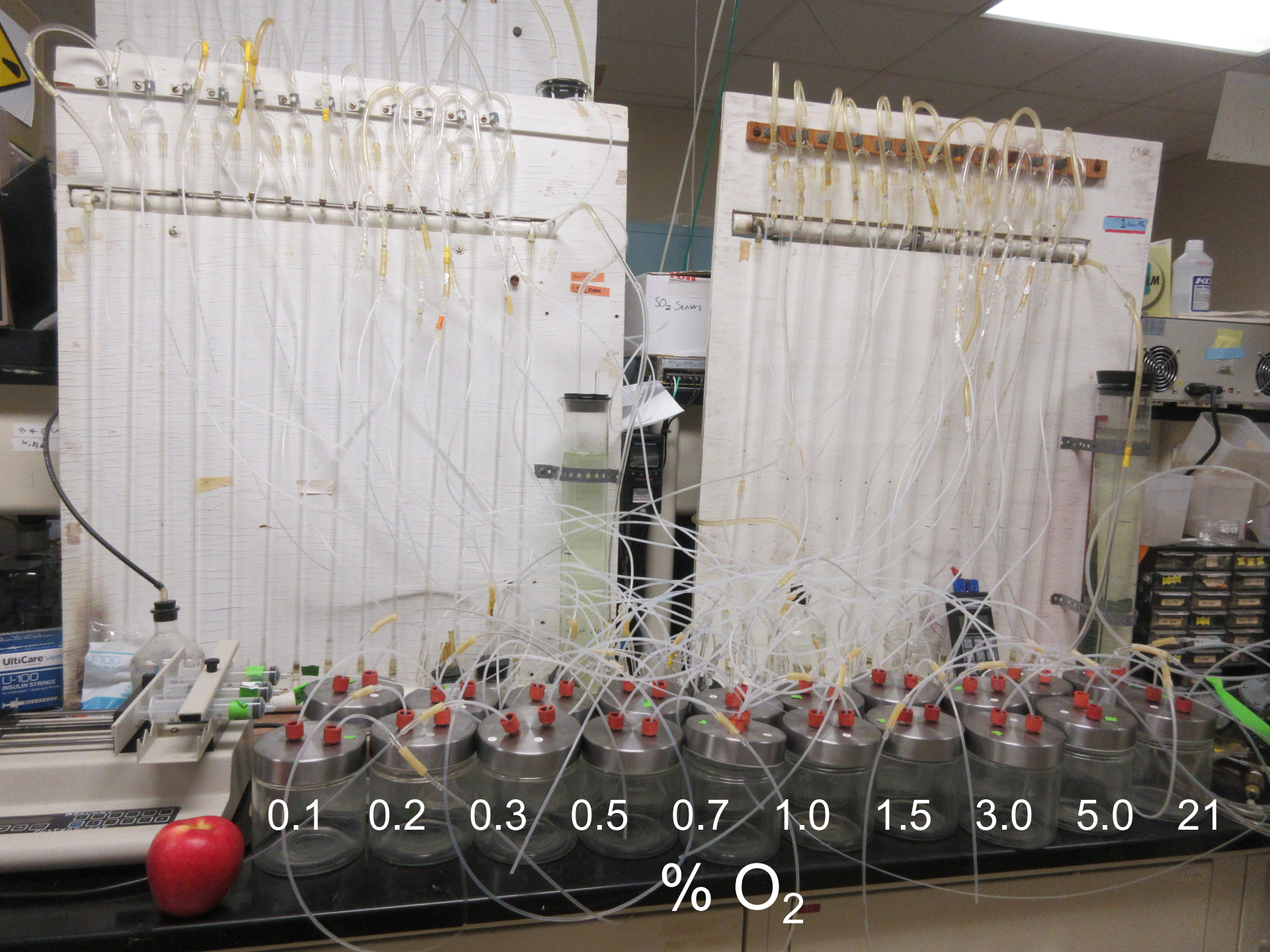
'Pods' in the room contain several bushels of apple
Valves in the base open to admit room air
Then close to allow the O_2 and CO_2 to change.
RQ is measured and used to set lower O_2 level

DCA study

We set up a system to determine tolerances of apple fruit to low O_2 for a number of apple cultivars at 32 or 38 F (0 or 3 C).

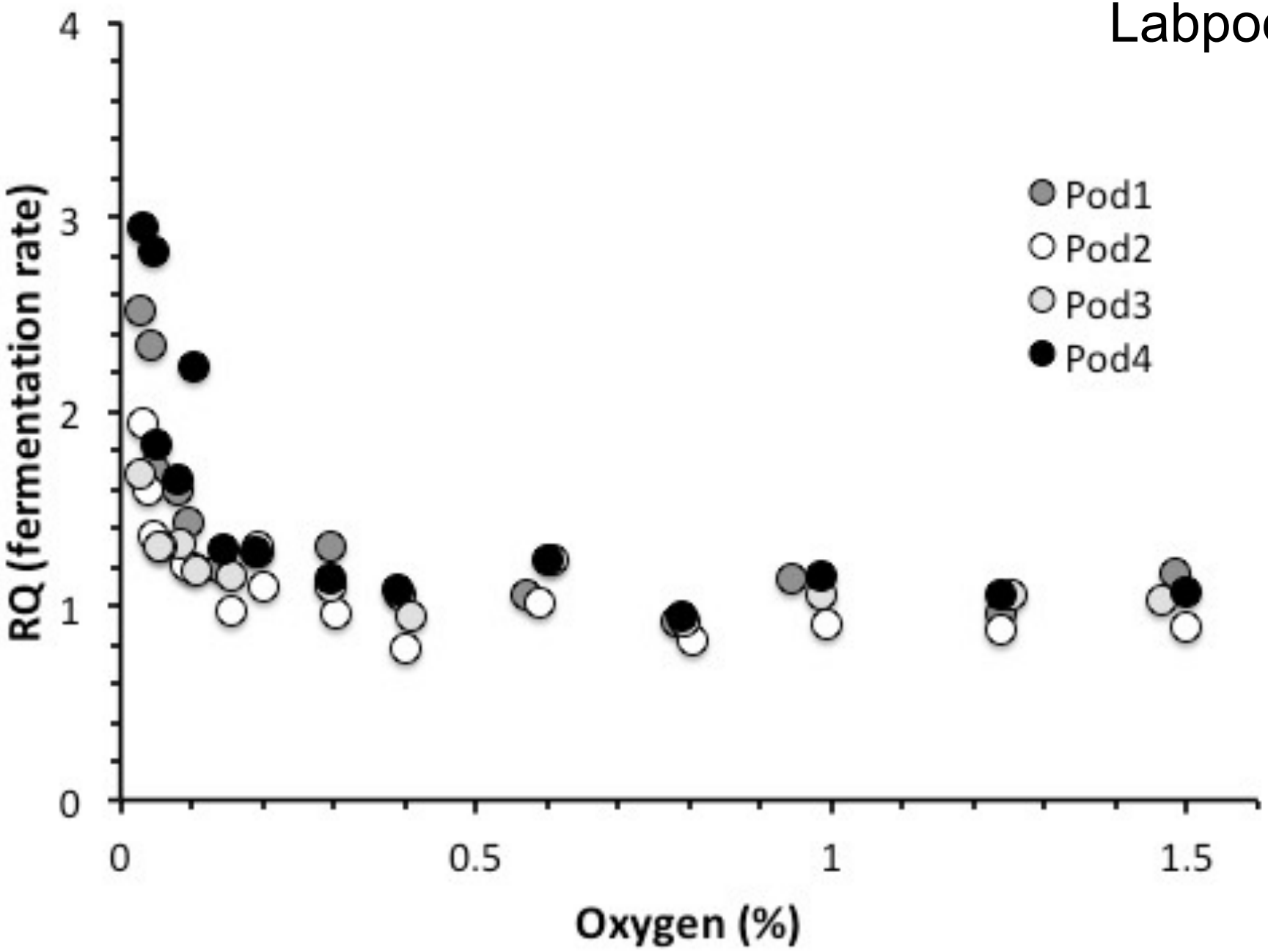
Cultivars tested so far include Gala, Honeycrisp, Jonathan, Jonagold, Golden Delicious, and Empire.

We are able to test two replicates of each oxygen level per run. The atmospheres evaluated are 0.1, 0.2, 0.3, 0.5, 0.7, 1, 1.5, 3, 5 and 21% O_2. After 24 hours at the target oxygen concentration, the rate of ethanol production was measured to determine fermentation activity. We compared the flow-through system with the LabPods on a head-to head basis using the same lots of fruit.

