The 43rd Biennial Meeting of The American Society of Sugar Beet Technologists

# Low concentration of chlorine dioxide gas reduced invert sugars and raffinose accumulation in postharvest sugarbeet roots

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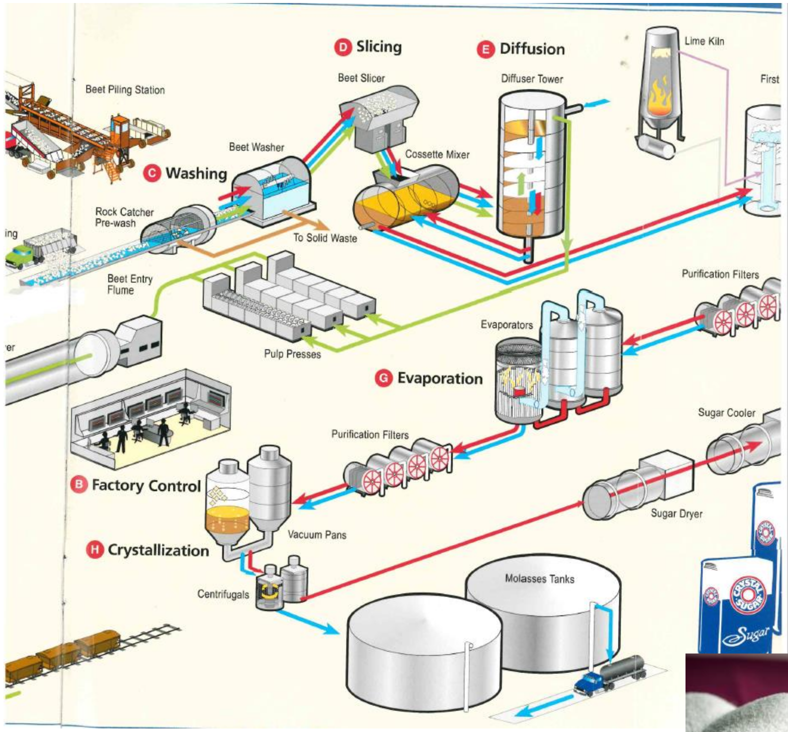
# Sugarbeet processing and sugar production

Sugarbeet production

Storage of postharvest sugarbeet roots




Factory processing

# Research objective

To identify Chlorine dioxide ($ClO_2$) gas treatment conditions to improve sugarbeet storage and postharvest quality

- Eliminating of pathogen growth
- Preventing storage diseases
- Improving sucrose retention
- Reducing concentration of invert sugars and other carbohydrates

## Rationale & Significance

- Approximately $ 900 million postharvest losses annually
- No promising preventive measures
- Necessity of mitigation strategy to minimize the losses

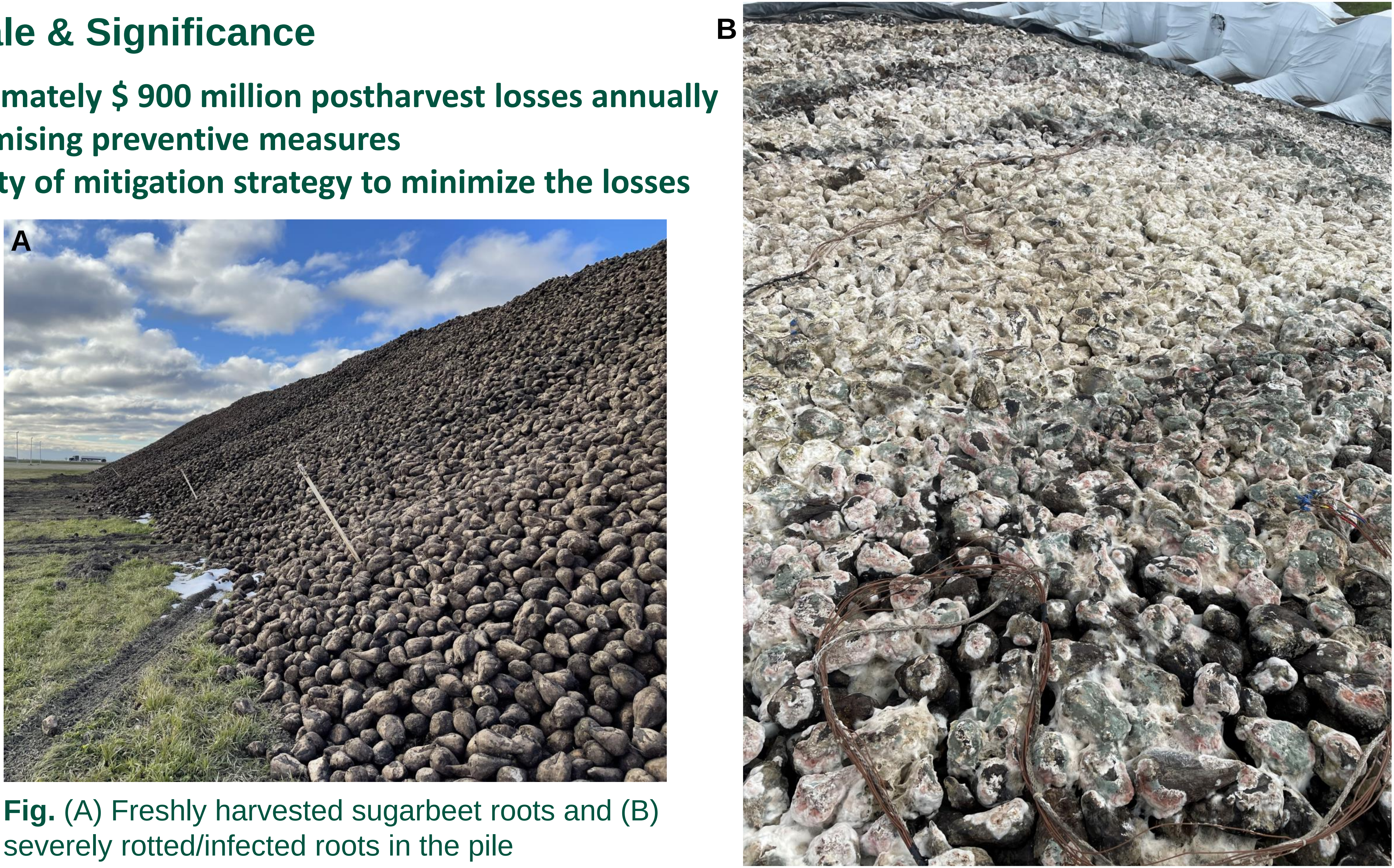
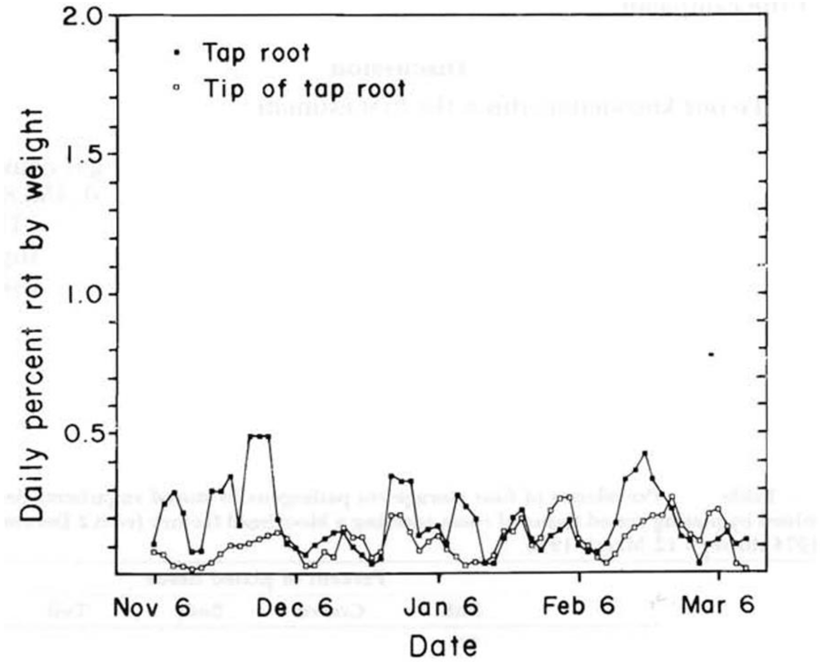



