# STORAGE DISORDERS OF APPLES

## EXTERNAL $CO_2$ INJURY

- Rough brown or bronze lesions on the skin, often partly sunken, with well-defined edges; more common on the non-blushed areas.
- Injury usually occurs early during the CA storage period.
- Susceptibility increases with rapid establishment of CA, especially increasing $CO_2$ levels before apples are cooled, low $O_2$ concentrations, SmartFresh(1-MCP) treatment, poor ventilation, free moisture on the skin, and immature fruit.

## INTERNAL $CO_2$ INJURY

- Sometimes called Brown Heart; defined brown necrotic core or cortex tissue, which is firm and moist but later becomes dry as moisture is lost to the surrounding healthy tissue; cavities form as desiccation continues, with light brown dry tissue forming the walls of the cavities; external appearance is often normal.
- Injury ceases when fruit are returned to normal atmospheres.
- Increased risk with low $O_2$ concentrations, delayed cooling, low storage temperature, and mature fruit.

## LOW $O_2$ INJURY

- Possible purpling and discoloration of the skin, alcoholic odors and flavors, fruit splitting, dark brown water-soaked lesions in the skin (resembling soft scald), and/or brown corky tissue below the skin or throughout the cortex.
- More often in <2% $O_2$ atmospheres, but symptoms vary with cultivar and storage regime; McIntosh are highly susceptible.
- Exacerbated by delayed cooling and low temperature storage with fluctuating $O_2$ levels; can be reduced by minimizing variation in atmosphere.

## CORE BROWNING

- Diffuse browning of flesh around the core and carpels, with often no clear distinction between healthy and affected tissue.
- Develops after several months of cold storage and becomes more extensive at room temperature.
- More prevalent in fruit that are harvested after an extended period of cloudy, cool or wet weather; incidence is reduced with advanced maturity, delayed cooling and storage, and low $O_2$ atmospheres (less than 2%).

## FLESH BROWNING

- Diffuse browning of the flesh, with no definite outline of the injured area; may affect outer flesh or core tissue or both areas; vascular elements often appear normal; usually no external symptoms; also known as Internal Browning.
- Apples grown in cool regions are more susceptible; 'Empire' is very susceptible (typically moist tissue and often found in the shoulder end of the fruit first); symptoms can be exacerbated by SmartFresh (1-MCP) treatment; sometimes associated with watercore, such as in 'Delicious'.
- Reduced by early harvest and depending on cultivar, possibly increased air movement and ventilation, higher storage temperatures, and reduced $CO_2$ concentrations.

## VASCULAR BREAKDOWN

- Browning of main vascular bundles and some adjacent tissue, with some radial extension into the flesh in severe cases.
- Usually develops later in the storage period (after 6 months).
- Associated with cool growing seasons; incidence and severity varies with chilling and senescence.

HONEYCRISP

## SOFT SCALD

- Sharply defined, irregularly shaped, smooth, brown lesions of the skin, which may damage the underlying flesh tissue; lesions often invaded by secondary infections, e.g. Alternaria or Cladosporium, resulting in darker or black color.
- Induced by low temperature; likely to occur in highly respiring cultivars that are cooled rapidly; higher incidence in apples near the cold air of evaporator coils; development stops when fruit removed from cold storage.
- Associated with advanced fruit maturity at the time of harvest, growing location and climate (dull, cool, wet summers), light crops, large fruit, vigorous trees on heavy soils, and fruit mineral content.

## SOGGY BREAKDOWN

- Moist, soft, brown, spongy flesh tissue, which can form complete rings in severe cases; can occur in the absence or presence of soft scald.
- Low temperature related, so worse in fruit stored below 2-3°C; more common in 'Honeycrisp' harvested at advanced maturity.
- Both soft scald and soggy breakdown are reduced in 'Honeycrisp' by delayed cooling, such as holding for 7 days at 10°C prior to cold storage.