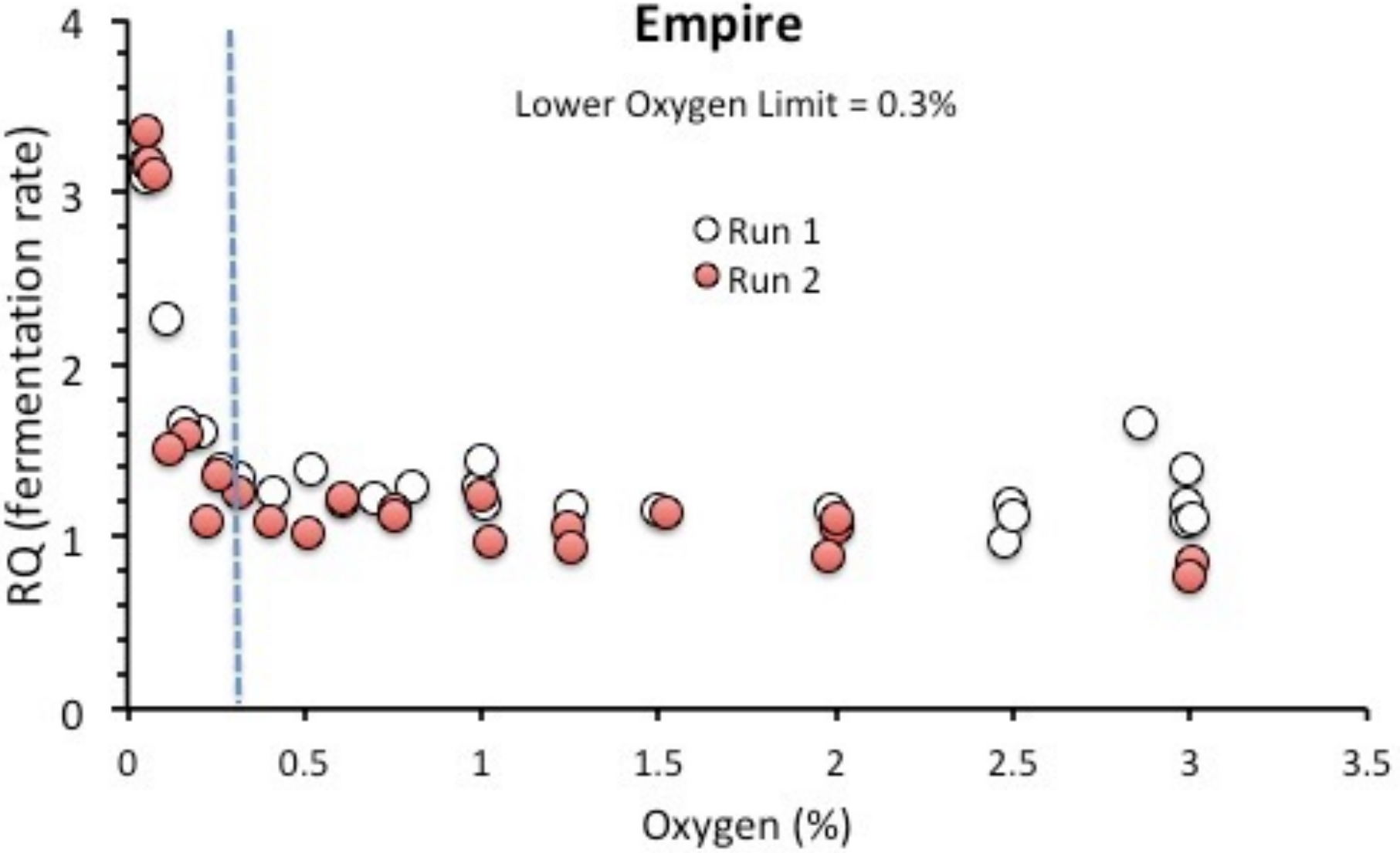

0.1 0.2 0.3 0.5 0.7 1.0 1.5 3.0 5.0 21
% O_2


Labpods at MSU

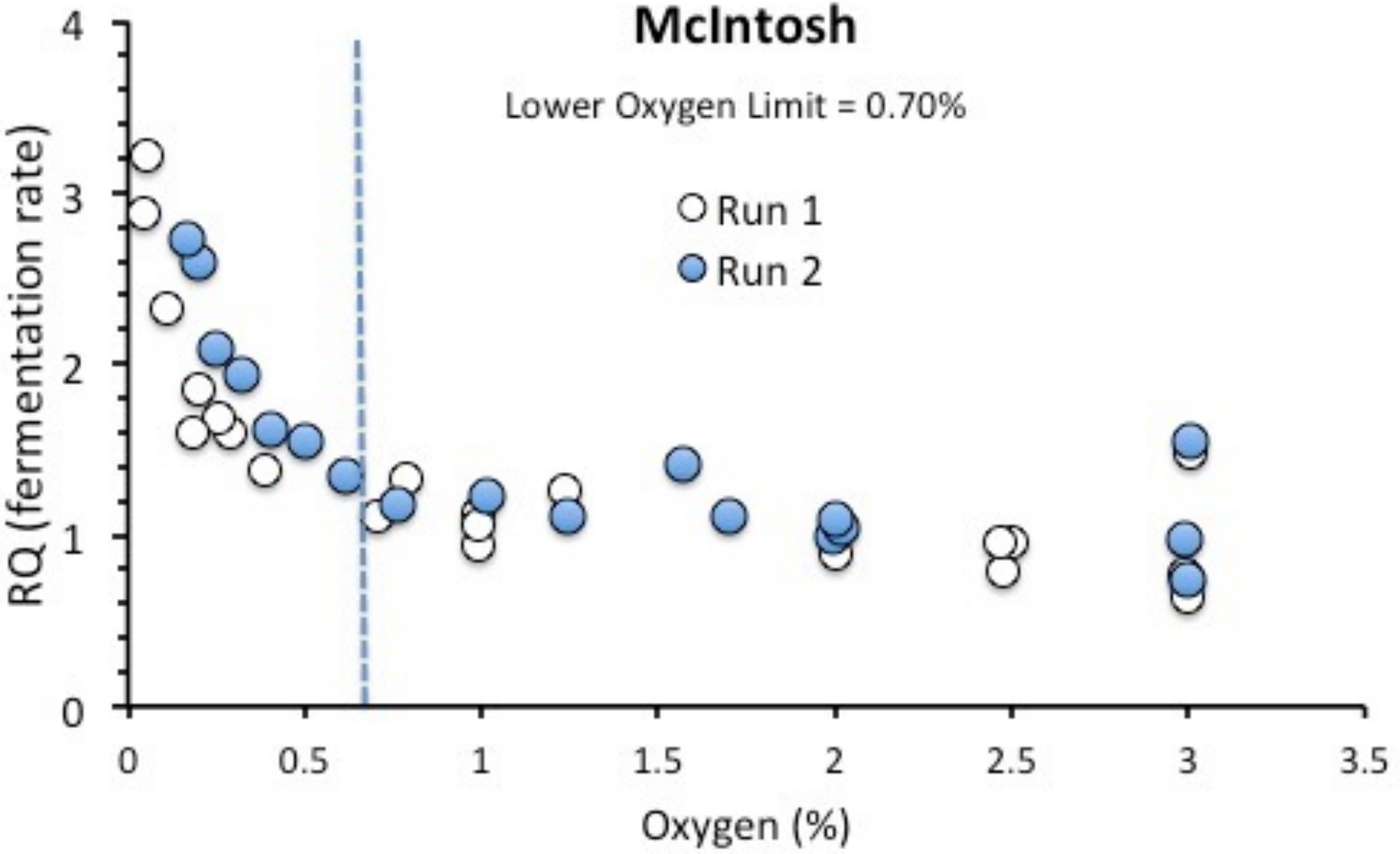
Labpod


RQ (fermentation rate)
4
3
2
1
0
0
0.5
1
1.5
Oxygen (%)
Pod1
Pod2
Pod3
Pod4

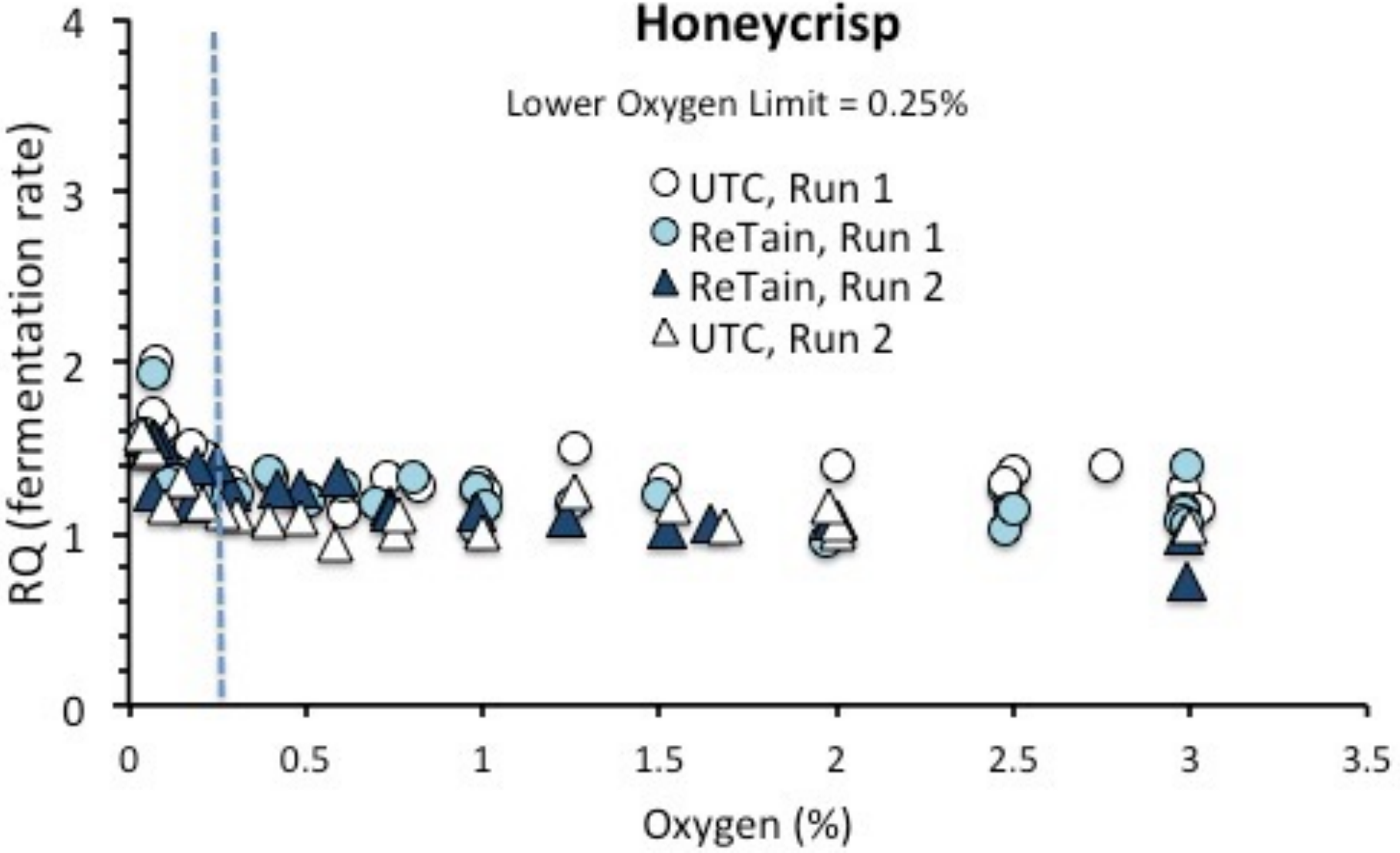
Labpod


Empire
Lower Oxygen Limit = 0.3%
Run 1
Run 2
RQ (fermentation rate)
Oxygen (%)
0
1
2
3
4
0
0.5
1
1.5
2
2.5
3
3.5

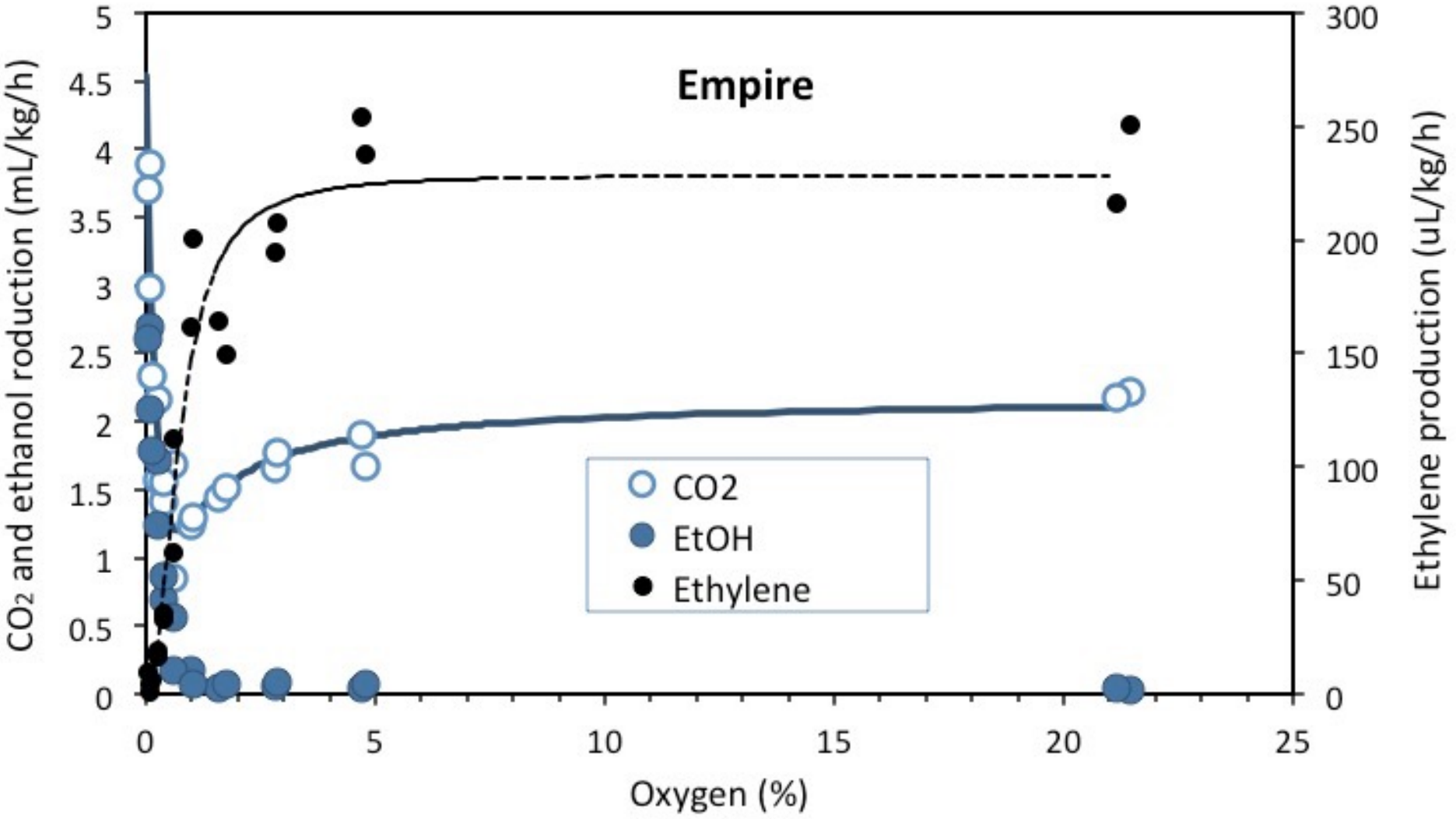
Labpod


McIntosh
Lower Oxygen Limit = 0.70%
Run 1
Run 2
RQ (fermentation rate)
Oxygen (%)
0
1
2
3
4
0
0.5
1
1.5
2
2.5
3
3.5

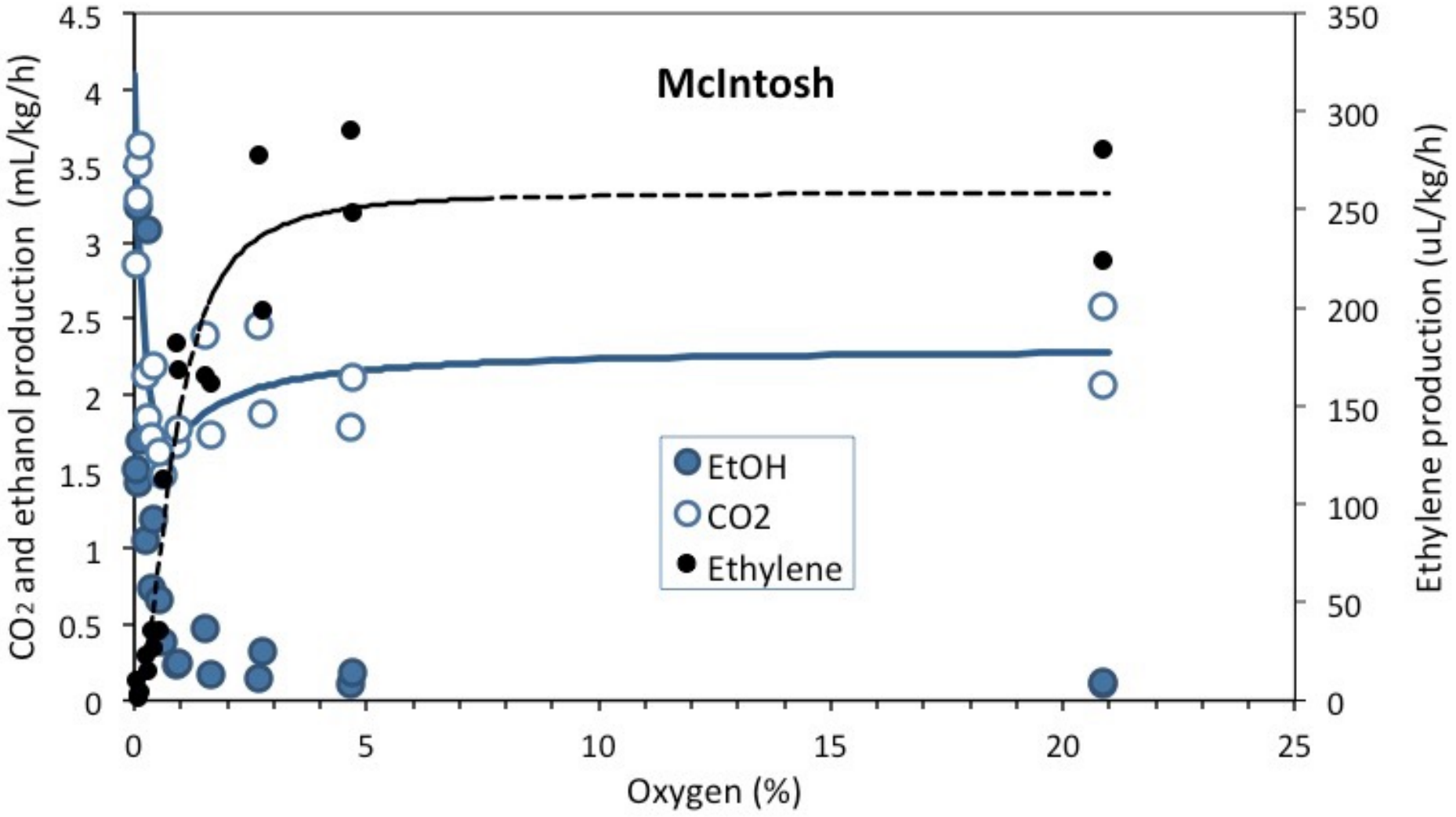
Labpod


Honeycrisp
Lower Oxygen Limit = 0.25%
UTC, Run 1
ReTain, Run 1
ReTain, Run 2
UTC, Run 2
RQ (fermentation rate)
Oxygen (%)
0
1
2
3
4
0
0.5
1
1.5
2
2.5
3
3.5

