8th Lecture: Physiology

Controlled (CA) and Modified Atmosphere (MAP)

Thanks To Science, You Can Eat An Apple Every Day

Journal The SALT-what is in your plate 2018

Controlled and modified atmosphere

In a controlled or modified atmosphere (CA), the composition of the atmosphere differs from the normal atmosphere

The difference between a modified atmosphere and the controlled atmosphere is in the degree of accuracy in oxygen control and the carbon dioxide

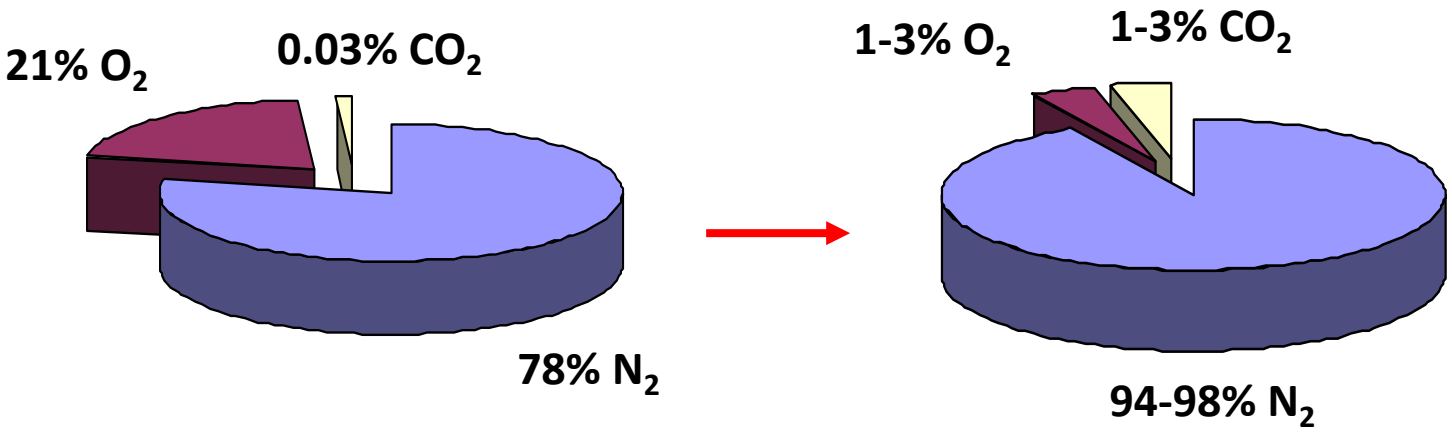
A controlled and modified atmosphere includes:

A decrease in oxygen
An increase in carbon dioxide,
The exclusion of carbon dioxide,
The exclusion of ethylene and other volatiles,
The preservation of temperature and humidity,

The level of accuracy varies in a controlled atmosphere and a modified atmosphere

Controlled atmosphere- CA

Storing produce at controlled concentration of oxygen and carbon dioxide, with the ethylene and the CO_2 being adsorbed.

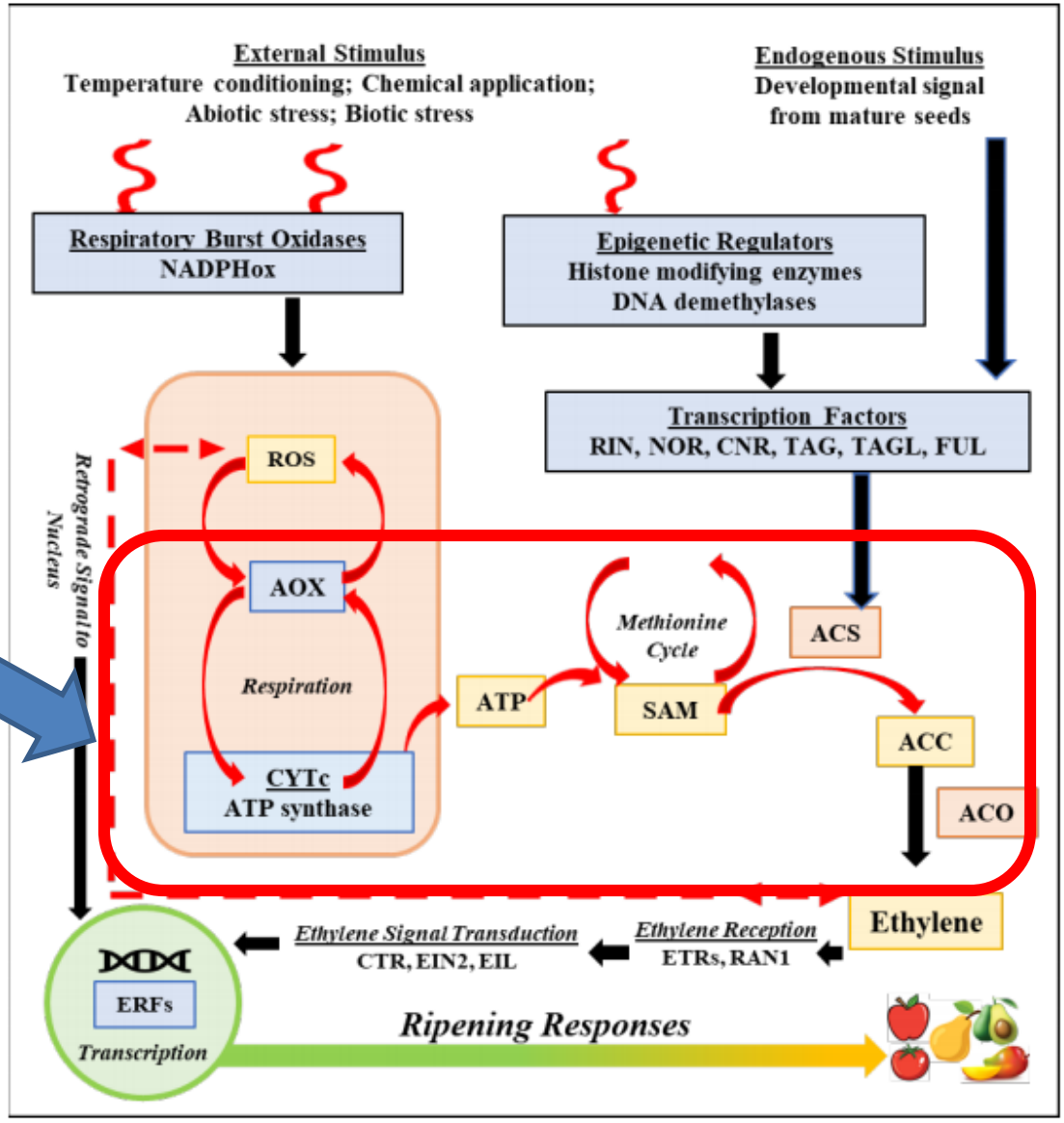


Normal atmosphere

Controlled atmosphere

CA

Mode of action



The relationship between respiration and ethylene production

Physiological and pathological benefit of a controlled and modified atmosphere

- Delaying maturation and ageing.
- Reducing respiration.
- Delay softening and therefore maintains firmness.
- Reduction of physiological defects as:
  i. Physiological diseases in apple and
  ii. Rust stains in lettuce.
- Inhibition of decay development.
- Inhibition and killing of insect development.