## SENESCENT BROWNING

- Similar to senescent breakdown, but fruit remains very firm and it does not always develop directly beneath the skin.
- More prevalent with extended storage durations and warmer storage temperatures.
- Advanced fruit maturity at harvest time is a major factor.

## $CO_2$ INJURY

- Characterized internally by defined areas of brown flesh tissue, which develop cavities as it becomes dry and moisture is lost.
- External $CO_2$ injury may also develop in CA-stored 'Honeycrisp.'
- Increased risk with rapid CA establishment, increasing $CO_2$ levels before apples are cooled, and low $O_2$ concentrations; may be aggravated by SmartFresh (1-MCP) treatment.

## LENTICEL BREAKDOWN

- Darkened or black lenticels, or superficial small brown spots surrounding lenticels; may become sunken over time and allow invasion of pathogens.
- Often develops following fruit packing; as firmness decreases, the spots grow in depth and diameter and sometimes coalesce.
- High susceptability in fruit with mineral imbalances, harvested with advanced maturity, and/or stored too long; may be aggravated by dump tank chemicals, soaps and detergents, waxes, and SmartFresh (1-MCP) treatment.

ADHERING TO LOCAL CA RECOMMENDATIONS FOR SPECIFIC APPLE CULTIVARS AND HAVING ACCURATE GAS CONTROL WITH LITTLE ATMOSPHERIC AND TEMPERATURE FLUCTUATION GREATLY REDUCES THE LIKELIHOOD OF DEVELOPING THESE DISORDERS


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## SUPERFICIAL SCALD

- Diffuse browning or bronzing of the skin, often confined to the non-blush areas of red cultivars.
- Develops after several months of cold storage and becomes more extensive at room temperature.
- Aggravated by fruit immaturity, delayed cold storage and CA establishment, high storage temperature and $O_2$ concentration, and restricted ventilation.

## WATER CORE

- Liquid-soaked tissue around the vascular bundles and nearby flesh, due to the accumulation of a sorbitol solution in the intercellular spaces.
- Small areas of water core tissue often recover in cold storage, but can cause flesh browning and breakdown in severe cases.
- Fruit maturity is the most dominant factor, with hastened or advanced maturity promoting water core development.

## SENESCENT BREAKDOWN

- Browning and breakdown that usually begins in the tissue directly underneath the peel and often darkens the skin; common near the calyx end; whole fruit may become dry and mealy.
- Exacerbated by advanced maturity, delayed cooling, warmer storage temperature, high humidity, extended storage, and water core; advances rapidly upon removal from cold storage.
- CA conditions that delay senescence also reduce the disorder.

## BITTER PIT

- Dark, sunken lesions at or beneath the fruit surface; may be present at harvest but more commonly become evident during storage.
- Caused by low levels of flesh calcium; more prominent in large apple cultivars, fruit from light crops, with excessive vegetative growth, severe thinning, boron deficiency, excess amounts of potassium, magnesium, or nitrogen, low seed numbers, drought, and heavy dormant pruning.
- Minimized by postharvest dips containing calcium, prompt cooling, low storage temperature, high relative humidity, and CA conditions.

## DPA INJURY

- Black lesions on the skin, which may penetrate into underlying tissue.
- Increased risk with higher DPA concentrations, free moisture on the skin, or when DPA solution remains on the fruit for extended periods of time.
- 'Empire' tends to be highly susceptible.


*Photos and Descriptions Courtesy of*
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# CA STORAGE SAFETY

BY J. A. BARTSCH

The oxygen content inside a sealed CA storage room will not support human life. This fact should be clearly displayed at every conceivable CA room entry point. Occasionally persons must enter rooms to gather samples or make repairs and it is imparative that they understand the hazards of these tasks. No one should ever enter or even place their head inside an operating room. Persons have passed out, fallen into the rooms and died just a few feet inside the doorway. Never enter alone, and never open a window or door without having at least one other person who is familiar with CA storage hazards near you. Make sure all employees and co-workers recognize the hazard and understand the meaning of the posted caution and danger signs. Make doubly sure all personnel read and understand the symptoms of asphyxia information printed below. It could save a life!