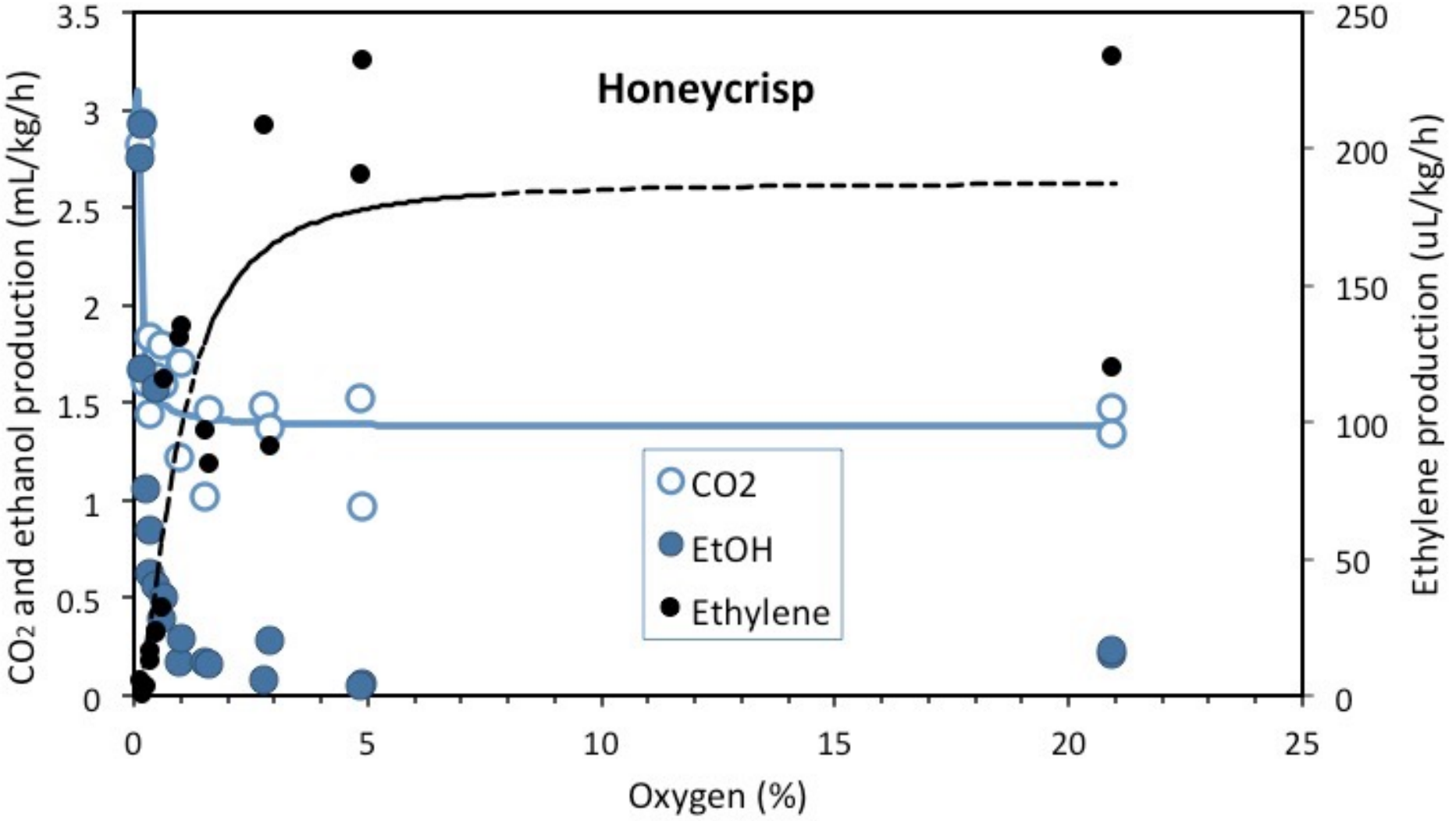
Flow-Thru


Empire
CO2
EtOH
Ethylene
CO_2 and ethanol roduction (mL/kg/h)
Ethylene production (uL/kg/h)
Oxygen (%)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
50
100
150
200
250
300
0
5
10
15
20
25

Flow-Thru


McIntosh
EtOH
CO2
Ethylene
CO_2 and ethanol production (mL/kg/h)
Ethylene production (uL/kg/h)
Oxygen (%)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
50
100
150
200
250
300
350
0
5
10
15
20
25

Flow-Thru


Honeycrisp
CO2
EtOH
Ethylene
CO2 and ethanol production (mL/kg/h)
Ethylene production (uL/kg/h)
Oxygen (%)
0
0.5
1
1.5
2
2.5
3
3.5
0
50
100
150
200
250
0
5
10
15
20
25

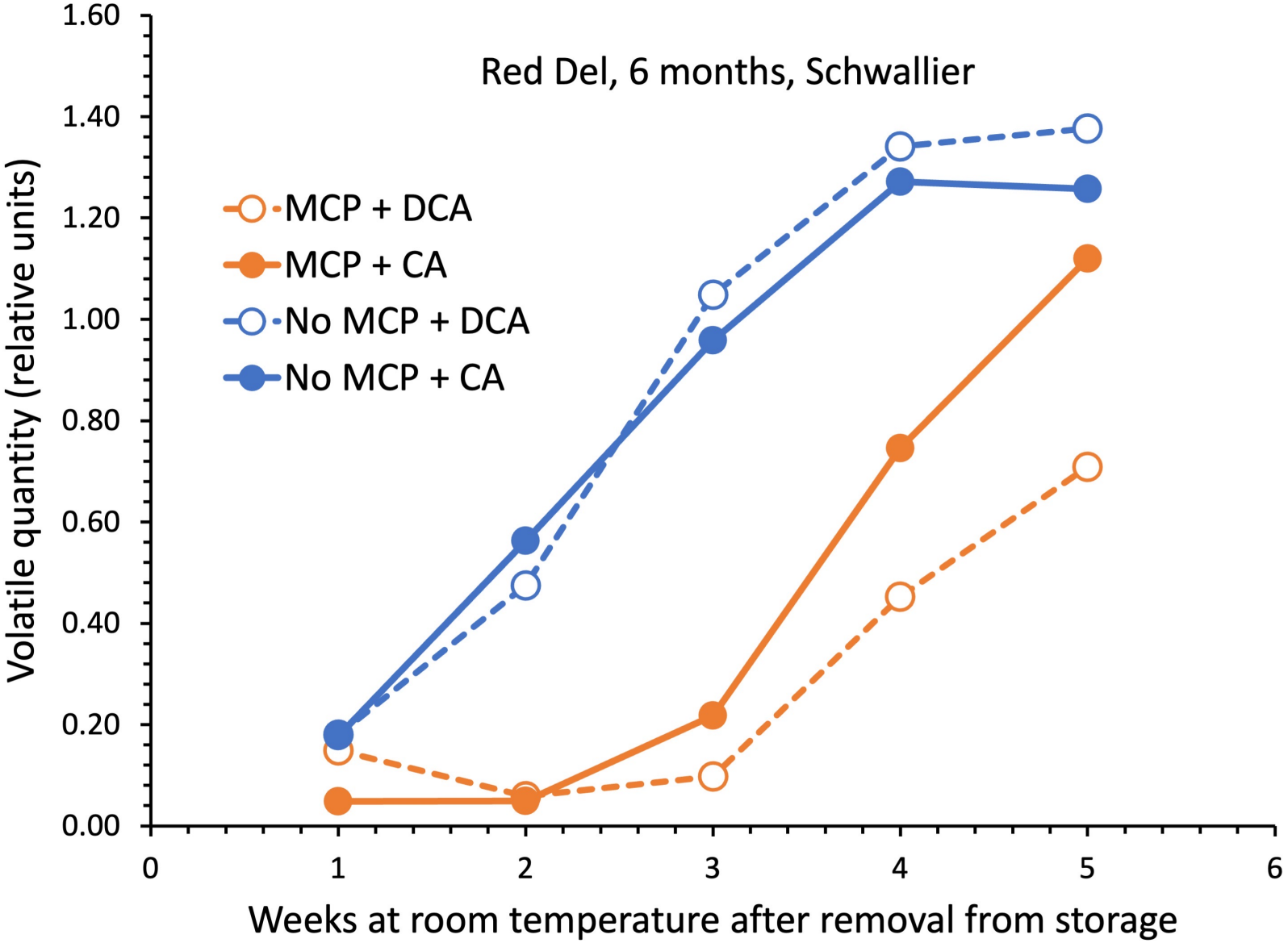
AROMA VOLATILE ANALYSIS

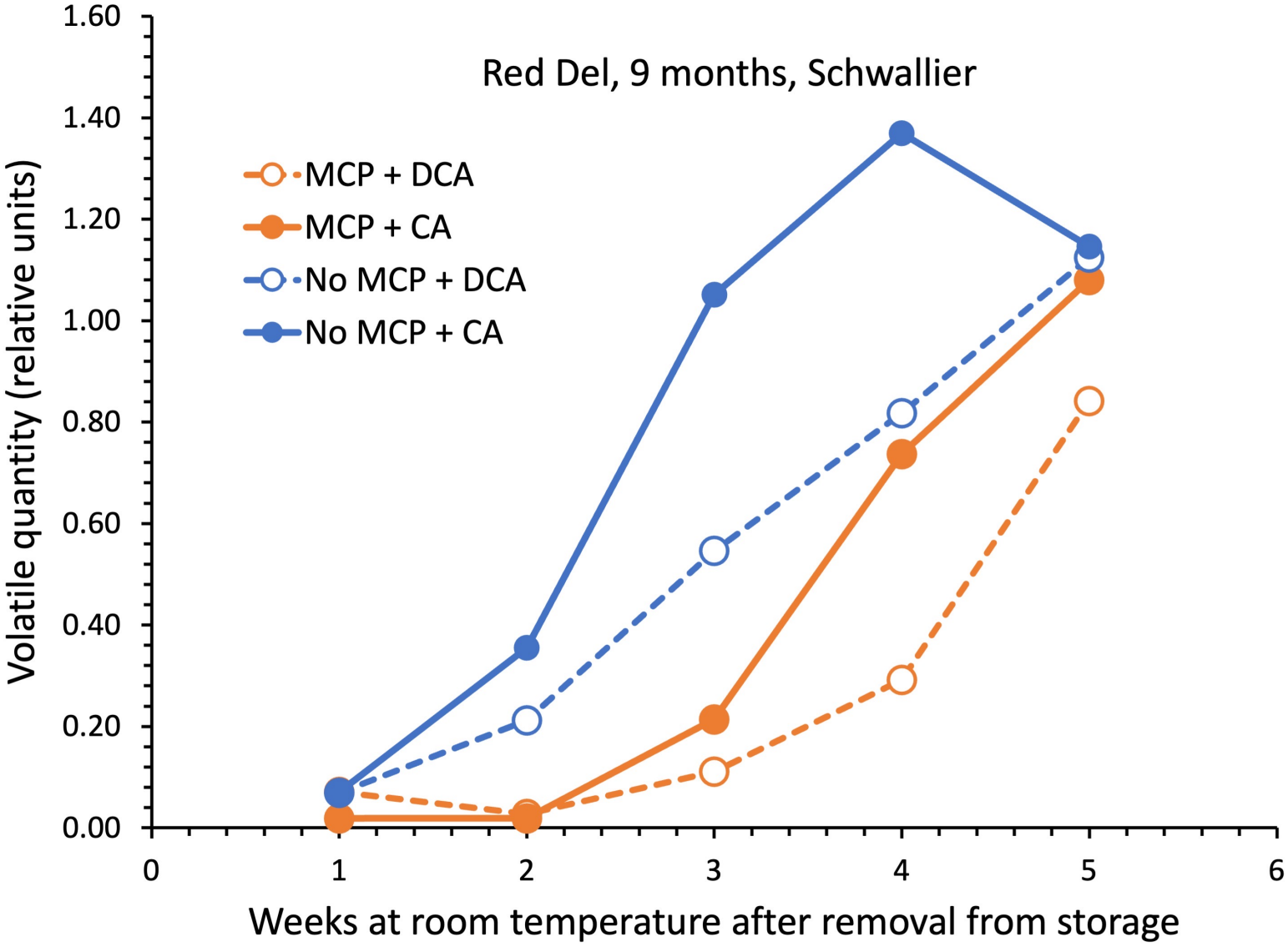
After repairs, repairs, repairs, replacement