**Fig.** (A) Freshly harvested sugarbeet roots and (B) severely rotted/infected roots in the pile

## Sugarbeet Storage Rot in the Red River Valley, 1974-75

W. M. Bugbee and D. F. Cole[1]




- During this 128-day period 1.22% by weight of roots processed were rotted.
- This amounted to an actual sugar loss of 1,113,240 lb plus another loss estimated at 1,781,184 lb of sucrose going to molasses.

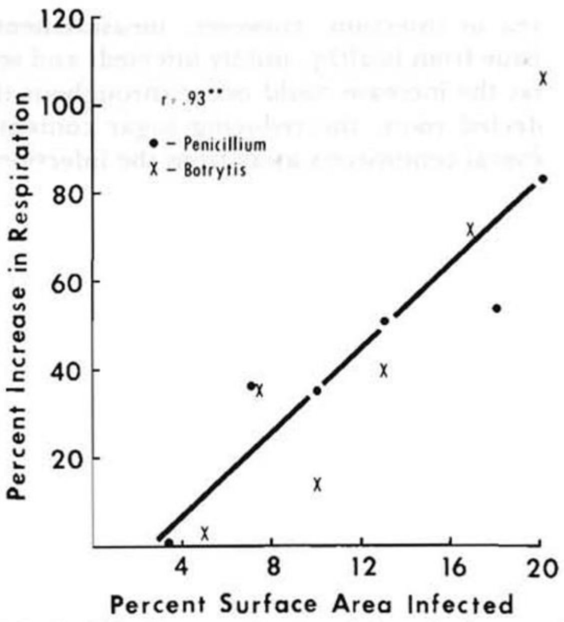



Figure 2.—Relationship of root surface area infected to increase in respiration rate.

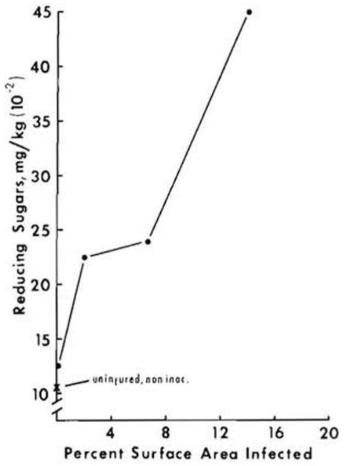
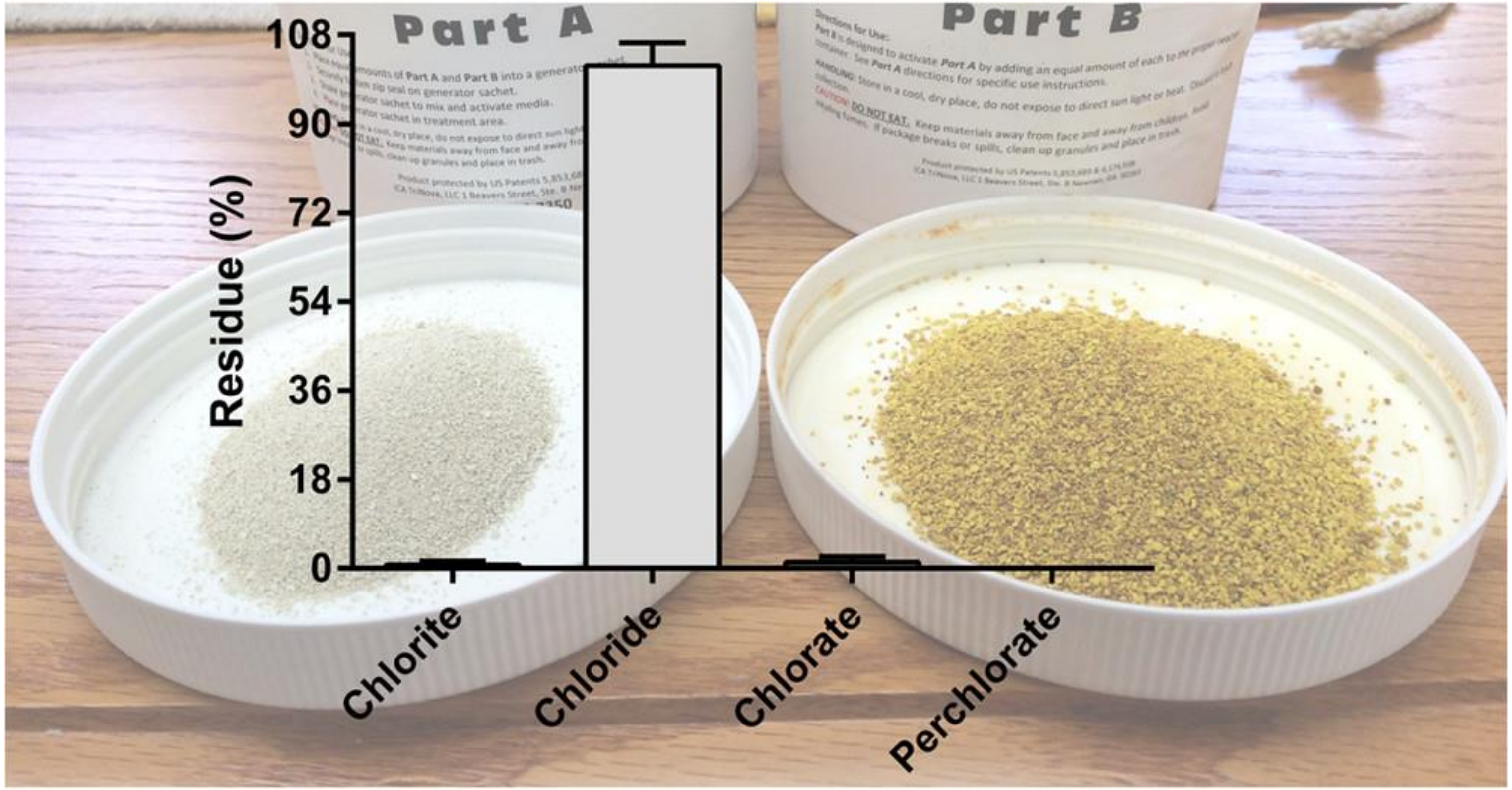



Figure 3.—Relationship of root surface area infected to increase in reducing sugars