Economic advantages in the use of a controlled atmosphere

1. Extending the storage period extends the marketing period.
2. Better quality strengthens competition
3. Reducing refrigeration expenses as a result of the decrease in respiration and the heat emitted by respiration.


K1
UWAGA!
SmartFresh
K2

Safety

Caution low oxygen concentration!

Do not enter the room if it is closed

Risk of blackout within 30 seconds and death within minutes

Safety

21% oxygen- Normal respiration
17% oxygen- Candle turned off
16-12% oxygen- Increase in respiration and heart rate
12-10% oxygen-Blackout
10-6% oxygen-Coma and vomiting.
6%-Become incontinent within 30 min and death

Necessary equipment in systems for a controlled atmosphere

Reduction of Oxygen

-**Oxygen burning:**

a- Open flame

b- Catalytic fire

-**Disposal/cleaning with nitrogen**

a- Liquid nitrogen

b- Separation of nitrogen from compressed air (molecular mesh system : membrane system)

Necessary equipment in systems for a controlled atmosphere

Reduction of CO_2

a. Water
b. Dry lime
c. Ethanolamine
d. Activated charcoal CO_2 scrubber
e. Molecular sieve network

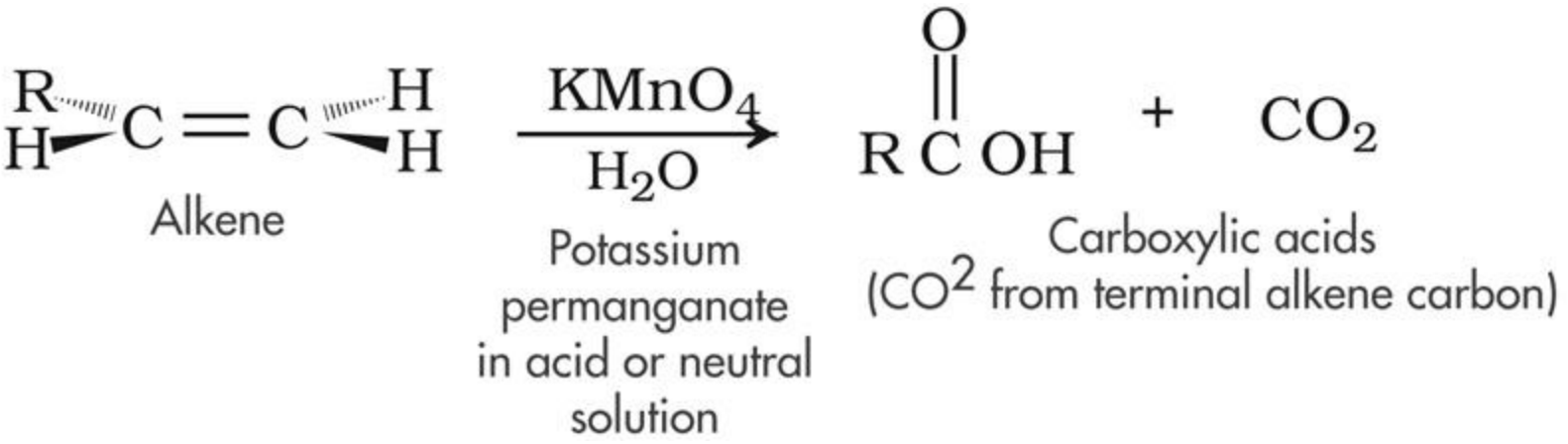
Necessary equipment in systems for a controlled atmosphere