SYMPTOMS OF ASPHYXIA

| | |
|---|---|
| 21% OXYGEN: | Standard atmospheric ratio. Breathing, all functions normal. |
| 17% OXYGEN: | A lit candle is no longer able to burn. |
| 16 - 12% OXYGEN: | Breathing increased and pulse rate accelerated. Ability to maintain attention and to think clearly is diminished, but can be restored with effort. Muscular coordination for finer skilled movement is somewhat disturbed. |
| 14 - 10% OXYGEN: | Conciousness continues, but judgement becomes faulty. Severe injuries (burns, bruises, broken bones) may cause no pain. Muscular efforts lead to rapid fatigue, may permanently injure the heart and induce fainting. |
| 10 - 6% OXYGEN: | Nausea and vomiting may appear. Legs give way, person cannot walk, stand or even crawl. This is often the first and only warning and it comes too late. The person may realize he is dying, but he does not greatly care. It is all quite painless. |
| LESS THAN 6% OXYGEN: | Loss of conciousness in 30-45 seconds if resting, sooner if active. Breathing in gasps, followed by convulsive movements, then breathing stops. Heart may continue beating a few minutes, then it stops. |

This description of asphyxia was taken from 'Noxious Gasses and the Principles of Respiration Influencing Their Action' by Yandell Henterson and Howard W. Haggard. Reinhold Publishing Corp., 330 W. 42nd Street, New York, NY.

**CA STORAGE CONTAINS LESS THAN 5% OXYGEN**

# STORAGE LEAKAGE SPECIFICATIONS

BY DAVID BISHOP

Many people not familiar with CA storage seriously underestimate the amount of sealing that is required in a CA store. A leakage rate should be included in any specification and contract for building a CA room and a test to check for this should be part of the acceptance criteria. These tests should then also be carried out yearly and any problems rectified before loading with produce.

This leak test is carried out by raising or lowering the room pressure and measuring the rate of decay. The pressure used is the maximum room pressure, which is typically 250 Pa (1"wc).

This should be measured on a sensitive indicator, which could be an inclined tube manometer, an electronic manometer, or a magnehelic indicator. It is essential that this indicator is accurate enough to easily measure the maximum pressure and to observe its decay.

The store is then prepared for testing by checking that all doors, hatches, drains, valves and pipes have been closed. The store pressure can be increased by using a fan blower; a domestic vauum cleaner is suitable for this purpose. Great care must be taken as even a small fan can generate enough pressure to structurally damage a large CA store. When the pressure has reached the required level, the blower is stopped and the inlet is sealed. If this pressure cannot be achieved then a large leak is indicated and remedial action is needed before continuing.

The rate at which this pressure falls is measured and is an indication of the store leakage rate. In Europe, the time taken for the pressure to fall from 20 mm water column to 13 mm is measured. In a store intended for storage 2.5% oxygen and above, the minimum recommended time is 7 minutes. For stores running at 2% oxygen and lower, 10 minutes should be the minimum. It is not uncommon for well constructed stores to take up to 20 minutes to lose 7 mm of water column. (The UK has used mm water column as the pressure specification because of its practical convenience in use. 25 mm – 1" water column = 250 Pa = 250 $Nm^{-2}$).

North American operators define their tests slightly differently and the time used here is when the pressure falls to half the starting value. For example, the time will be the same for a fall from 1" to ½" as that from ½" to ¼". The acceptable time for this is 30 minutes for all low oxygen stores with all types of scrubbers, but for 3% oxygen rooms 20 minutes is acceptable. Incidentally, the North American "20 minute" room is equivalent to 12 minutes on the UK test and the "30 minute" room is the same as 18 minutes.

Another method of testing used in some areas requires the use of a variable speed fan to adjust an air flow rate to achieve required pressure. This flow is then the leak rate of the room.