Mumford and Wyse, 1976

# Chlorine dioxide ($ClO_2$)



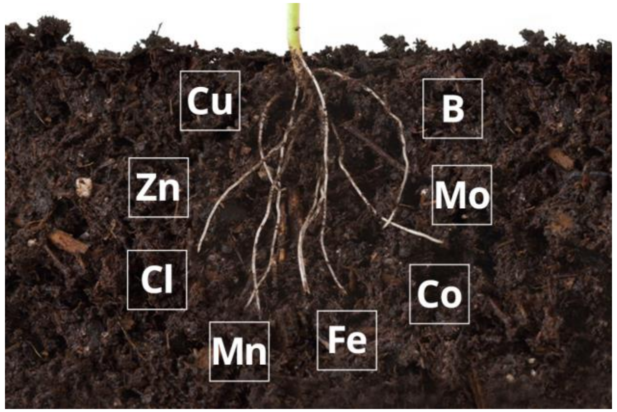

**Fast release:**

Part A: Granular sodium chlorite

Part B: Ferric chloride hexahydrate

**Slow release:**

Sodium chlorite zeolite; ZC Impregnate




$ClO_2$ ➡ chloride ($Cl^-$) ➡ chlorite ($ClO_2^-$) ➡ chlorate ($ClO_3^-$) ➡ perchlorate ($ClO_4^-$)

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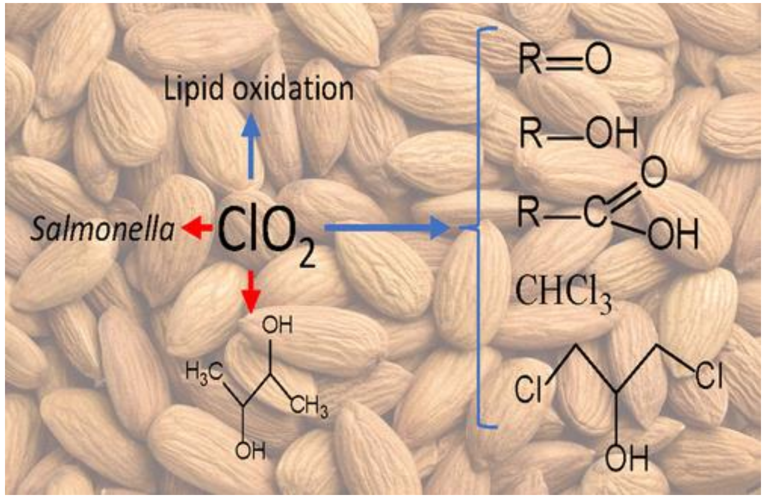
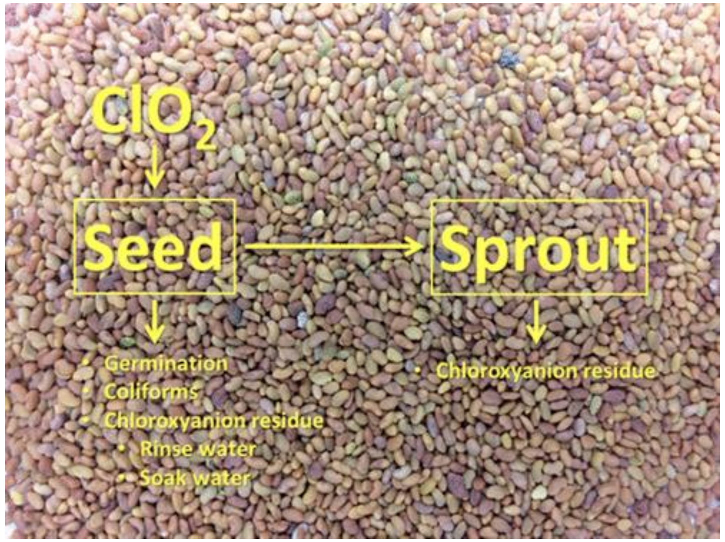
Smith et al. (2016); DOI: (10.1021/acs.jafc.6b04011)

# Application of chlorine dioxide in different crops


ARTICLE | April 20, 2020

**Distribution and Chemical Fate of [$^{36}$Cl]Chlorine Dioxide Gas on Avocados, Eggs, Onions, and Sweet Potatoes**

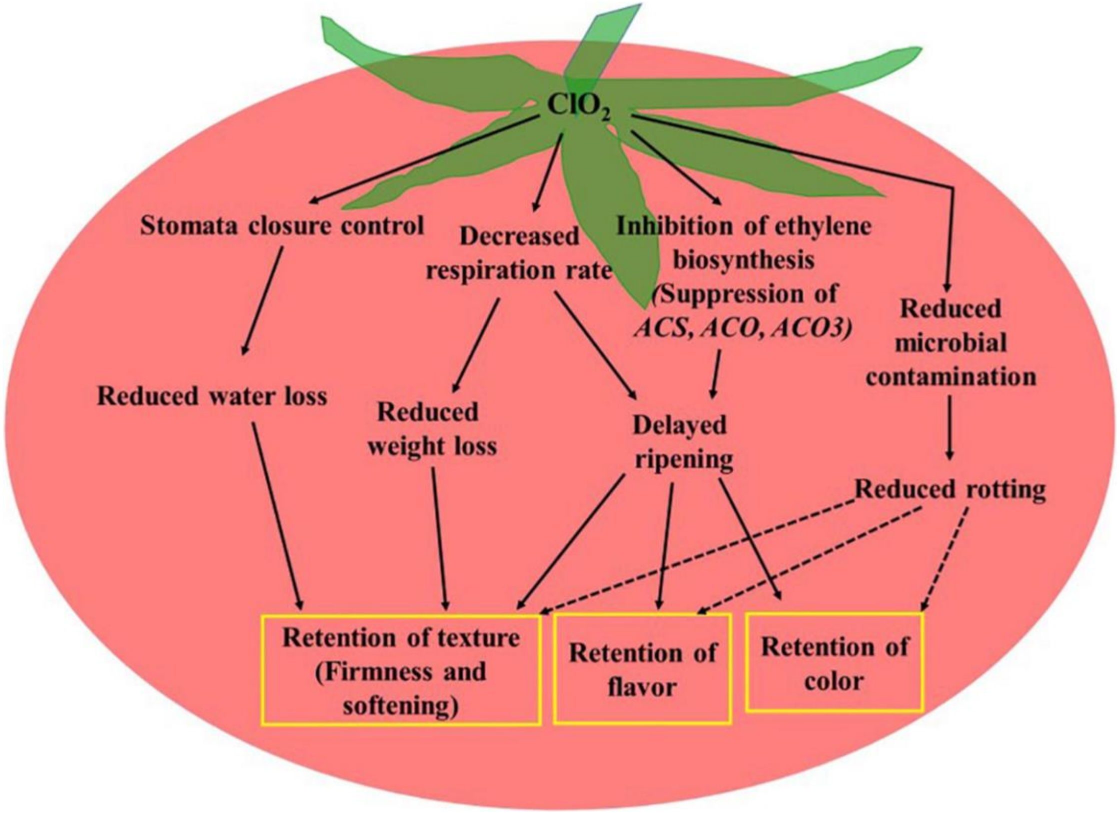
David J. Smith*, and Abigail Scapanski

CHEMISTRY AND BIOLOGY OF AROMA AND TASTE | March 22, 2023

**Lipid Oxidation and Volatile Compounds of Almonds as Affected by Gaseous Chlorine Dioxide Treatment to Reduce *Salmonella* Populations**

Wenli Wang, David J. Smith, Helen Ngo, Zhonglin Tony Jin, Alyson E. Mitchell, and Xuetong Fan*