Reduction of ethylene

a. Ethylene absorber, $KMnO_4$

b. Ozone

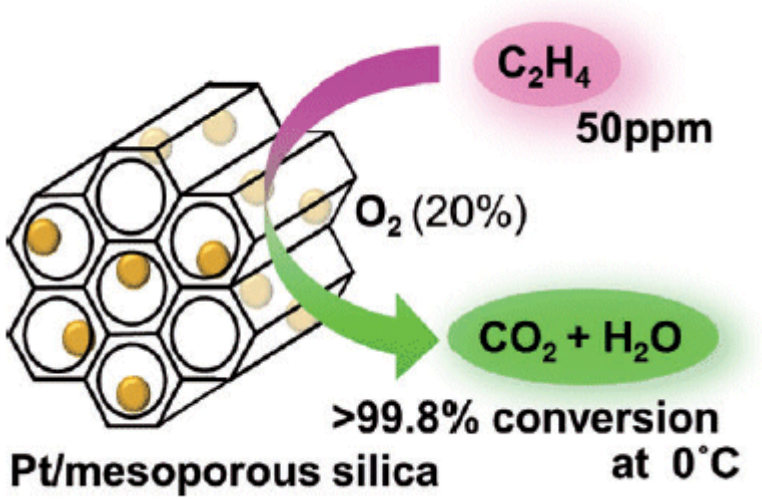
c. UV-C light



Ethylene effect on deciduous fruits

Necessary equipment in systems for a controlled atmosphere

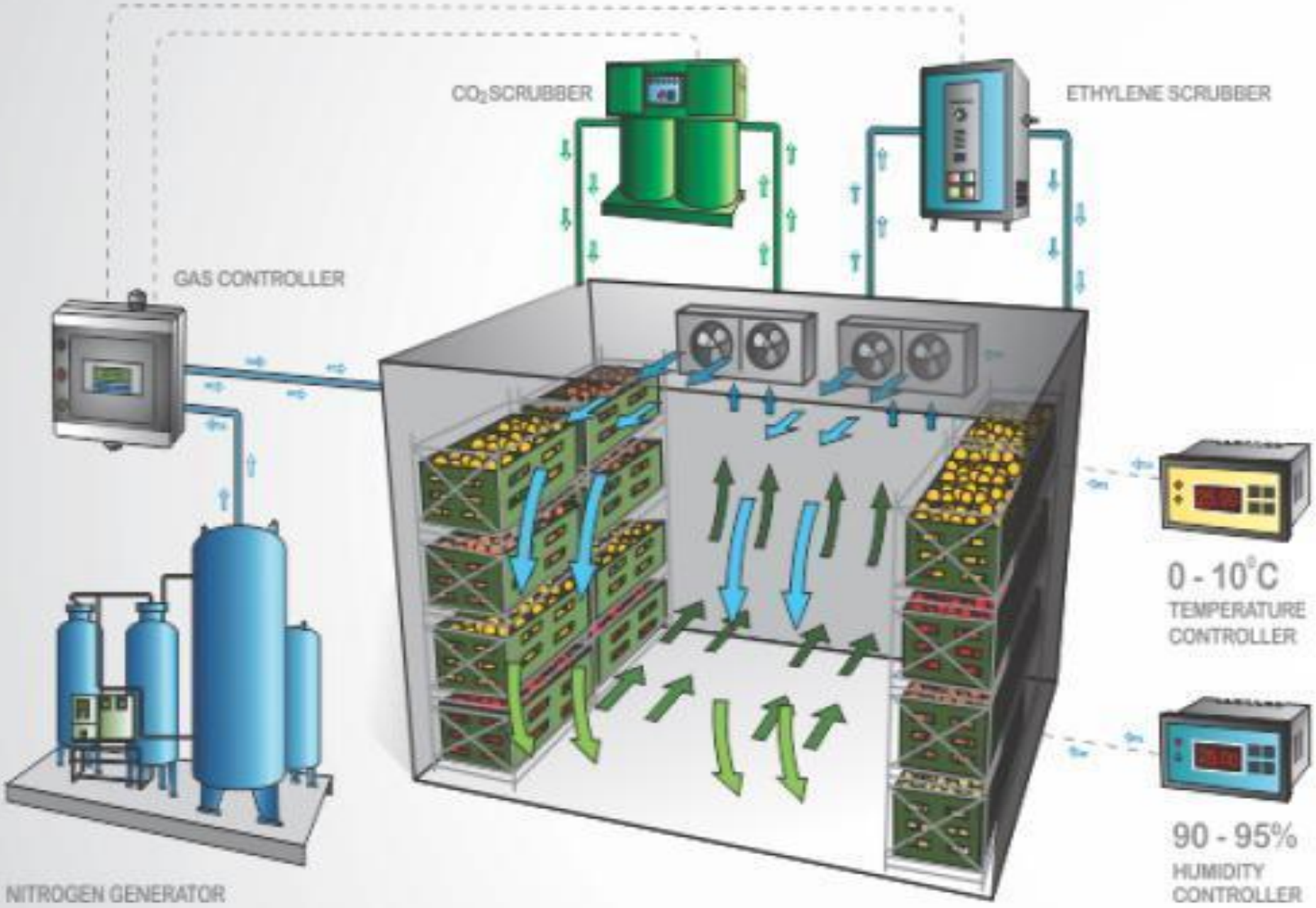
Reduction of Ethylene



Photocatalytic system

Photocatalytic system


BIO TURBO 1000
BIO TURBO 1000


CO_2 SCRUBBER
ETHYLENE SCRUBBER
GAS CONTROLLER
0 - 10°C
TEMPERATURE
CONTROLLER
90 - 95%
HUMIDITY
CONTROLLER
NITROGEN GENERATOR