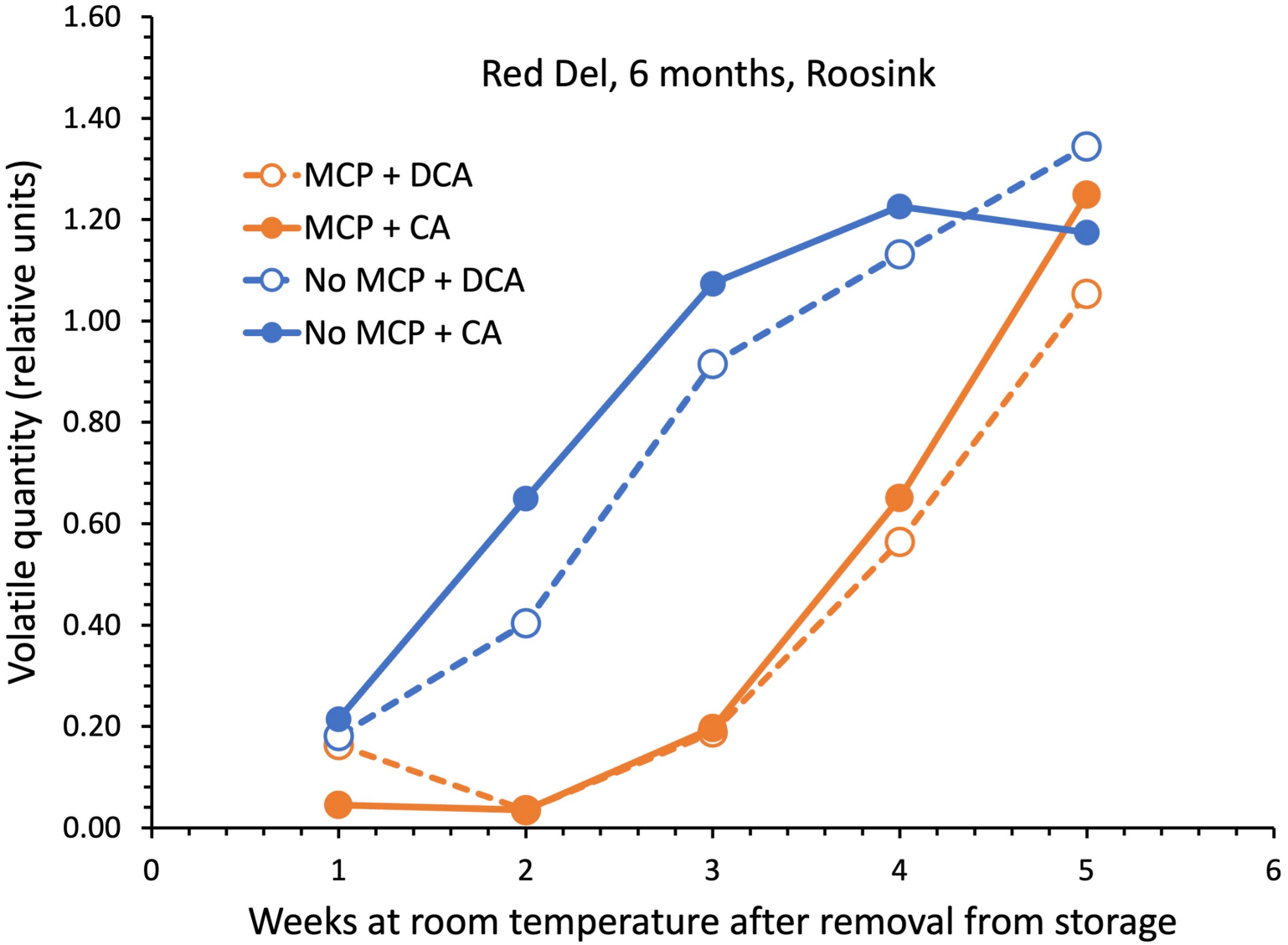
CA & DCA study

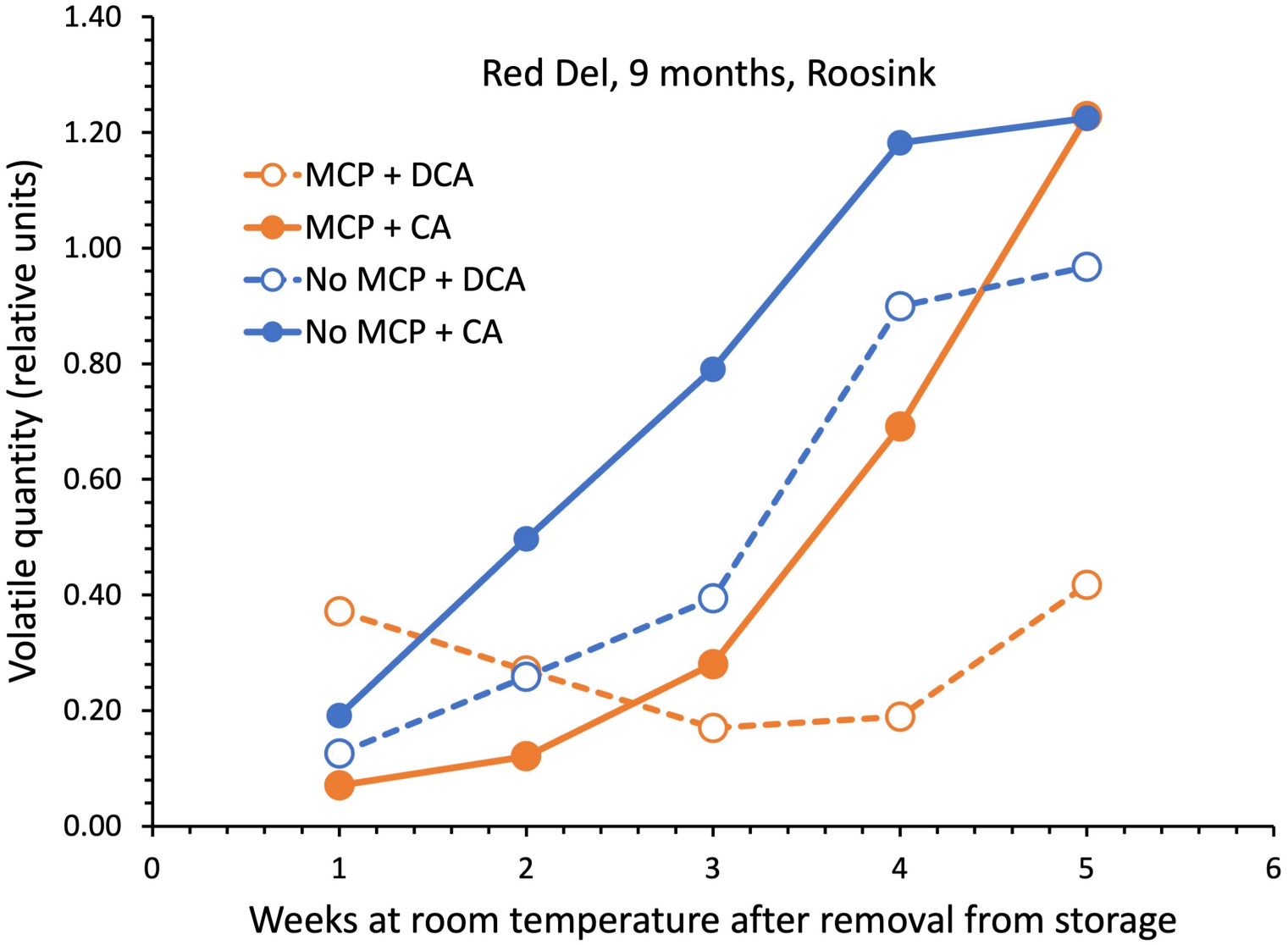
Over 2 years, fruit of several different varieties Gala, McIntosh, Jonagold, Golden Delicious, Red Delicious, Fuji, and Evercrisp were stored in CA or under simulated DCA conditions for 3, 6, and either 9 or 11 months. Half of the fruit were treated with 1 ppm 1-MCP.

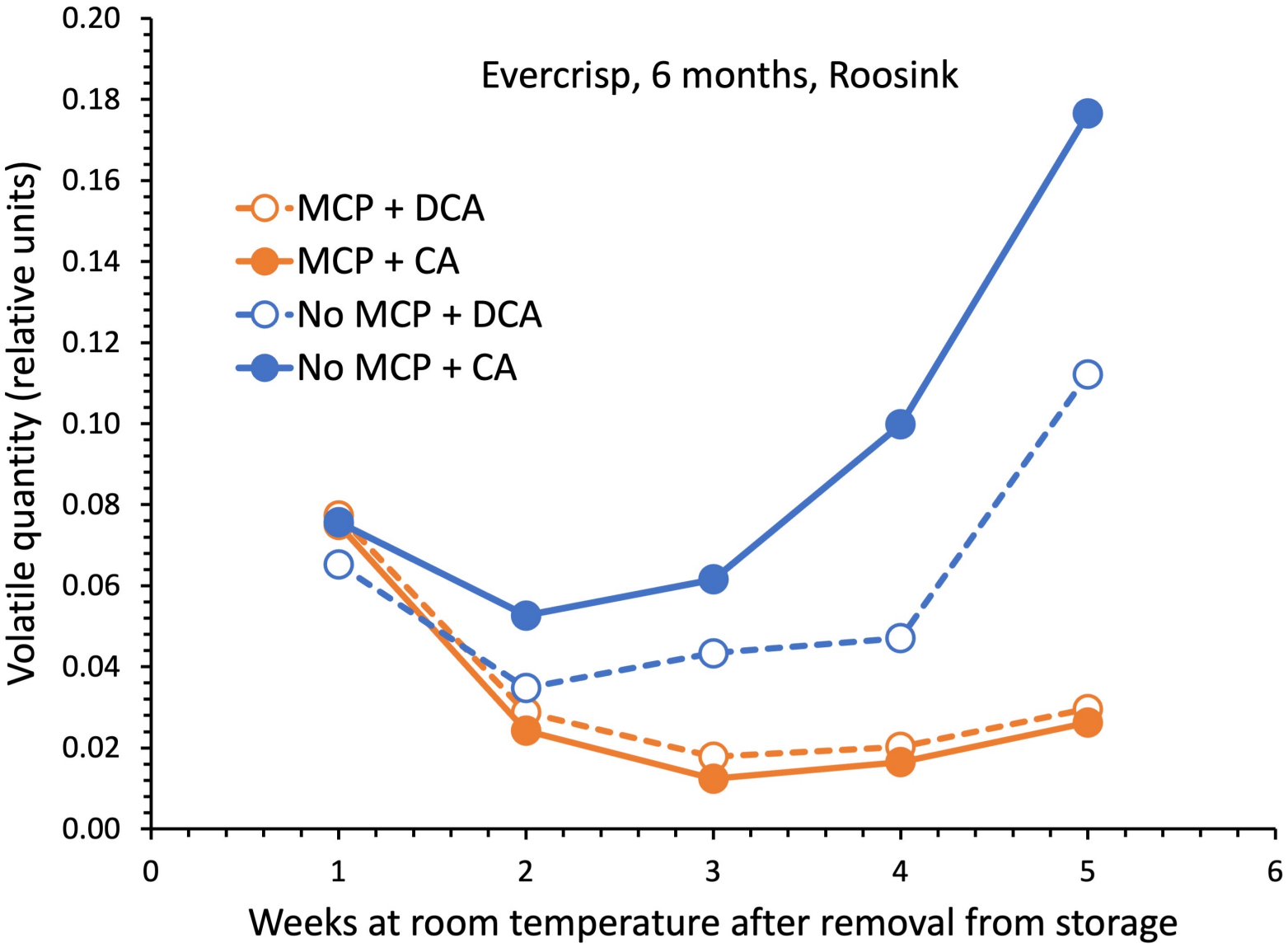
We evaluated 5 replicate fruit from each treatment combination and evaluated the aroma volatile production from the fruit for up to 5 weeks after removal from storage, holding the fruit at 22 C (room temperature).