# Potential Mechanisms Regulating Postharvest Quality by $ClO_2$




Malka and Park, 2022

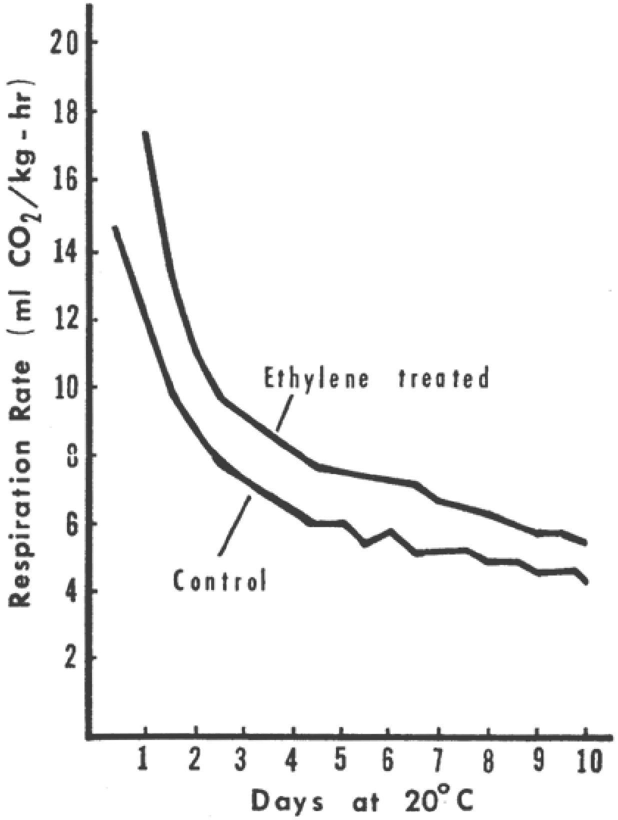



Figure 7. Influence of 1000 ppm ethylene pretreatment on the subsequent respiration rate of sugarbeet roots.

Wyse, 1973

# Bucket system for the storage experiment


2023

2024

# Studying the effect of chlorine dioxide for improving storage quality of sugarbeet roots (2023)

## Experimental outline:

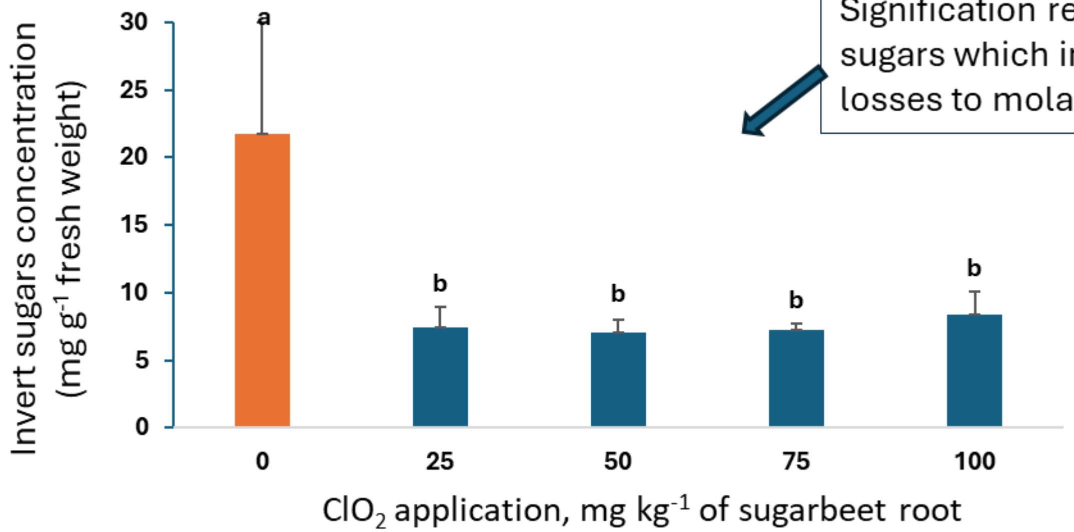
- Chlorine dioxide doses: 0, 25, 50, 75, 100 mg per kg of sugarbeet roots
- 10 kg beet roots per bucket
- Replication: 4
- Stored for 7 weeks (Feb-March, 2023) at 5°C
- Precursors supplemented at every week

**Granular sodium chlorite**
**+**
**Ferric chloride hexahydrate**

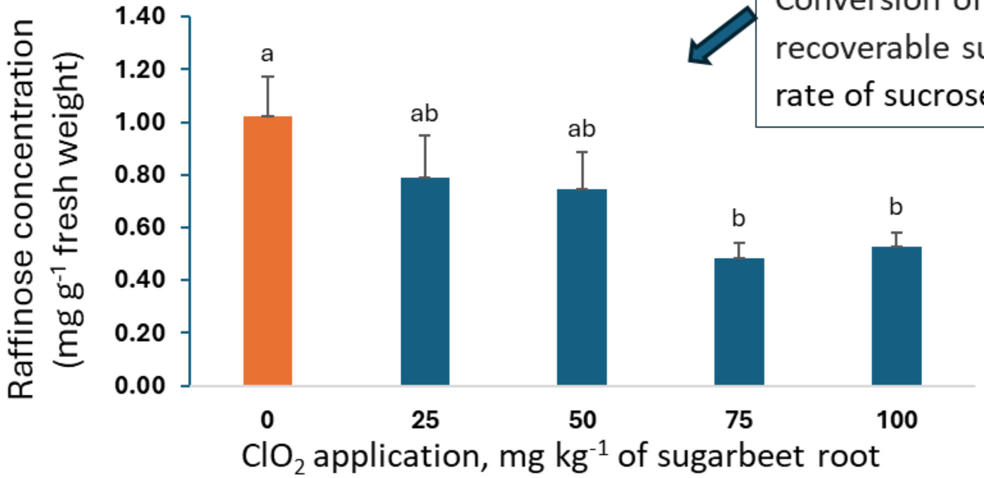
# Inhibition of storage diseases and non-sugars by $ClO_2$ in stored sugarbeet roots (2023)


**Microbial growth and rotting of sugarbeet roots without application of $ClO_2$ (A); no infection on beet roots treated with 25 mg of $ClO_2$ $kg^{-1}$ of roots (B)**

Signification reduction of invert sugars which increases sucrose losses to molasses during processing




Conversion of sucrose to raffinose reduces recoverable sucrose yields and decrease the rate of sucrose crystallization




(Histograms that do not share a letter are significantly different ($P<0.05$) based on Fisher's LSD).

# Effect of chlorine dioxide to suppress microbial growth in sugarbeet roots (2024)

Fig. Plastic buckets after installation of fans and septum.