ULO – Ultra Low Oxygen
DCA – Dynamic controlled atmosphere

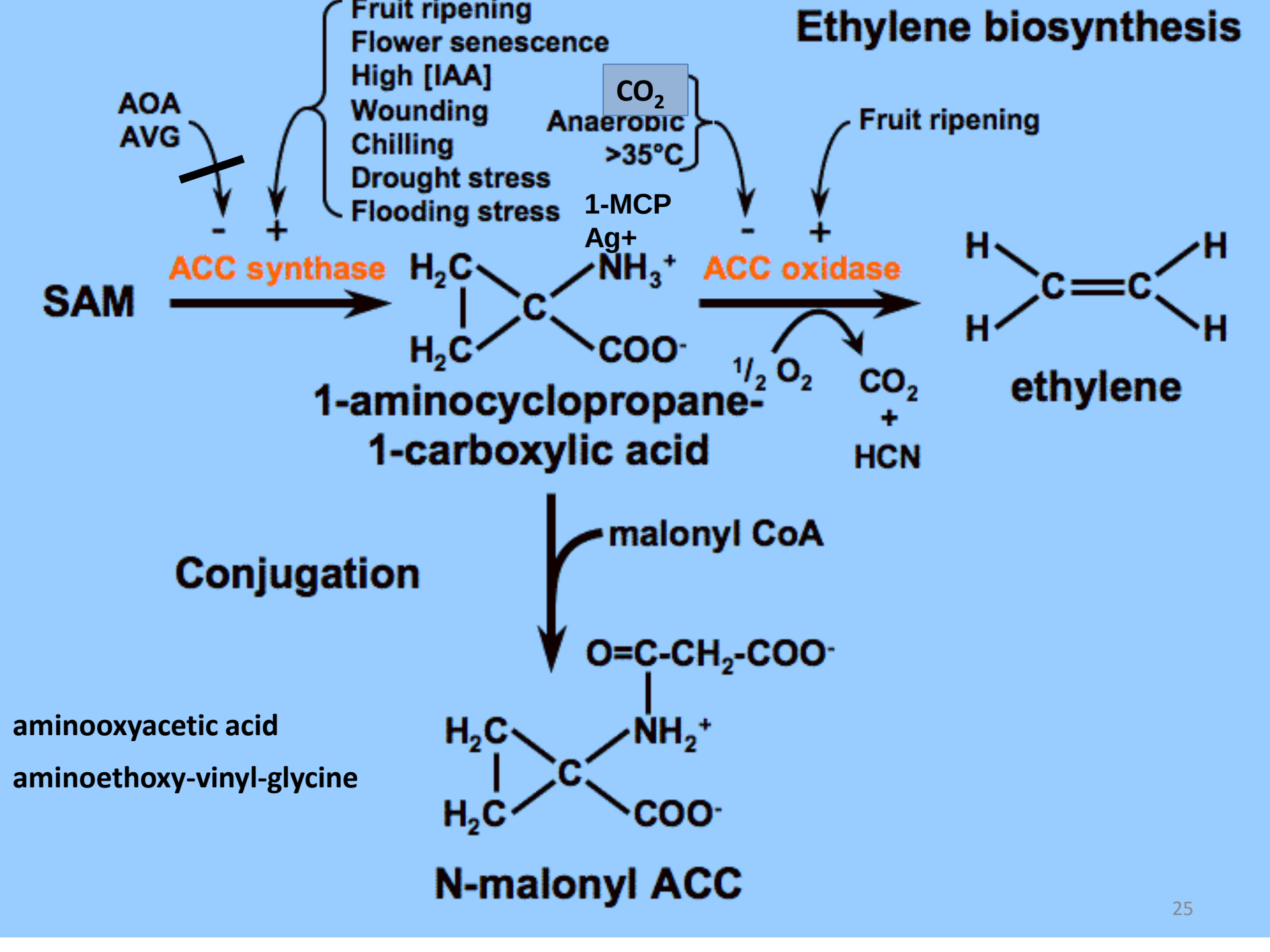

ROOM 4
O2= 0.8%
CO2= 1.1%
16:08
21-11-12
F1
F2
F3
F4
F5
F6
F7
F8
1
2
3
4
5
6
7
8
9
0
POWER
RX
TX

Commodity	Temp.range (°C)	CA		Potential for benefit (*)
		% O_2	% CO_2	
Deciduous tree fruits				
Apple	0 – 5	1 – 3	1 – 5	A
Apricot	0 – 5	2 – 3	2 – 3	C
Cherry, sweet	0 – 5	3 –10	10 – 15	B (A)
Fig	0 – 5	5 – 10	15 – 20	B
Grape	0 – 5	2 – 5	1 – 3	C
Kiwifruit	0 – 5	1 – 2	3 – 5	A
Nectarine	0 – 5	1 – 2	-3 – 5	B
Peach	0 – 5	1 – 2	3 – 5	B
Pear, Asian	0 – 5	2 – 4	0 – 1	B
Pear, European	0 – 5	1 – 3	0 -1	A
Persimmon	0 – 5	3 – 5	5 – 8	B
Plum and prune	0 – 5	1 – 2	0 – 5	B
Raspberry and other cane berries	0 – 5	5 – 10	15 – 20	A

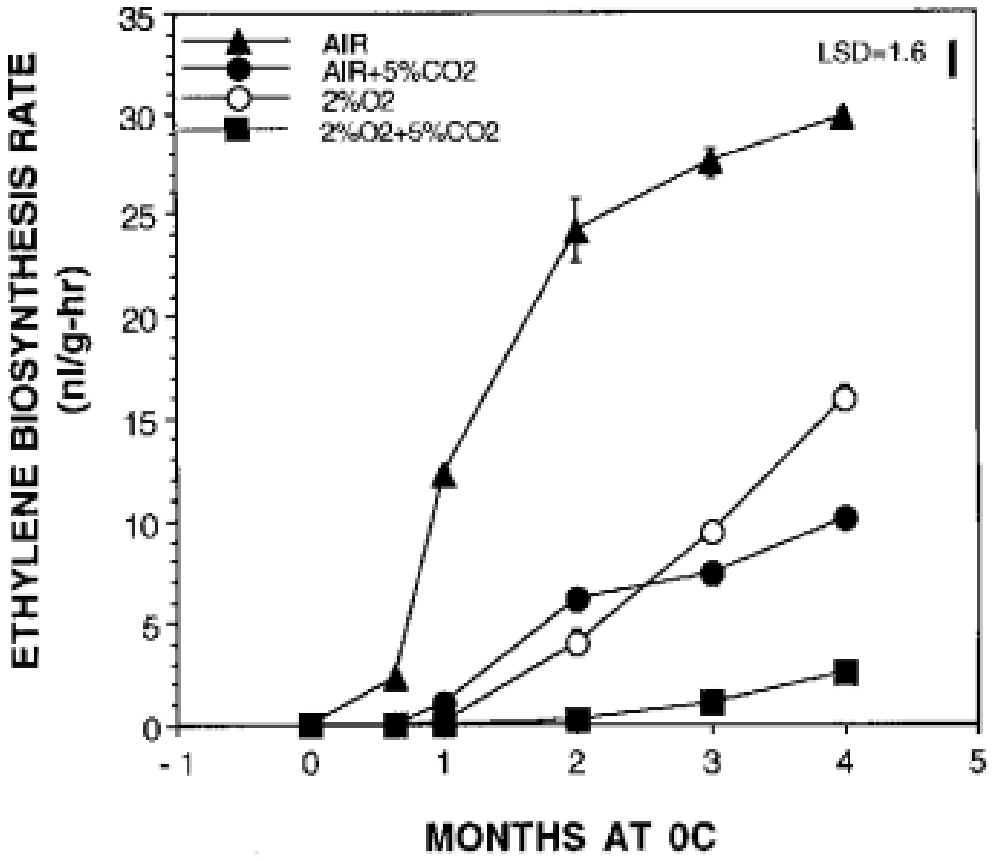
Fruits	Temperature	Weight Kg	Weight Lbs	Normal Cold Storage	Controlled Atmosphere Storage
Early Apple 	1°C 34°F	300	660	4 months	7 months
Apple 	1°C 34°F	300	660	4 months	7 months
Late Apple 	2°C 35°F	300	660	5 months	8 months
Blackcurrant 	2°C 35°F	125	275	6 days	40 days
Blueberry 	0°C 32°F	180	400	7-10 days	40 days
Cherry 	0°C 32°F	180	400	6 days	25 days
Chesnut 	0°C 32°F	270	600	18 days	75 days
Kiwi 	0°C 32°F	200	440	70 days	5 months
Pear 	0°C 32°F	300	660	4 months	7 months
Plum 	0°C 32°F	220	480	18 days	50 days
Redcurrant 	0°C 32°F	125	275	6-10 days	40 days
Grapes 	0°C 32°F	200	440	1.5 months	3 - 5 months