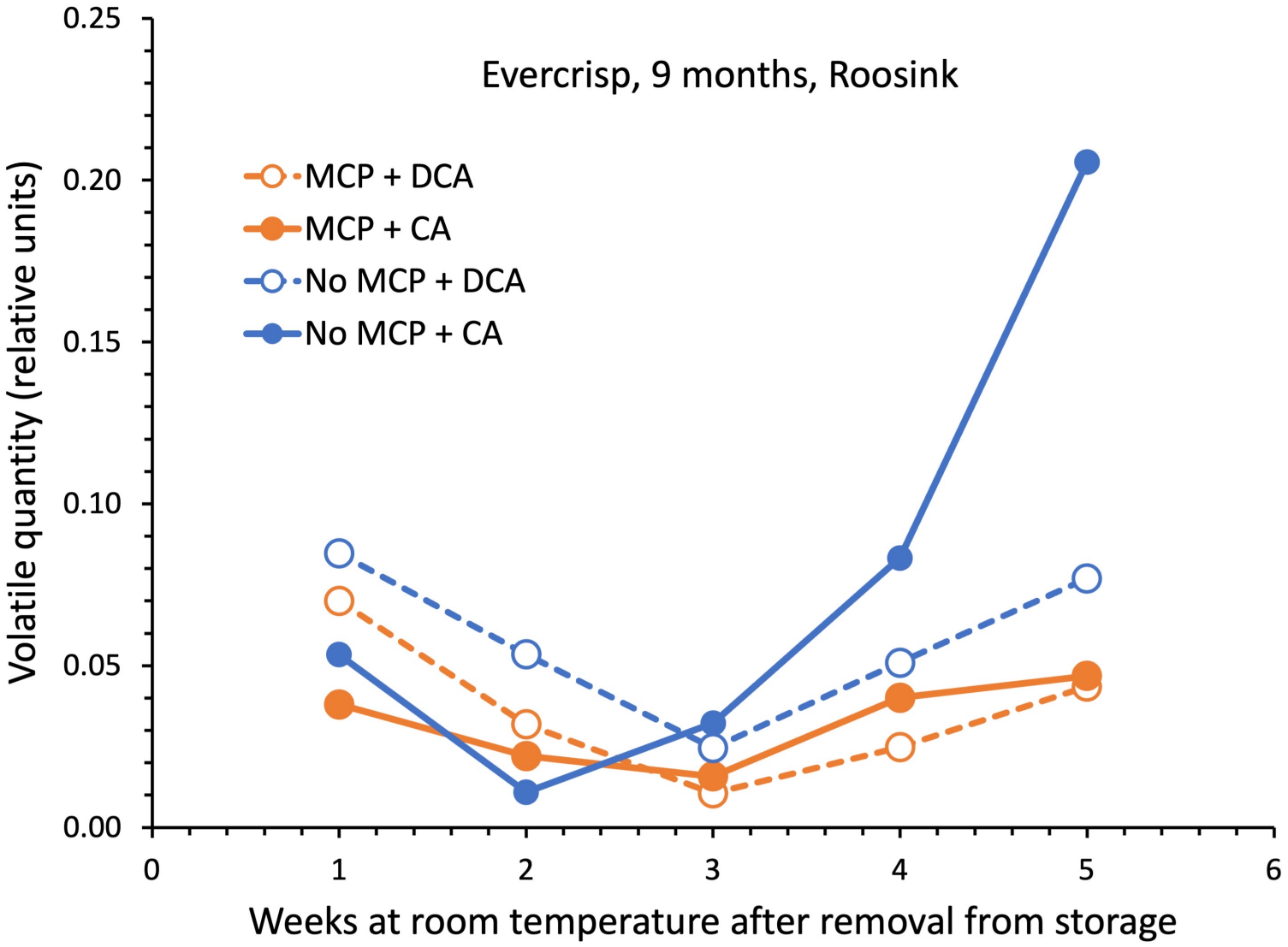

Red Del, 6 months, Schwallier
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage


Red Del, 9 months, Schwallier
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage


Red Del, 6 months, Roosink
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage

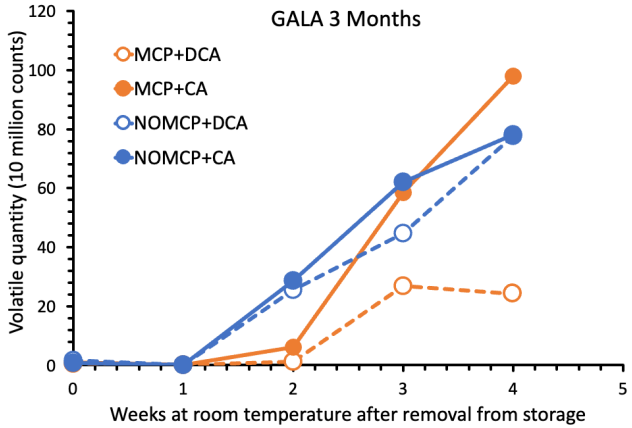

Red Del, 9 months, Roosink
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage


Evercrisp, 6 months, Roosink
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage

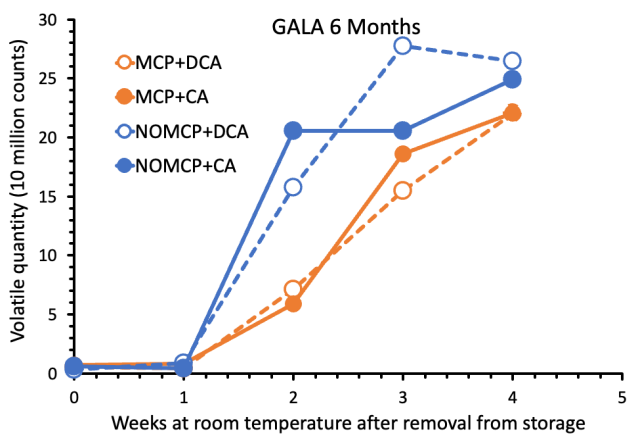

Evercrisp, 9 months, Roosink
MCP + DCA
MCP + CA
No MCP + DCA
No MCP + CA
Volatile quantity (relative units)
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
Weeks at room temperature after removal from storage

GALA

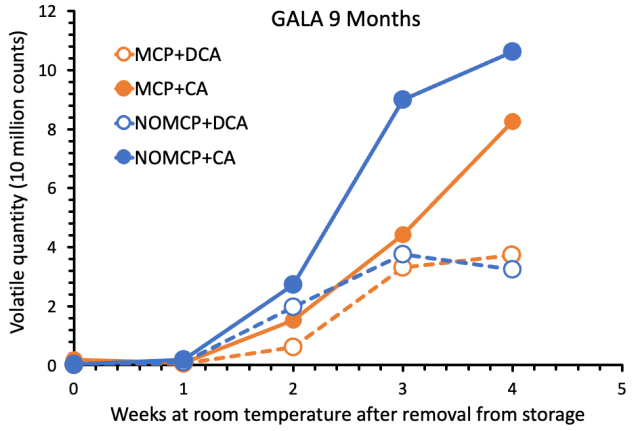
3 Mo



6 Mo

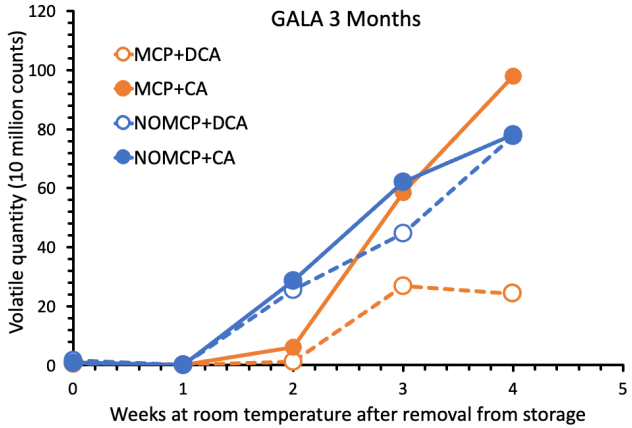


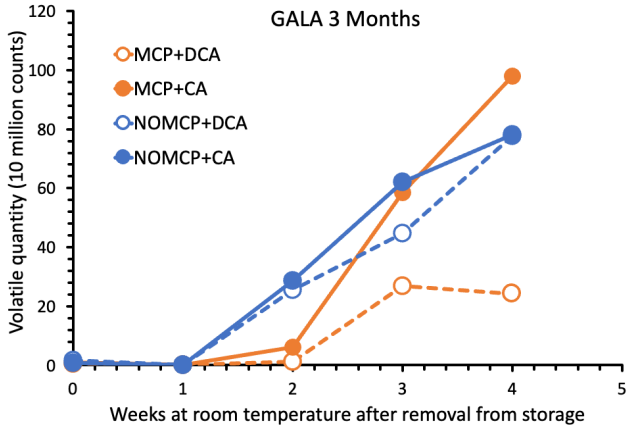
9 Mo



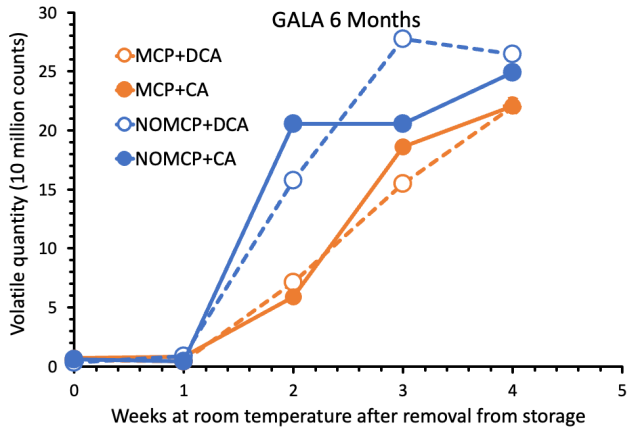
GALA

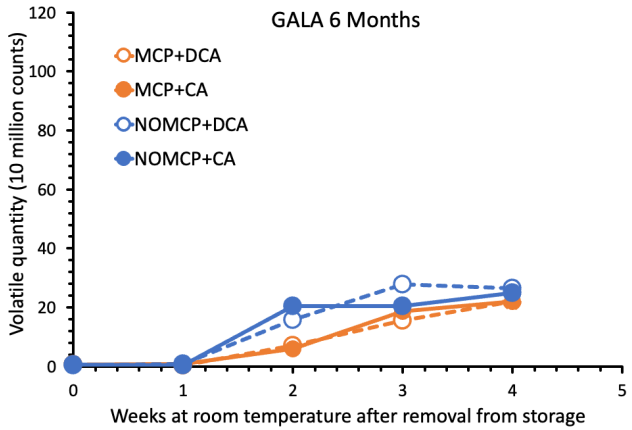
3 Mo





6 Mo





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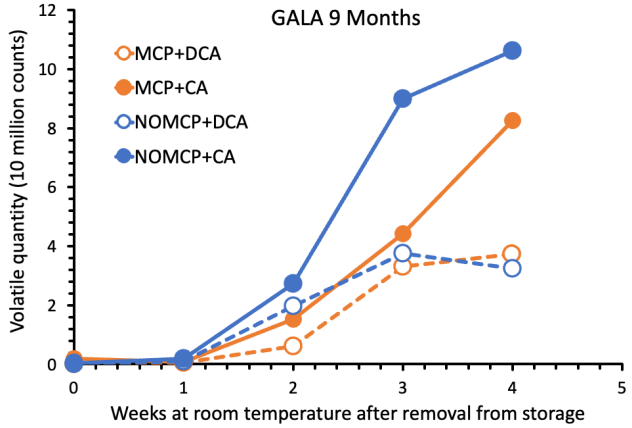
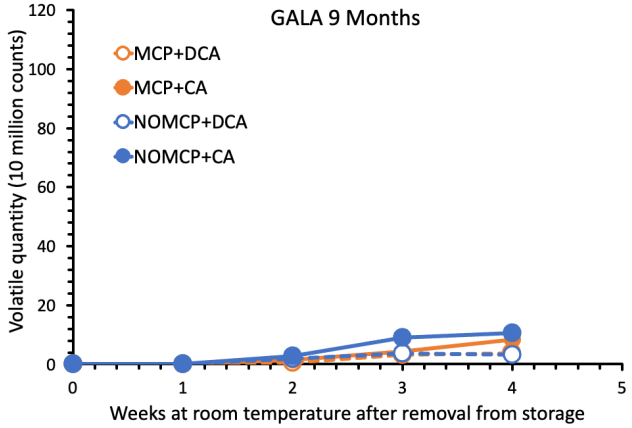
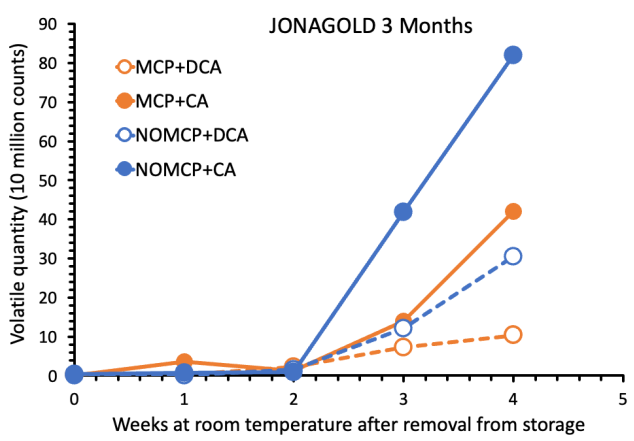