- 7 weeks (March-May, 2024) at 5°C

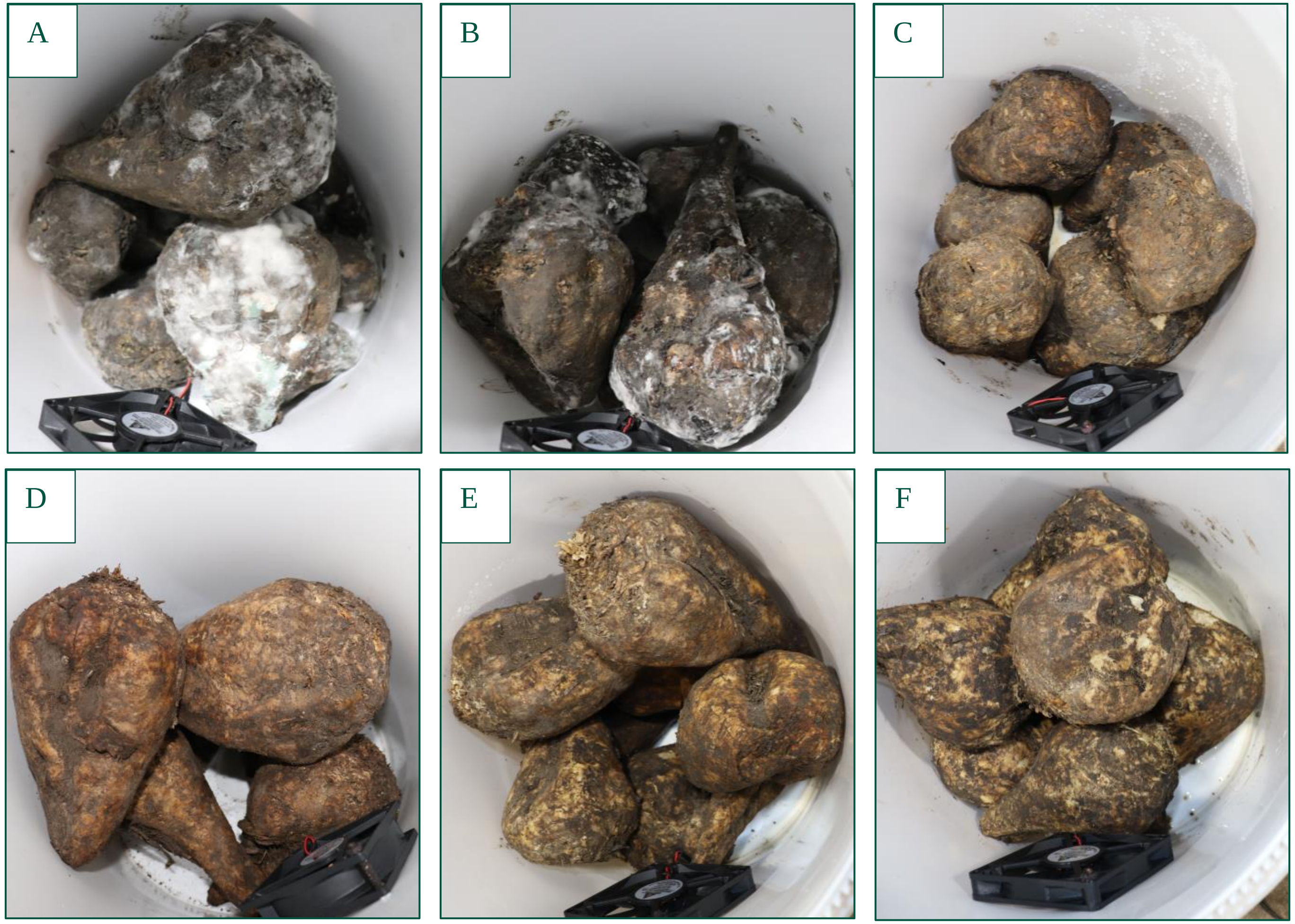



Fig. A and B; without chlorine dioxide (A = open lid and B = closed lid), C = 10 mg/kg, D = 25 mg/kg, E = 50 mg/kg and F = 100 mg/kg sugarbeet root.

# Sugarbeet storage pathogens isolated from control and low dose $ClO_2$ treatment