Mechanism of action of CA

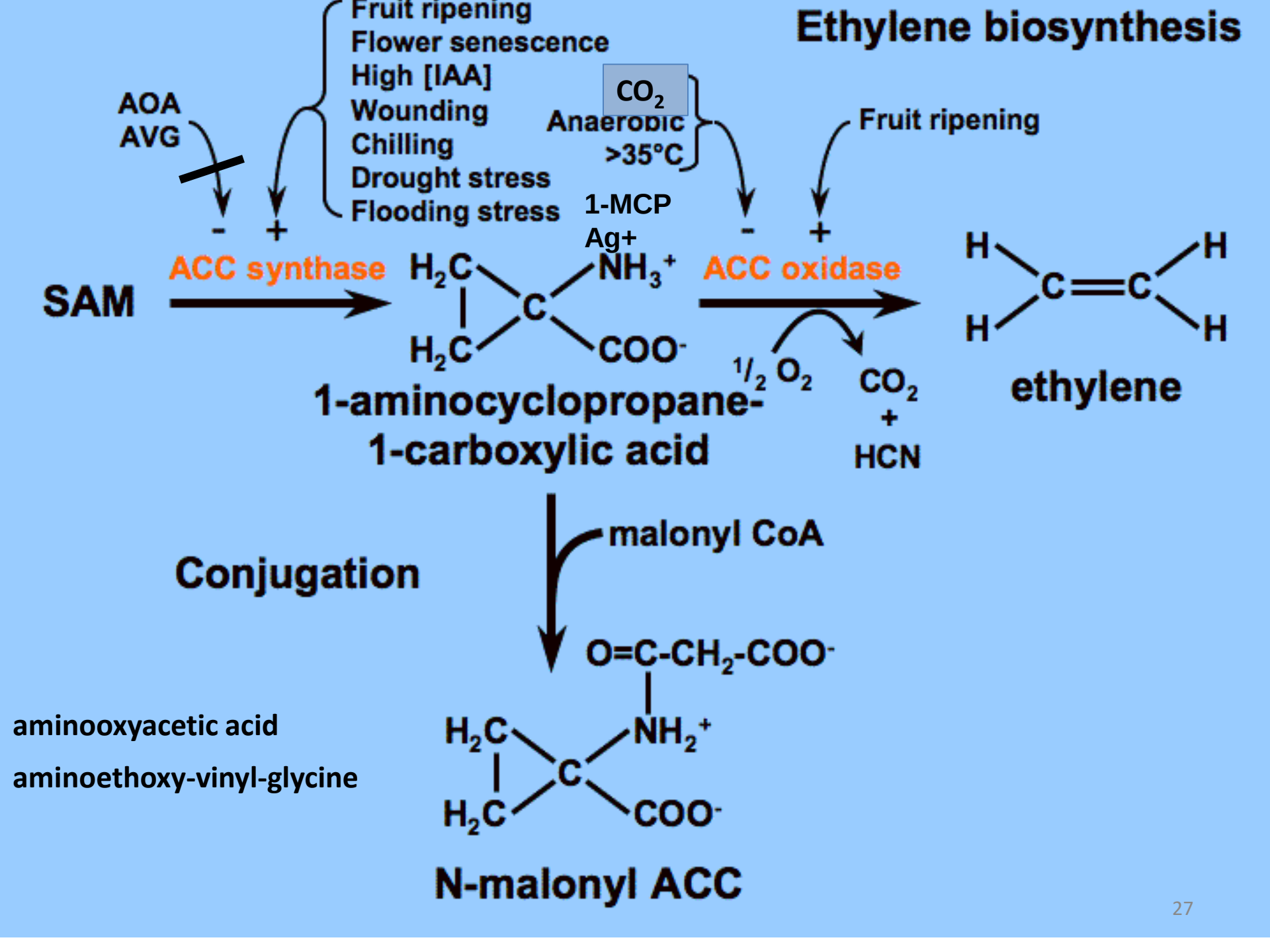
Inhibition of ethylene production


Ethylene biosynthesis
Fruit ripening
Flower senescence
High [IAA]
Wounding
Chilling
Drought stress
Flooding stress
AOA
AVG
CO2
Anaerobic
>35°C
Fruit ripening
1-MCP
Ag+
SAM
ACC synthase
ACC oxidase
1-aminocyclopropane-1-carboxylic acid
1/2 O2
CO2 + HCN
ethylene
Conjugation
malonyl CoA
aminooxyacetic acid
aminoethoxy-vinyl-glycine
N-malonyl ACC

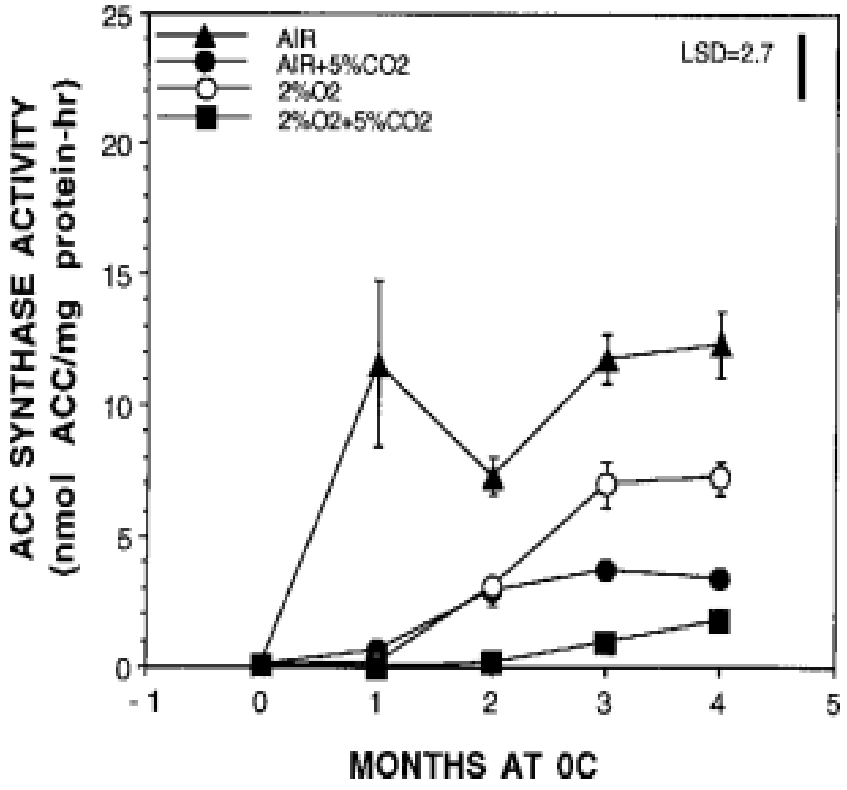
Mechanism of action of controlled atmosphere (partial)