If a room does not meet the leak specification, remedial action is required. The leaks can be difficult to find and some patience will be required. In a quiet area most leaks can be located by listening to their "whistle" by someone inside the sealed store. Smoke canisters can be discharged as an aid to leak detection. The most common leaks are around the floor/wall or the wall/ceiling joints. Doors and door frames are another area of potential problems.

Taken From "CONTROLLED ATMOSPHERE STORAGE: A Practical Guide" by David Bishop. © 1996 DBI.

# CA STORAGE CHECKLIST

## A GUIDE TO SUCCESSFUL CONTROLLED ATMOSPHERE STORAGE

BY JAMES SCHAEFER

BEFORE START OF SEASON

1. Instruct all new employees regarding the dangers involved with CA storage rooms.
2. Check all gas sampling lines for leaks.
3. Check all temperature probes for accuracy.
4. Check portable analyzers for proper operation: 21.0% $O_2$ with outside air, zero span with calibration gas bottle, which should also be checked at the main system.
5. Check stores are leak-tight and pass the recommended pressure tests.
6. Check scrubbers for leakage and correct operation, including all electric valves and analyzers.
7. Check and/or change filters & oil on Permeas.

DURING LOADING

1. Check the fruit mineral analysis is acceptable (especially for long-term storage).
2. Check chemical drenches are made up to the correct concentrations.
3. Check that the store is loaded uniformly and the store is full.
4. Check the temperature probes are in fruit bins and evenly placed throughout the store.
5. Place probe 4 in the middle of the room/bin stacks & core probe in apple by the door.
6. Place glass of water by the door as a failsafe for freezing temperature check.
7. Confirm core temperature is below 40°F before starting pulldown of oxygen.
8. Load bins into room with proper spacing for airflow and obtain CA conditions as rapidly as possible or per SmartFresh™ recommendations.

AFTER SEALING

1. Know the $CO_2$ level recommended for the fruit inside ($CO_2$ will increase rapidly overnight with door closed)
2. Measure and record gas and temperatures twice a day immediately after sealing.
3. Check analyzers daily with fresh air.
4. Calibrate analyzers with test gas every week.
5. Take independent gas readings with portable analyzer directly from the store at weekly intervals. If difference greater than 0.2% put fans on high speed for 2 HRS, recalibrate analyzers and check again. If error still present ask for service.
6. Inspect samples of fruit from the store on a regular basis.
7. If store $O_2$ less than 1.6% check fruit samples for alcohol at monthly intervals.
8. Run evaporator fans continuously for first 40 days, then fan cycle.

GENERAL

1. This is only a general guide. Consult documents from USDA and IHR or your local advisers for moredetailed advice.
2. Do not enter the store once sealed. Low oxygen atmospheres will not support human life. You will pass out within 30 seconds and die within minutes.
3. Do not ever seal a room that does not contain lime without turning on a piece of equipment, i.e. nitrogen generator to start pull-down or a $CO_2$ scrubber. The respiration of fruit in the room will cause the $CO_2$ levels in the room to rise very rapidly, damaging the fruit.
4. It is always good practice to have an open container of water inside the storage and in clear view from the window as a fail safe way to check for ice and sub-freezing temperatures.
5. If in doubt, ask.

Storage Control Systems, Inc., while celebrating 30 years of providing CA equipment to the apple industry worldwide, presents the second revision of their apple disorder poster. Dr. Jennifer DeEll partnered with us again and brings the latest problems warehouses face as they store multiple cultivars under the most stressful scenarios. We hope this poster will provide useful information to help you keep your apples healthy. As an added bonus, we have included someinformation involving safety hazards and general operating guidelines. Storage Control Systems, Inc.'s owner Jim Schaefer is involved with a group of companies that can design, build, cool, and manage all your "CA" needs. Look for continued information on our website, or look directly at www.michganpanel.com for building methods using insulated metal panels, or www.thinkAEG.com for information on using Frigadon Chiller secondary refrigeration using Hycool as the cooling media. As always, SCS continues to move forward with new goals every day.

Celebrating 30 Years of Innovation


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