- Fungal isolates: *Botrytis cinerea*, *Penicillium* sp. *Fusarium* sp.
- Yeast isolates: *Candida* sp., *Pichia membranifaciens*
- Bacterial isolate: *Leuconostoc mesenteroides*

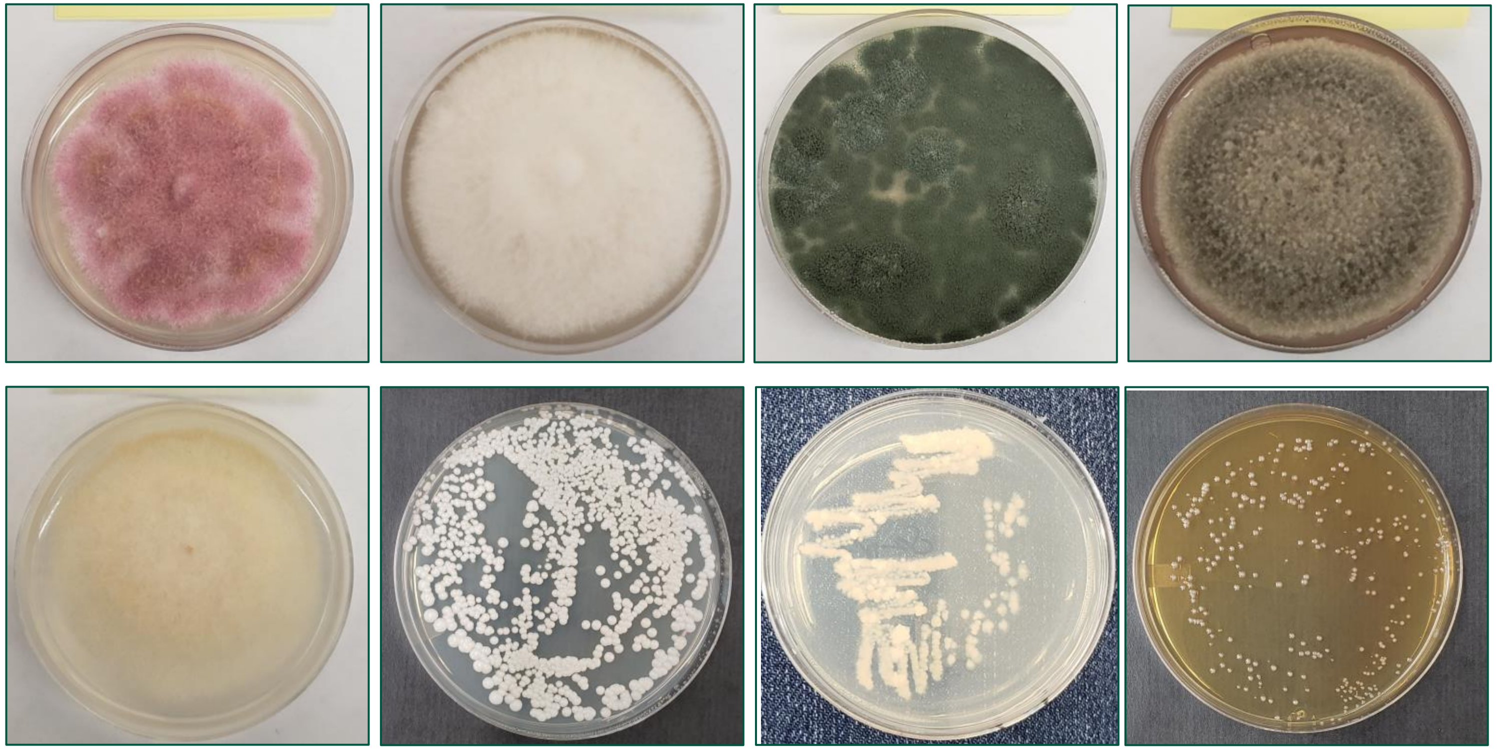
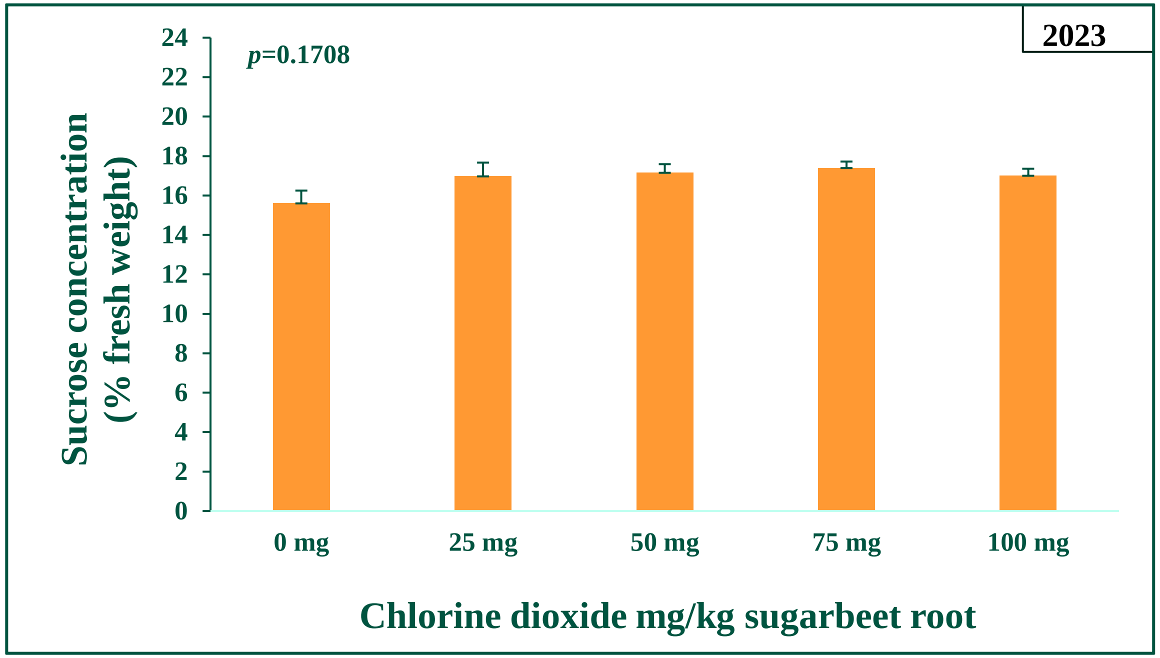
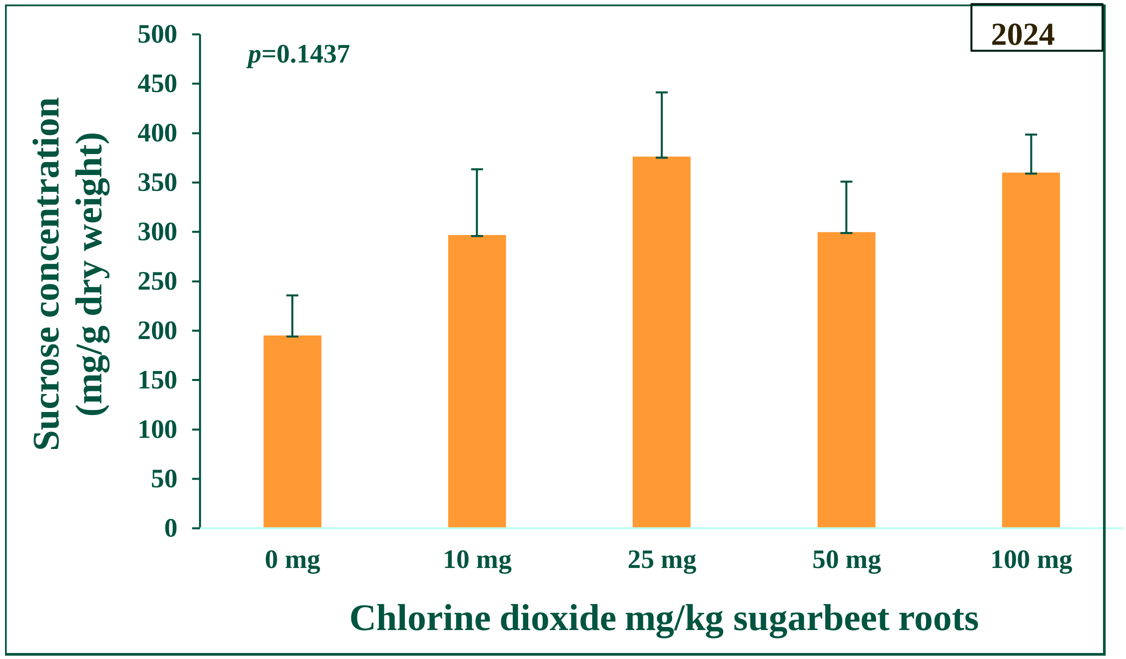