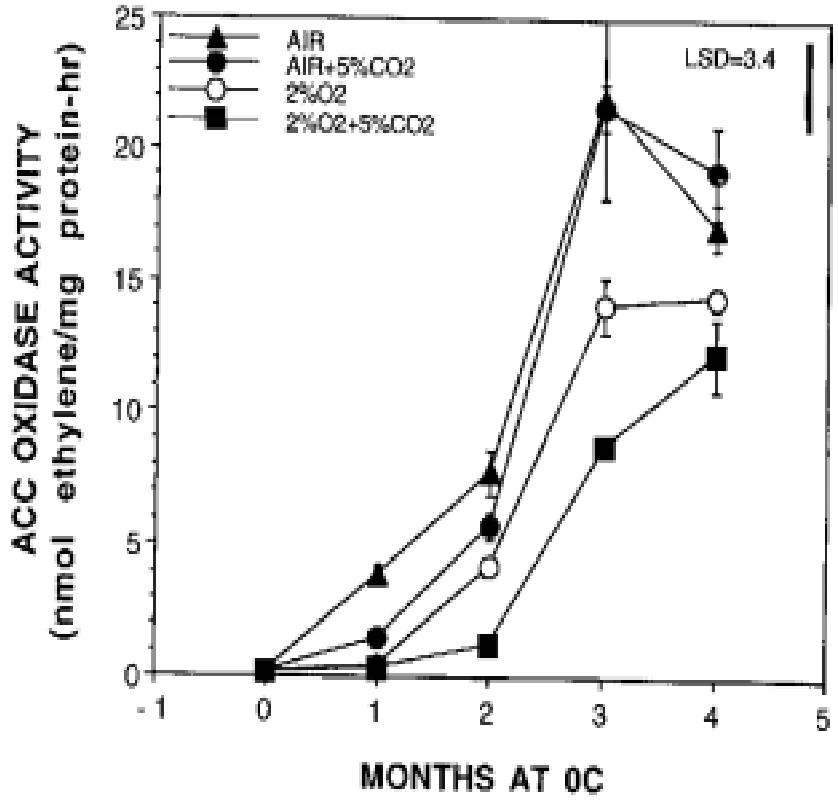


Effects of oxygen and carbon dioxide concentrations on ethylene activity in apple stored in 0 C


Ethylene biosynthesis
Fruit ripening
Flower senescence
High [IAA]
Wounding
Chilling
Drought stress
Flooding stress
AOA
AVG
CO2
Anaerobic
>35°C
Fruit ripening
1-MCP
Ag+
SAM
ACC synthase
ACC oxidase
1-aminocyclopropane-1-carboxylic acid
1/2 O2
CO2 + HCN
ethylene
Conjugation
malonyl CoA
aminooxyacetic acid
aminoethoxy-vinyl-glycine
N-malonyl ACC

Mechanism of action of controlled atmosphere (partial)

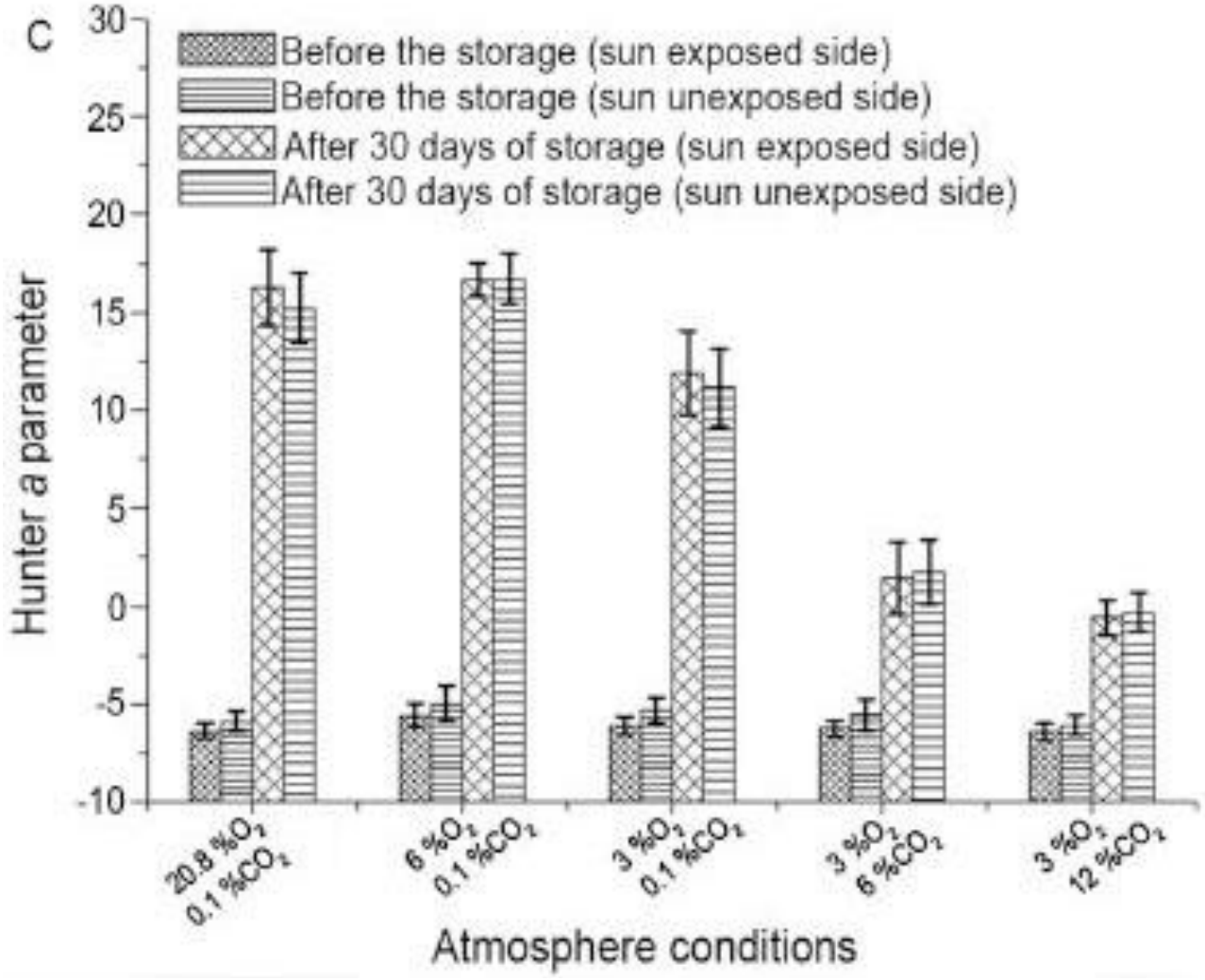




Effects of oxygen and carbon dioxide concentrations on the activity of the enzymes ACC-synthase and ACC-oxidase in apple stored in 0 C