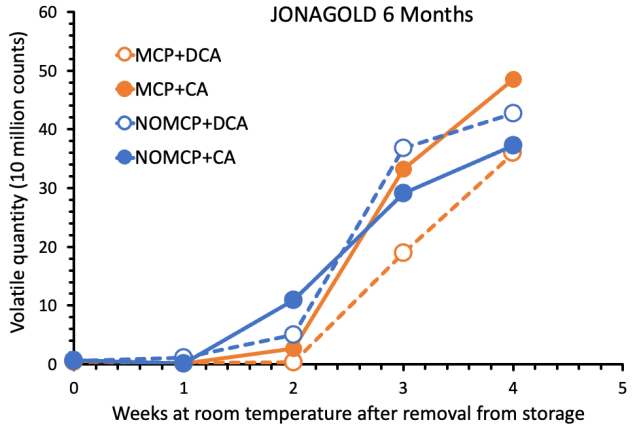


JONAGOLD

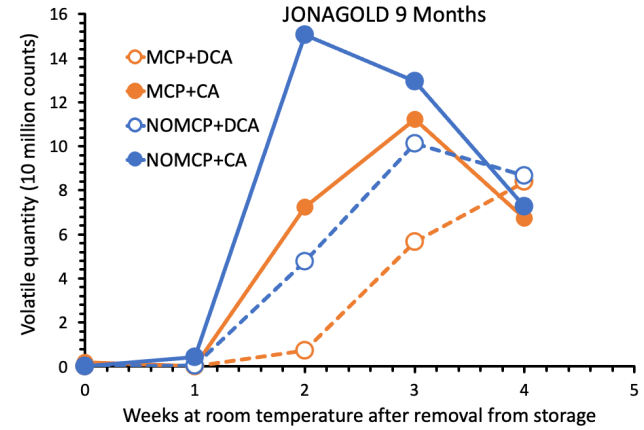
3 Mo



6 Mo

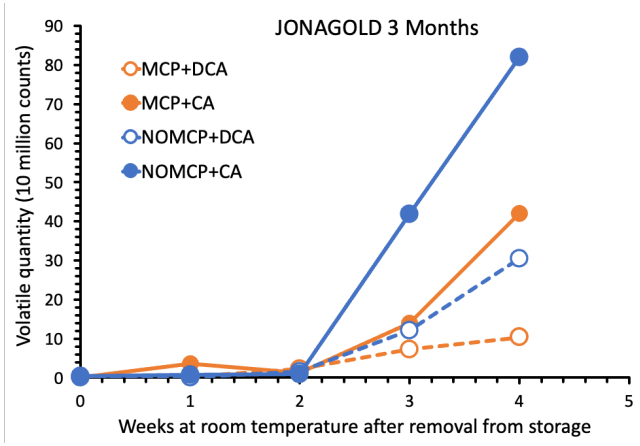


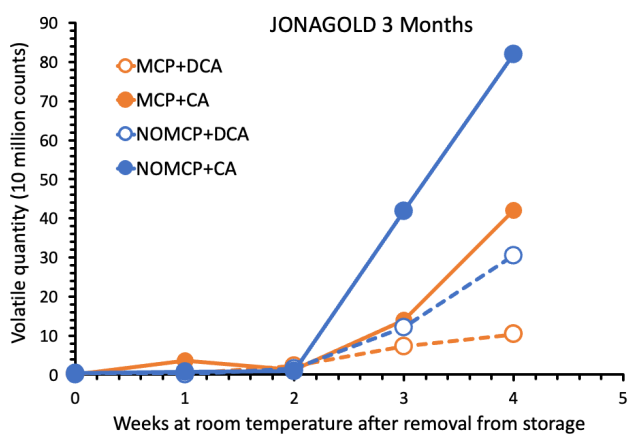
9 Mo



JONAGOLD

3 Mo





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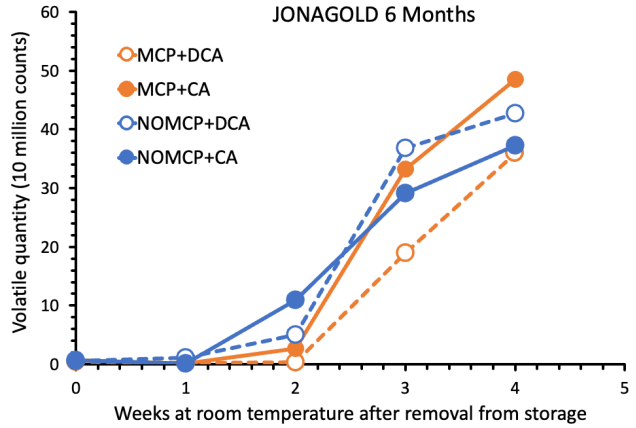
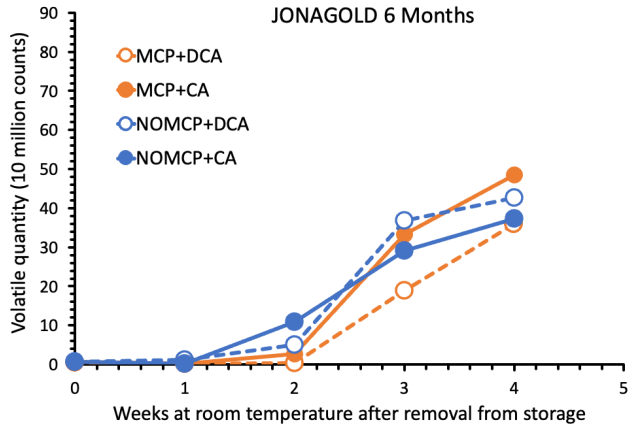
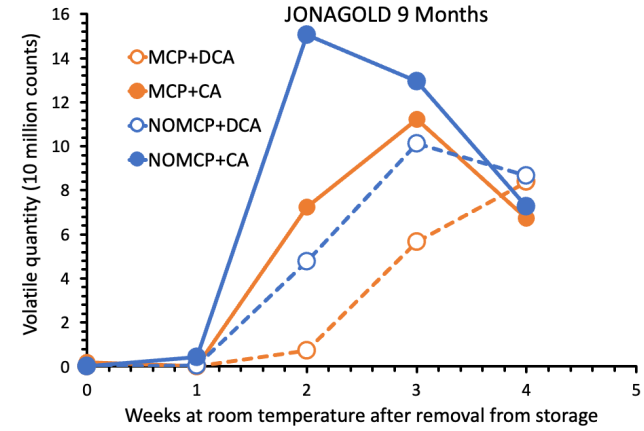
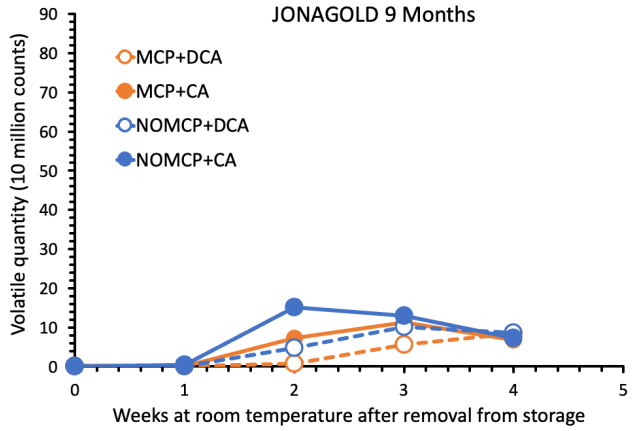




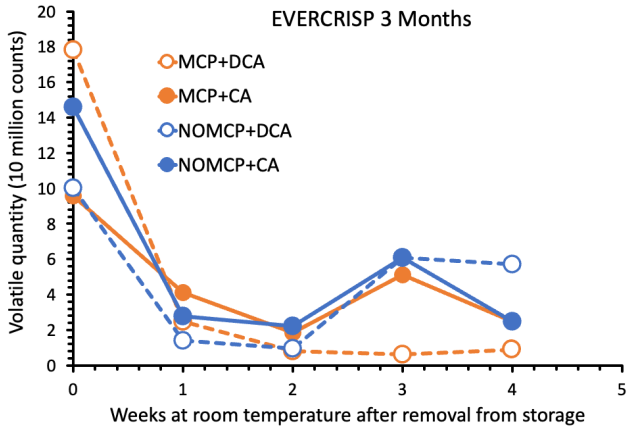
9 Mo





EVERCRISP

3 Mo



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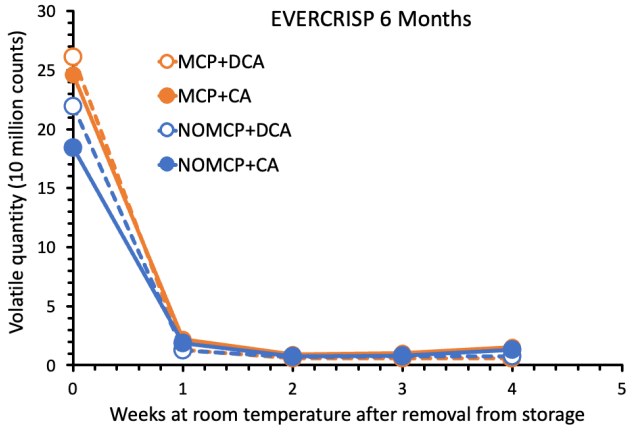
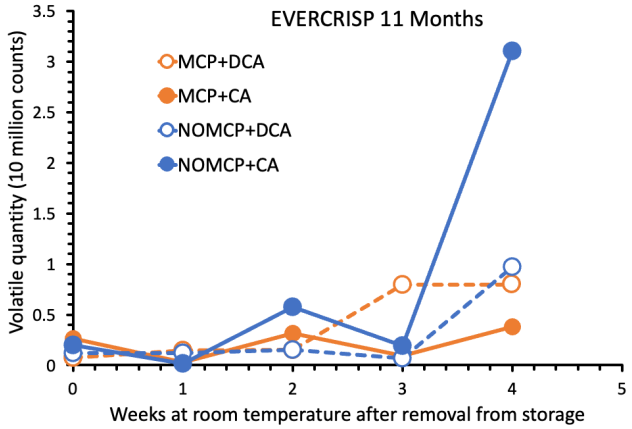
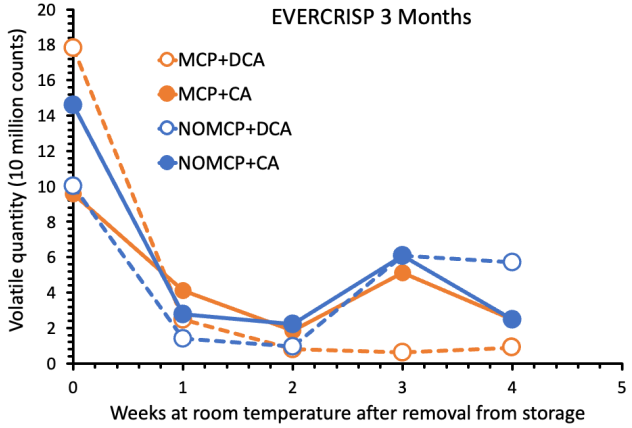


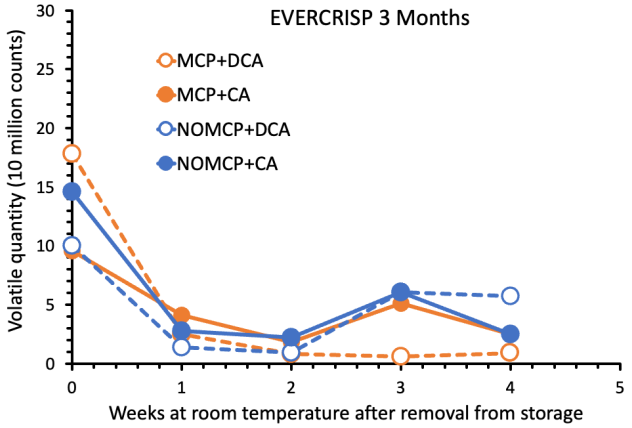
11 Mo



EVERCRISP

3 Mo





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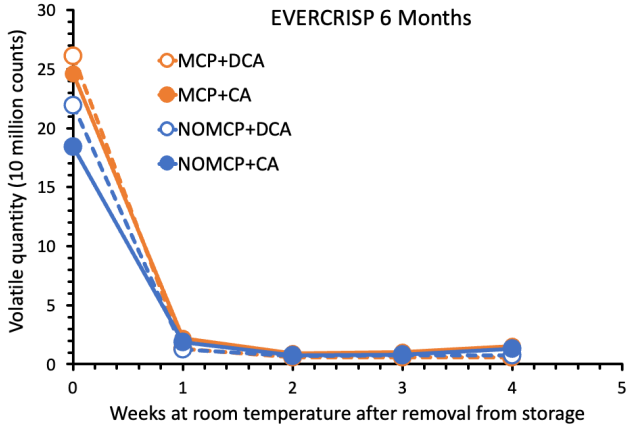

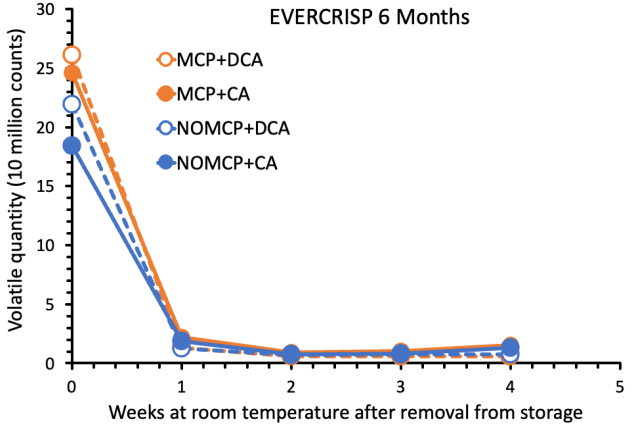

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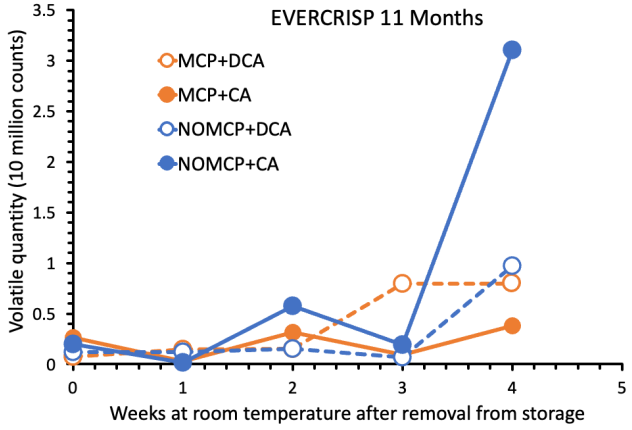