**Fig. Microbial isolates recovered from the sugarbeet root tissues**

# Sucrose content in $ClO_2$ treated sugarbeet roots

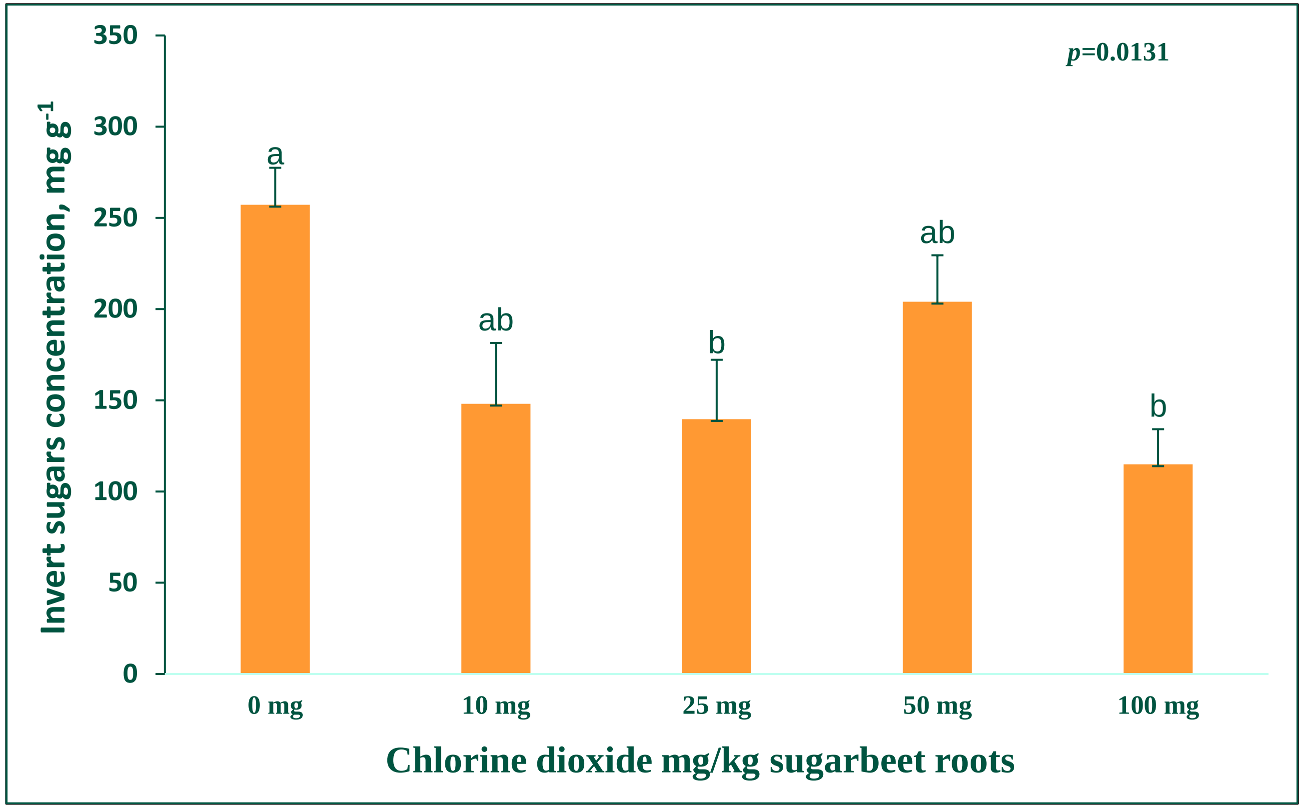


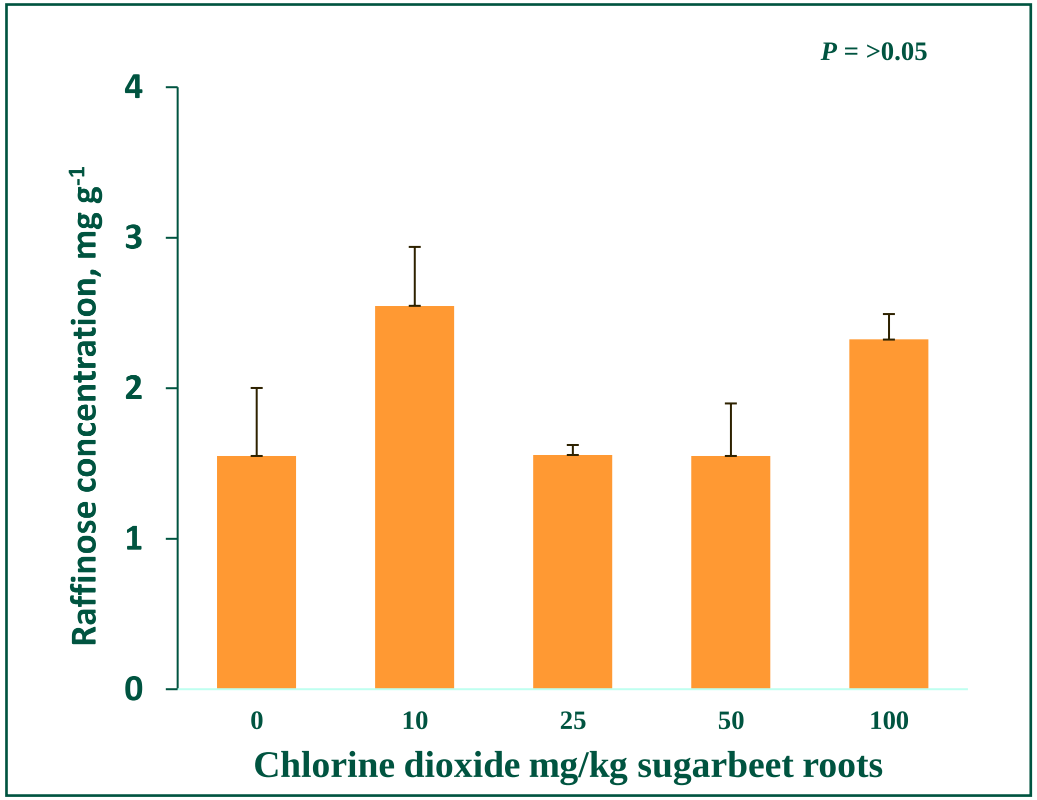




| Treatment (mg/kg) | Sucrose (%, FW) | Δ(Treatment- 0 mg/kg) | Δ (%) |
|---|---|---|---|
| 0 | 15.6 | - | - |
| 25 | 17.0 | 1.37 | 8.8 |
| 50 | 17.2 | 1.55 | 9.9 |
| 75 | 17.4 | 1.79 | 11.5 |
| 100 | 17.0 | 1.4 | 9.0 |

| Treatment (mg/kg) | Sucrose (mg/g, DW) | Δ(Treatment- 0 mg/kg) | Δ(%) |
|---|---|---|---|
| 0 | 195.1 | - | - |
| 10 | 296.8 | 101.7 | 52.1 |
| 25 | 376.1 | 181.0 | 92.8 |
| 50 | 299.9 | 104.8 | 53.7 |
| 100 | 360.0 | 164.9 | 84.5 |

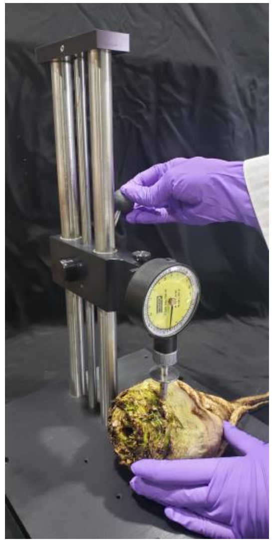
# Invert sugars and raffinose concentration in $ClO_2$ treated sugarbeet roots (2024)

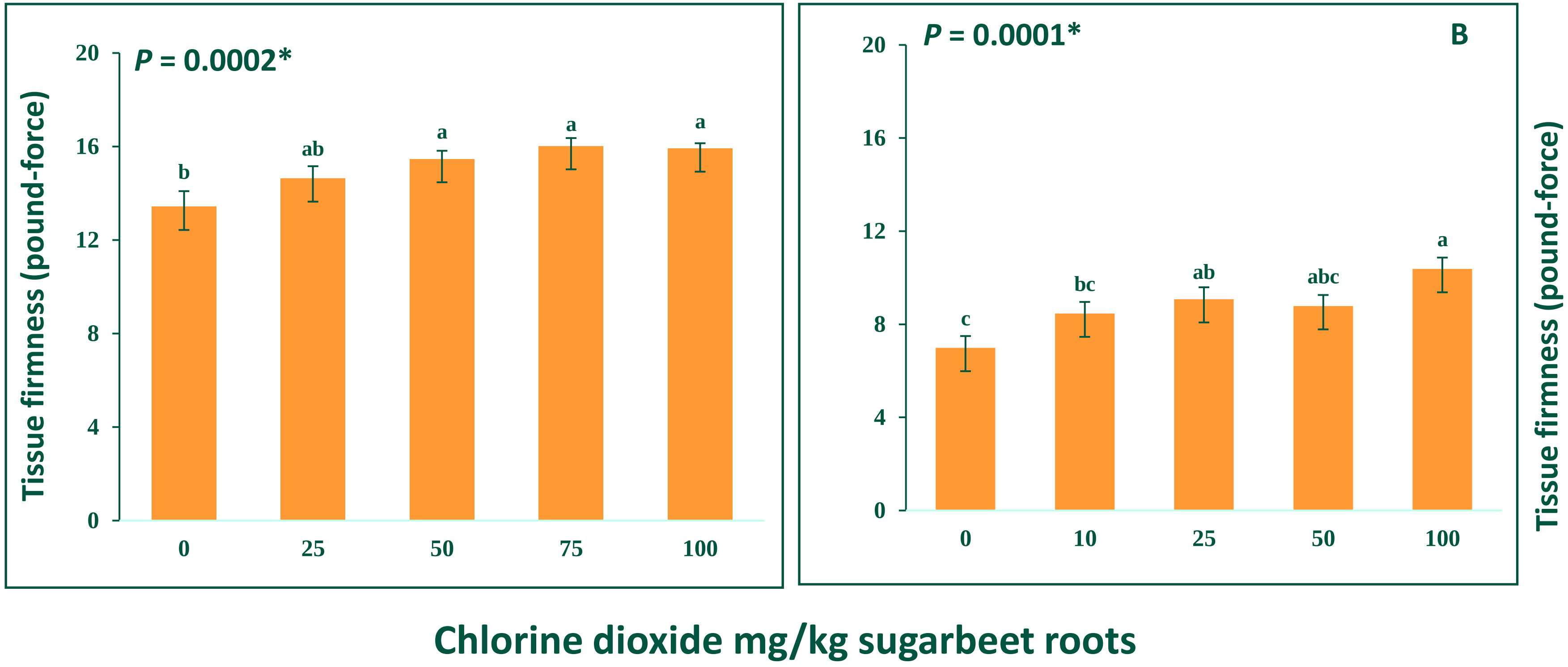


# Tissue firmness of $ClO_2$ treated sugarbeet roots

(puncture resistance/mechanical strength and tissue firmness)