Mechanism of action of CA:

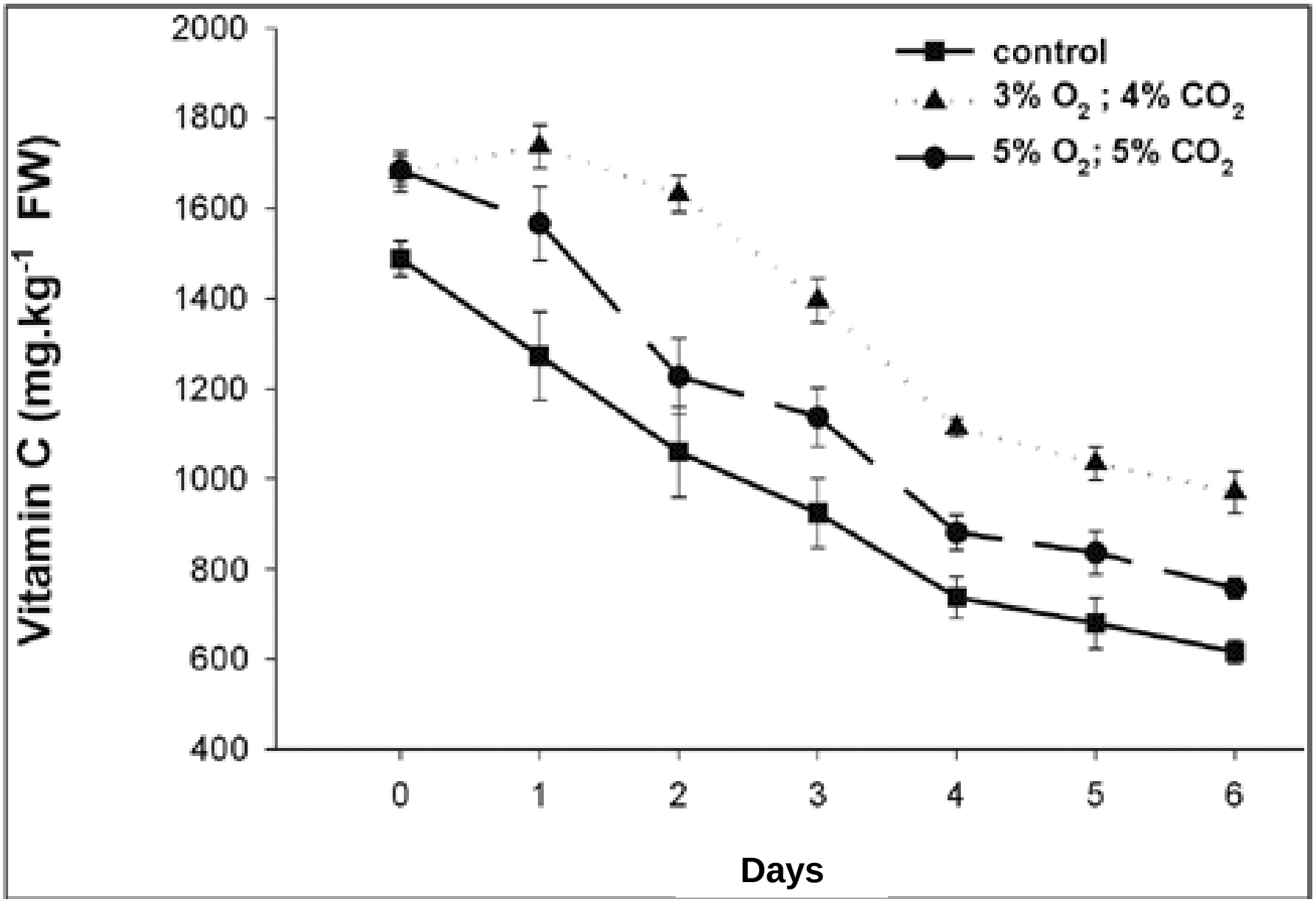
Internal color



Red color development in papaya stored in a controlled atmosphere for 30 days at 13 C and humidity of 85-95%

Mechanism of action of CA:

Effect on Nutritional factors



The contents of vitamin C in lettuce leaves stored in different controlled atmospheres at 5 degrees C for 6 days.