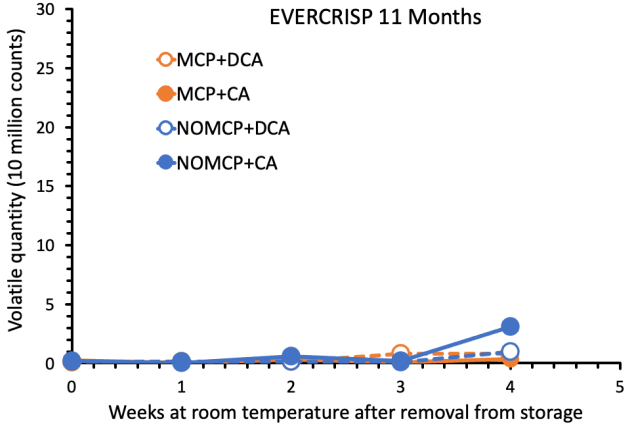

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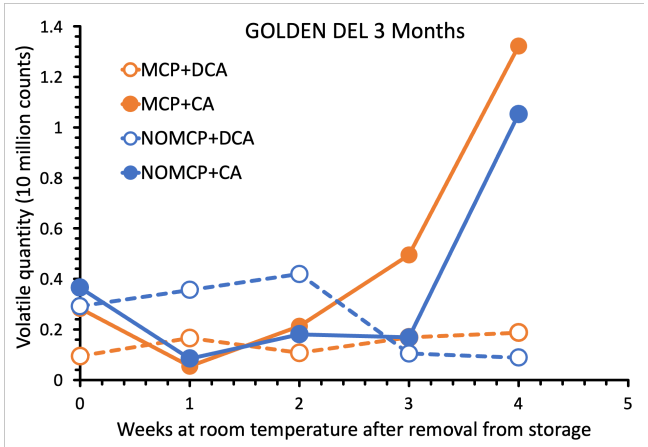

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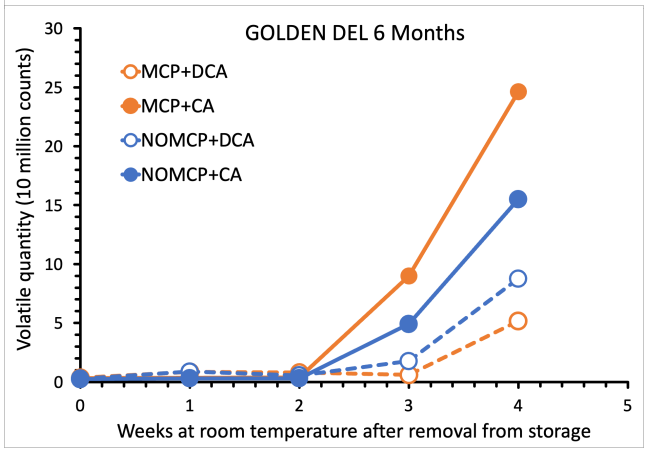

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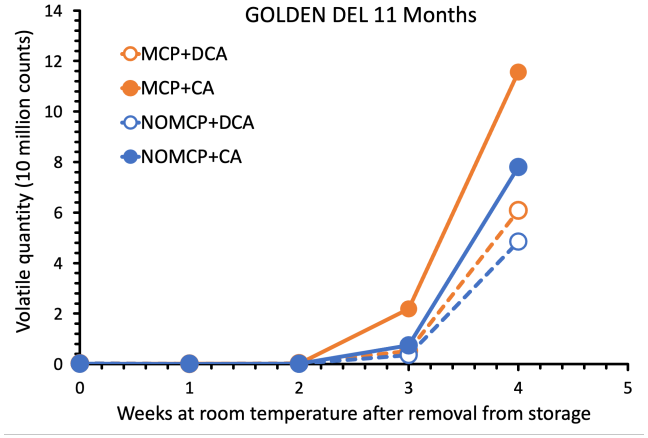

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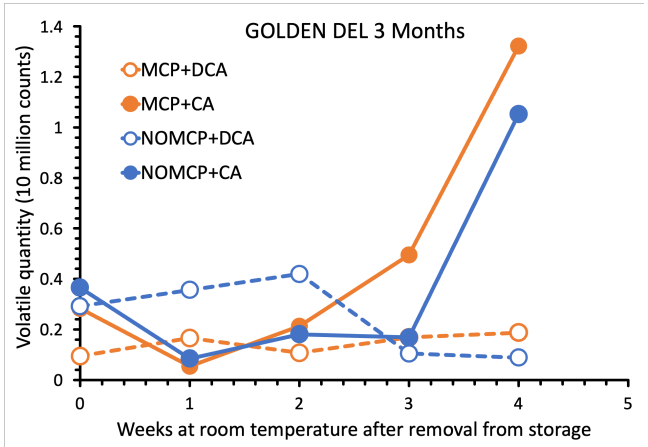

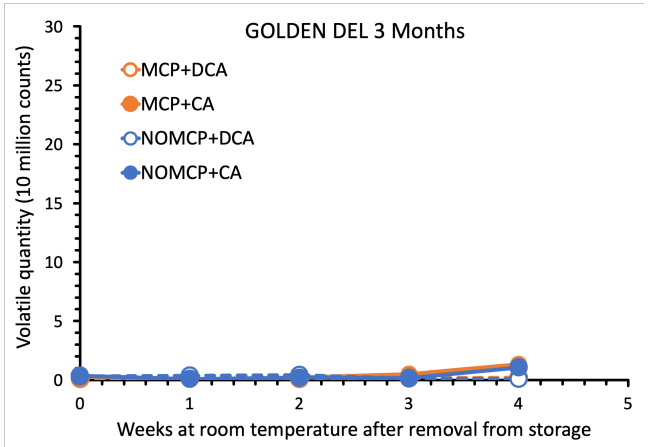

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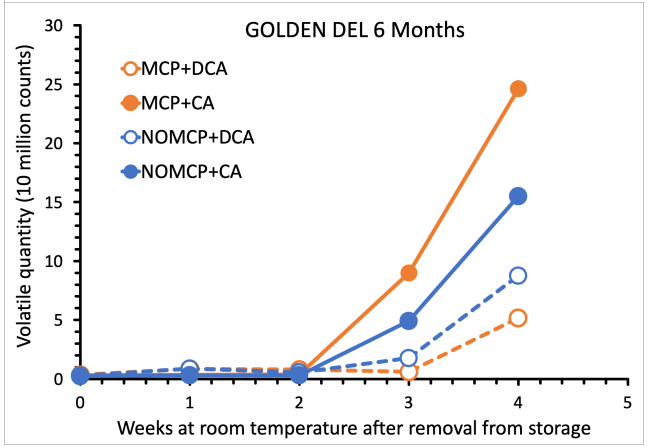

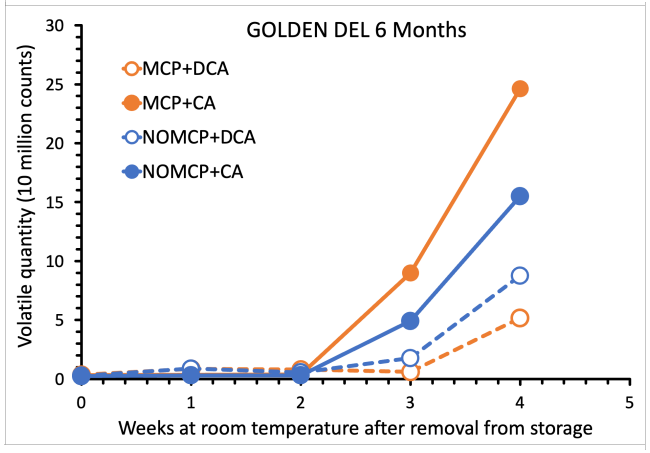

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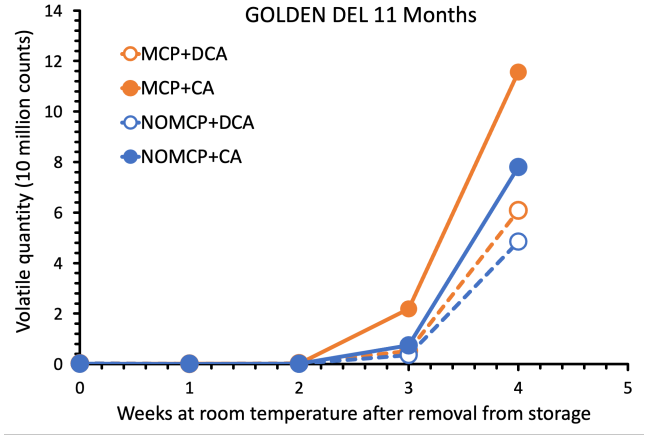

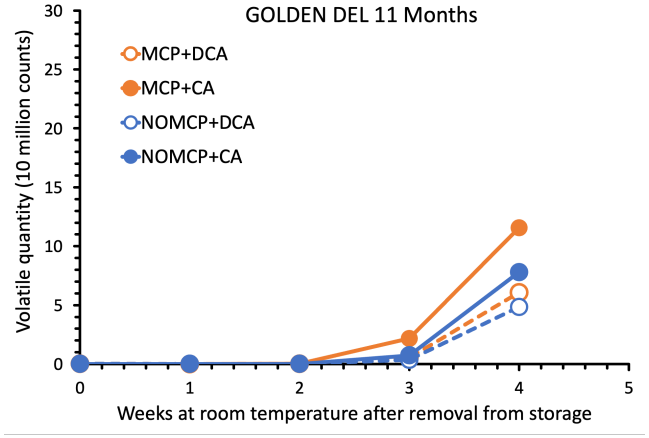

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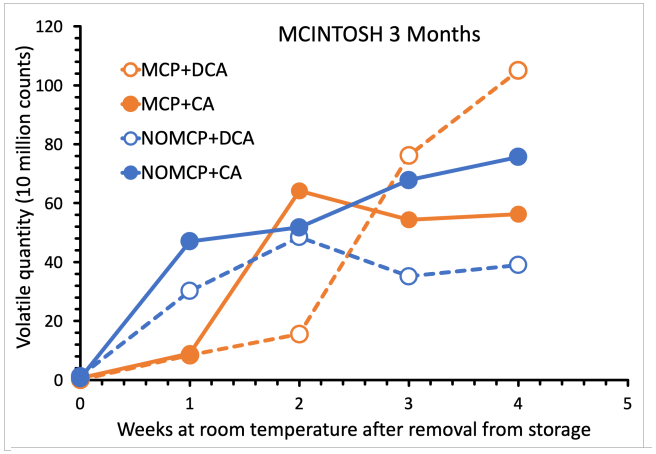

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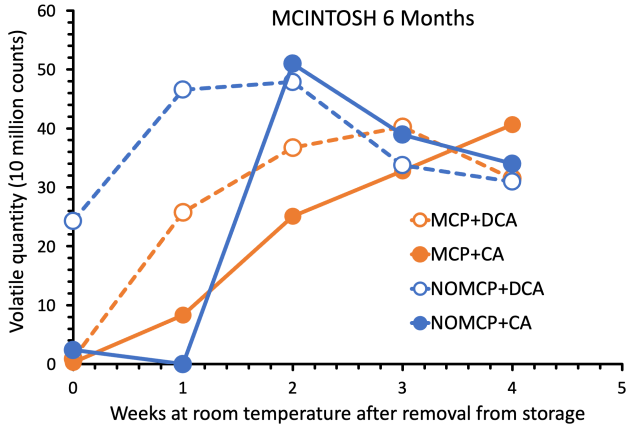

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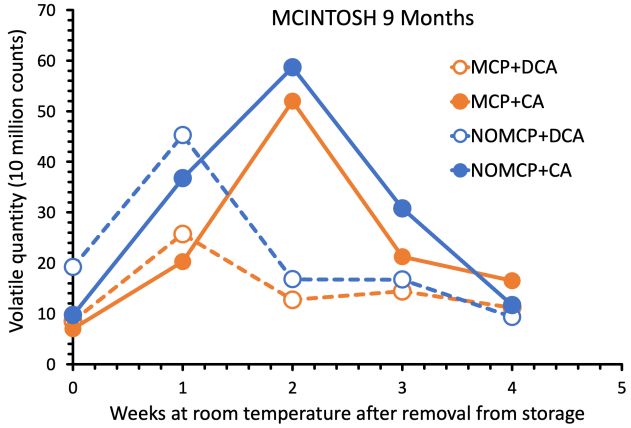

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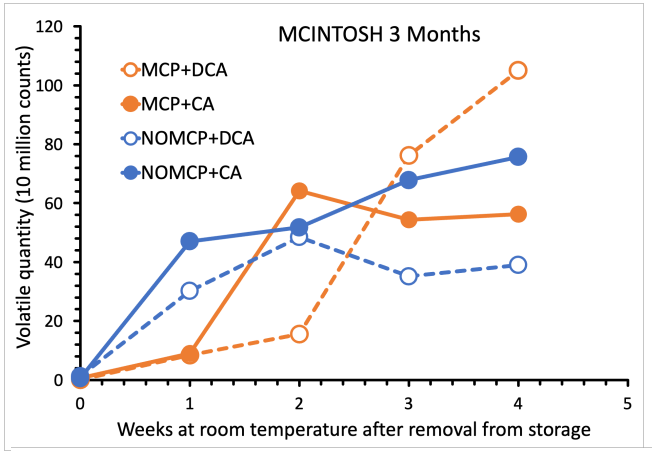