# Effect of $ClO_2$ on conidial germination of a major storage pathogen, *Penicillium claviforme*

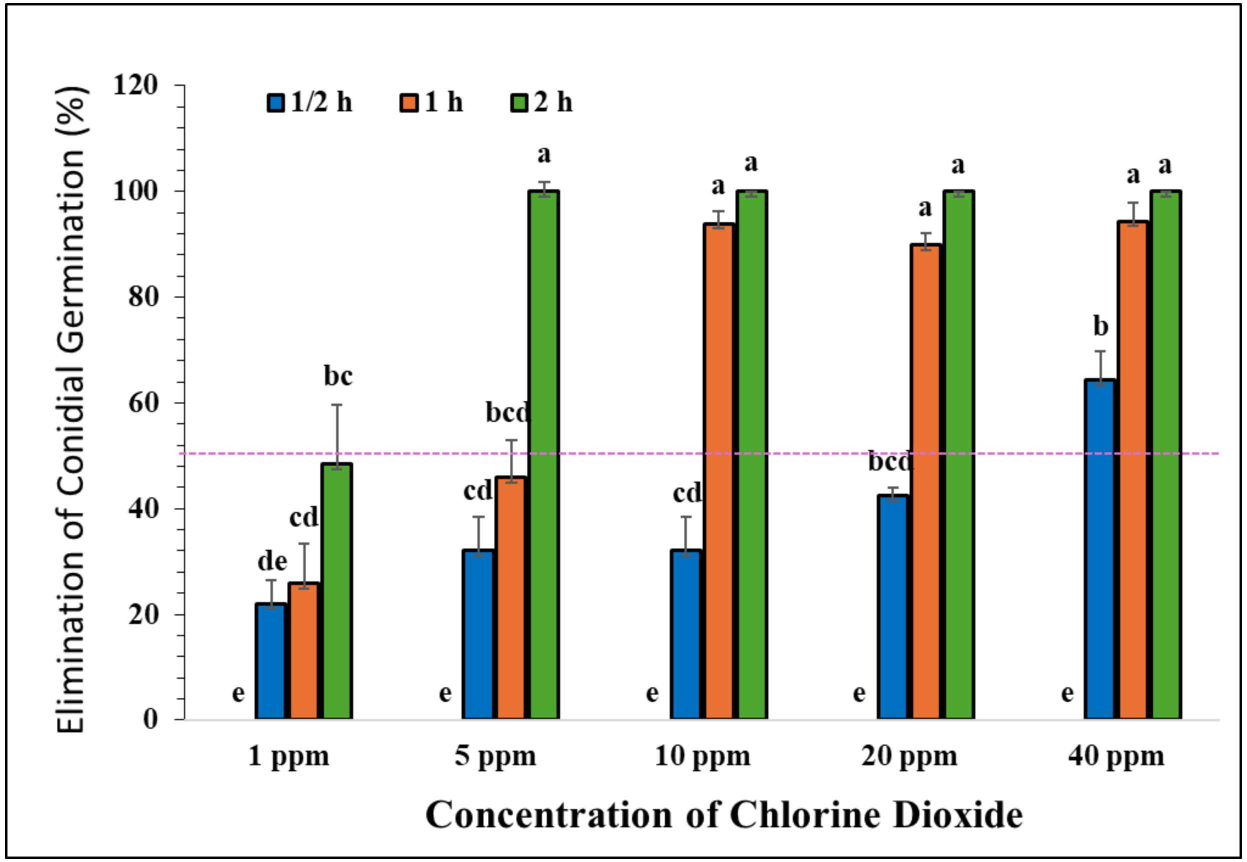
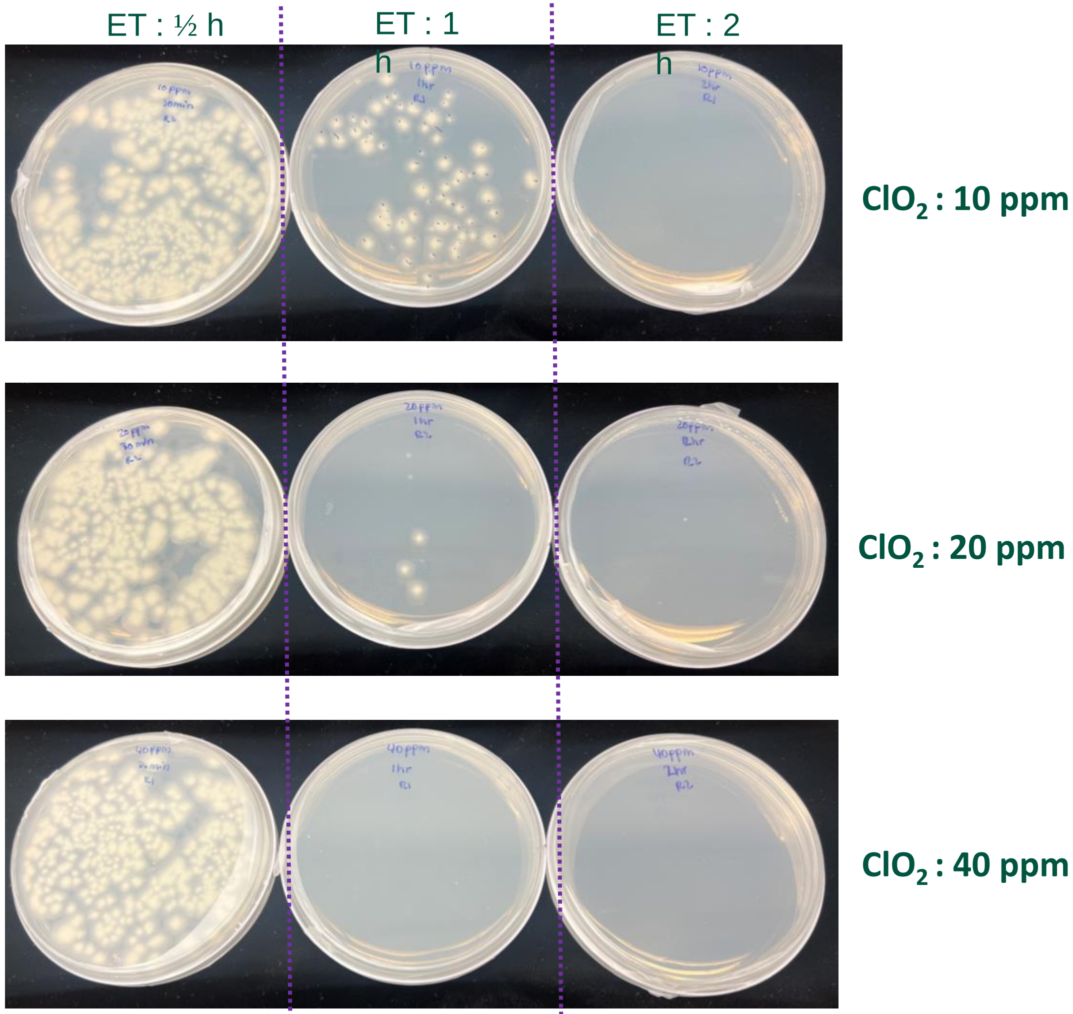



**Fig.** Conidial germination of *P. claviforme* with or without $ClO_2$ exposure at 1/5/10 or 20 ppm for ½, 1 and 2 h prior to plating on potato dextrose agar. Histograms that do not share a letter are significantly different ($P<0.01$) based on Tukey HSD post-hoc test.




ET = Exposure time with $ClO_2$

## The application of $ClO_2$ is effective to eliminate the conidial germination of *Penicillium claviforme*

# Acknowledgements

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American Crystal Sugar Company

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