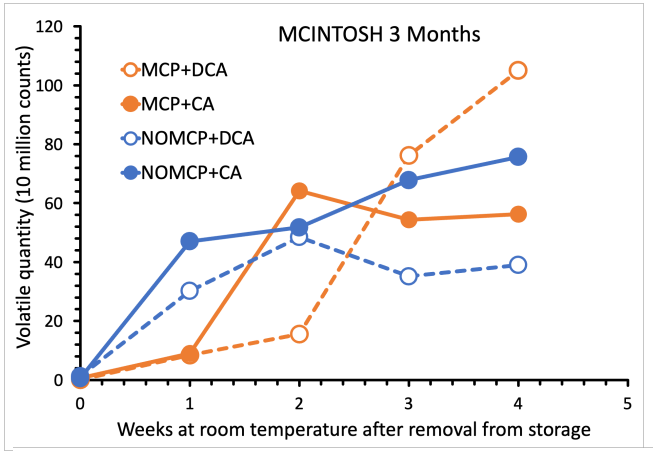

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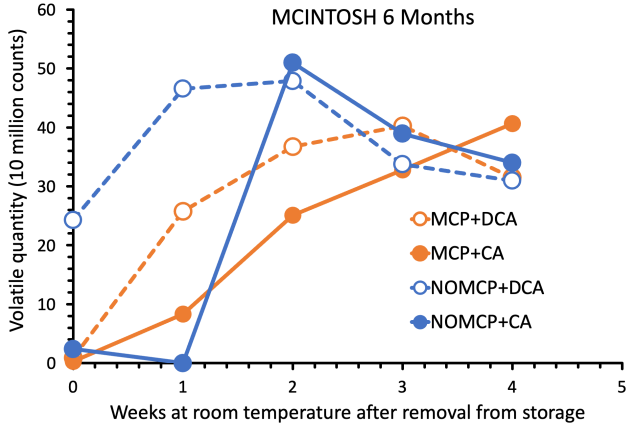

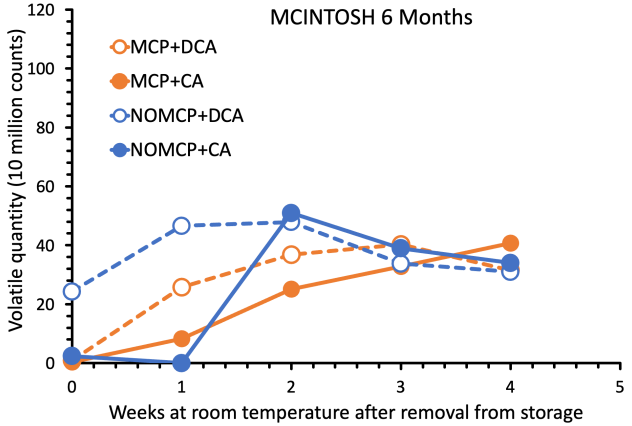

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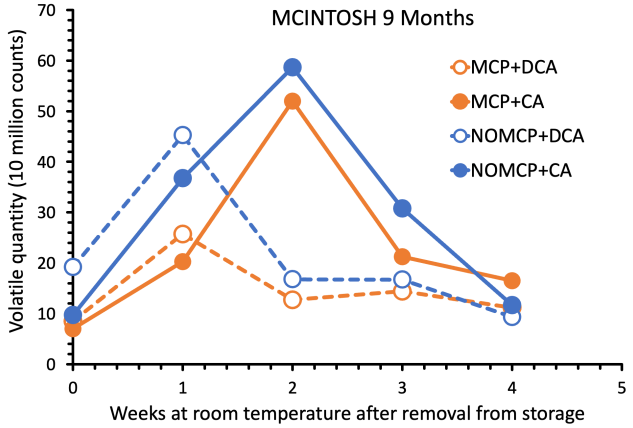

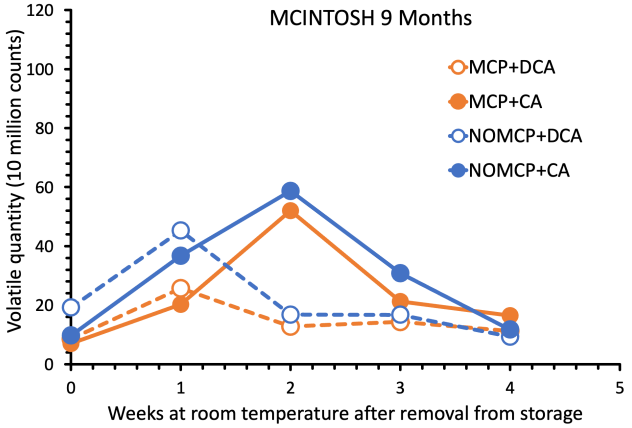

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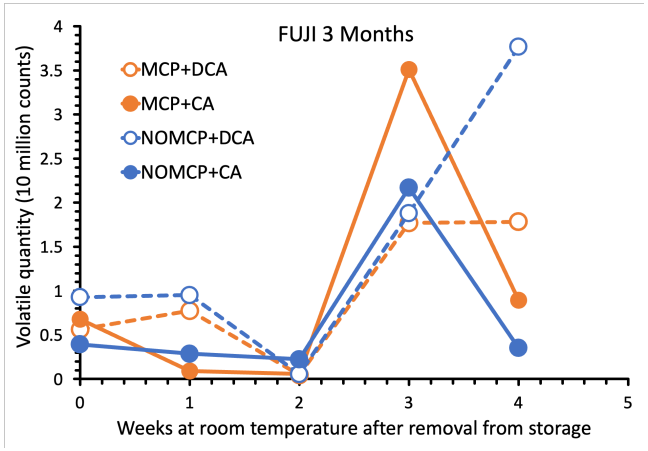

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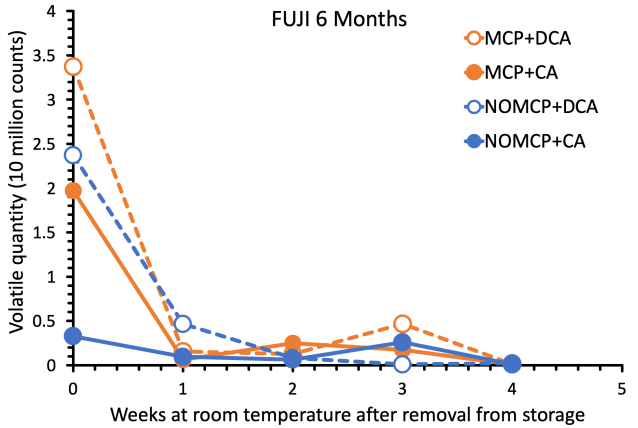

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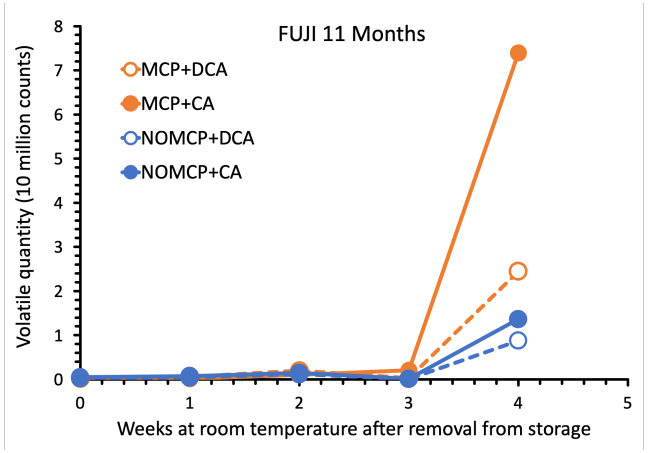

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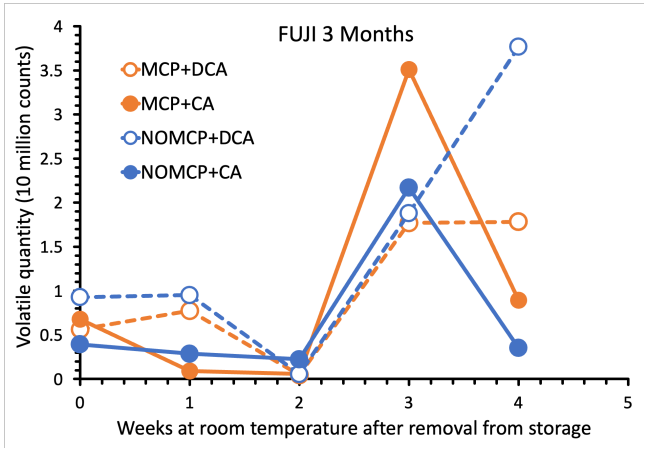

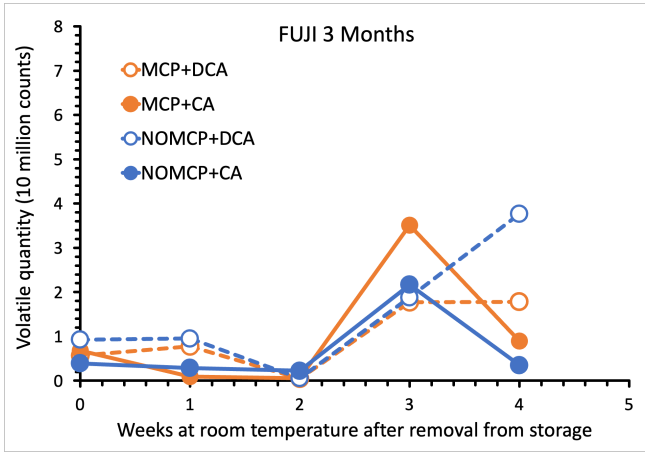

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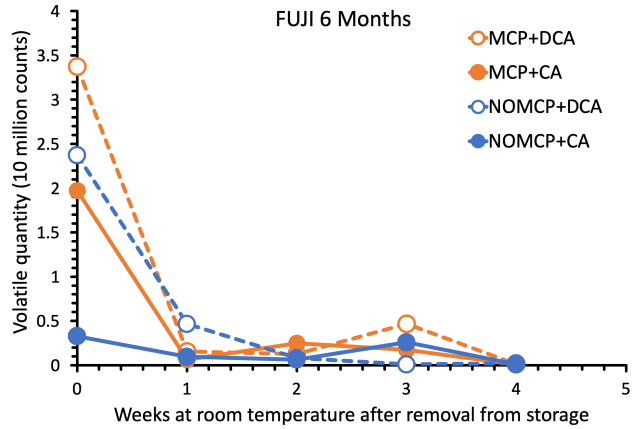

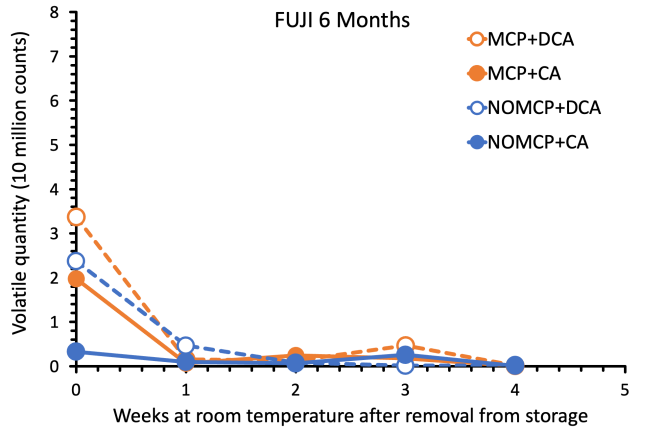

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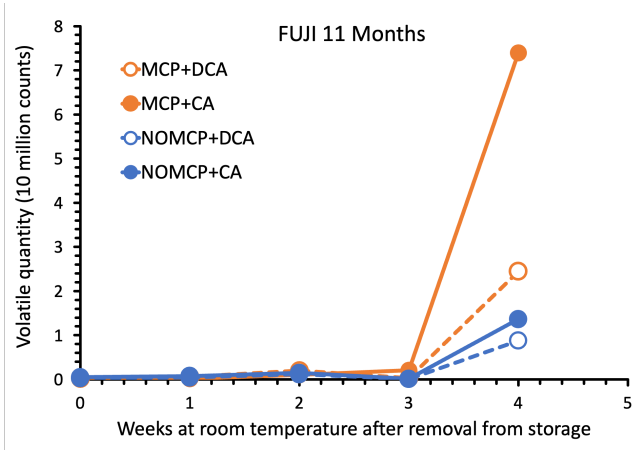

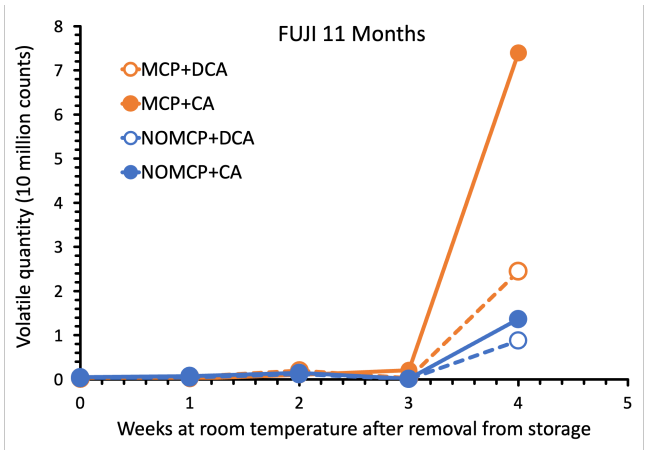

SUMMARY COMMENTS

1-MCP INHIBITS THE RECOVERY OF VOLATILE AROMA COMPOUNDS

DCA INHIBITS THE RECOVERY OF VOLATILE AROMA COMPOUNDS

THE GREATEST IMPACT ON AROMA COMPOUND FORMATION OFTEN COMES FROM DURATION OF STORAGE.

IN SEVERAL CASES TREATMENT EFFECTS APPEAR TO BE ADDITIVE – TWO TREATMENTS (E.G. DCA AND MCP, or DCA AND DURATION) NEGATIVELY IMPACT AROMA MORE THAN JUST ONE. THREE TREATMENTS IMPACT AROMA COMPOUNDS MORE THAN JUST TWO.