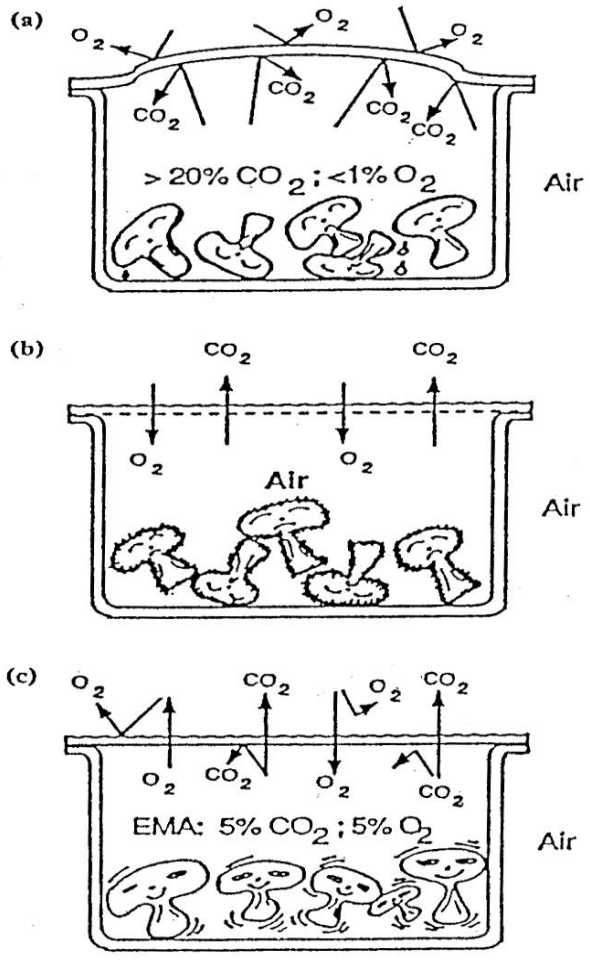
Container for controlled atmosphere

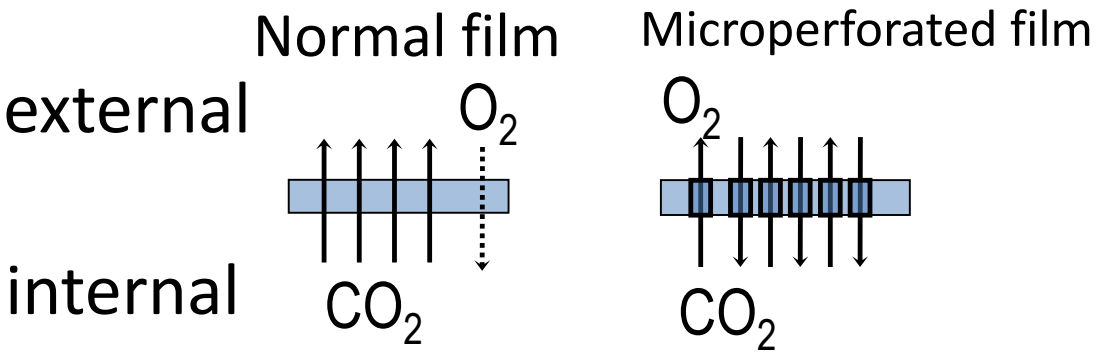
MODIFIED ATMOSPHERE

Modified atmosphere

MA is dependent on the changes in the respiratory gases inside the packaging (oxygen and carbon dioxide).

The achieved equilibrium depends on the rate of product respiration and depends on the storage temperature, the weight of the product, and the capability to transfer gases by packing material. Ethylene can accumulate in the packaging.

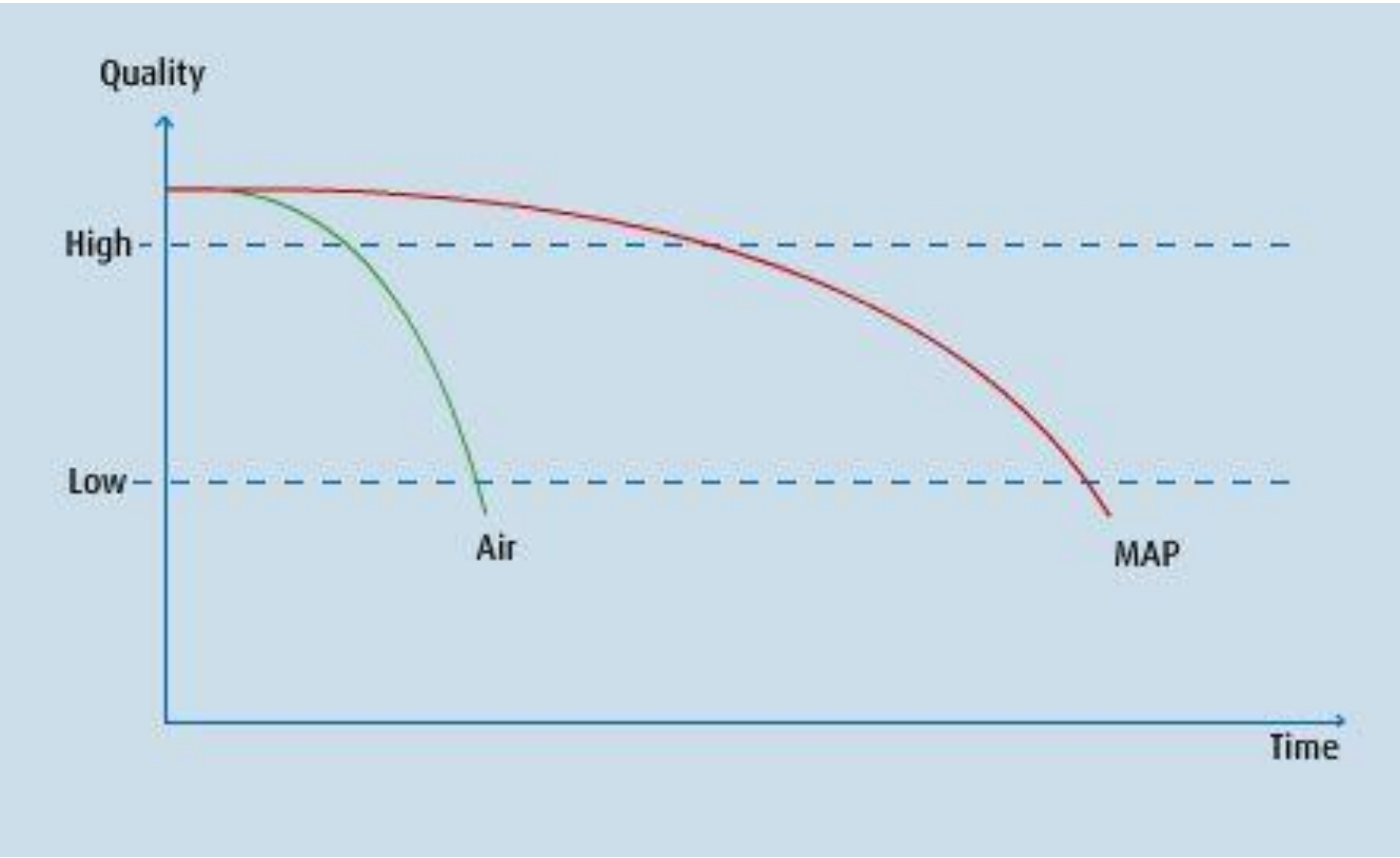




EMA- The atmosphere between the pack and the environment can be modified due to a micro perforation of the packaging film

The role of gases in the package

Oxygen will encourage the development of aerobic bacteria and can inhibit the development of anaerobic bacteria.
Nitrogen is an inherited gas that replace oxygen. Also used is use as filler gas to prevent packaging from collapsing.
CO_2 is responsible for the fungi static and bacteriostatic effect (prolonging the period of the lag of the bacterial growth). Inhibits maturation and aging.



Quality of produce over time in a normal atmosphere and in a modified atmosphere

Modified Atmosphere

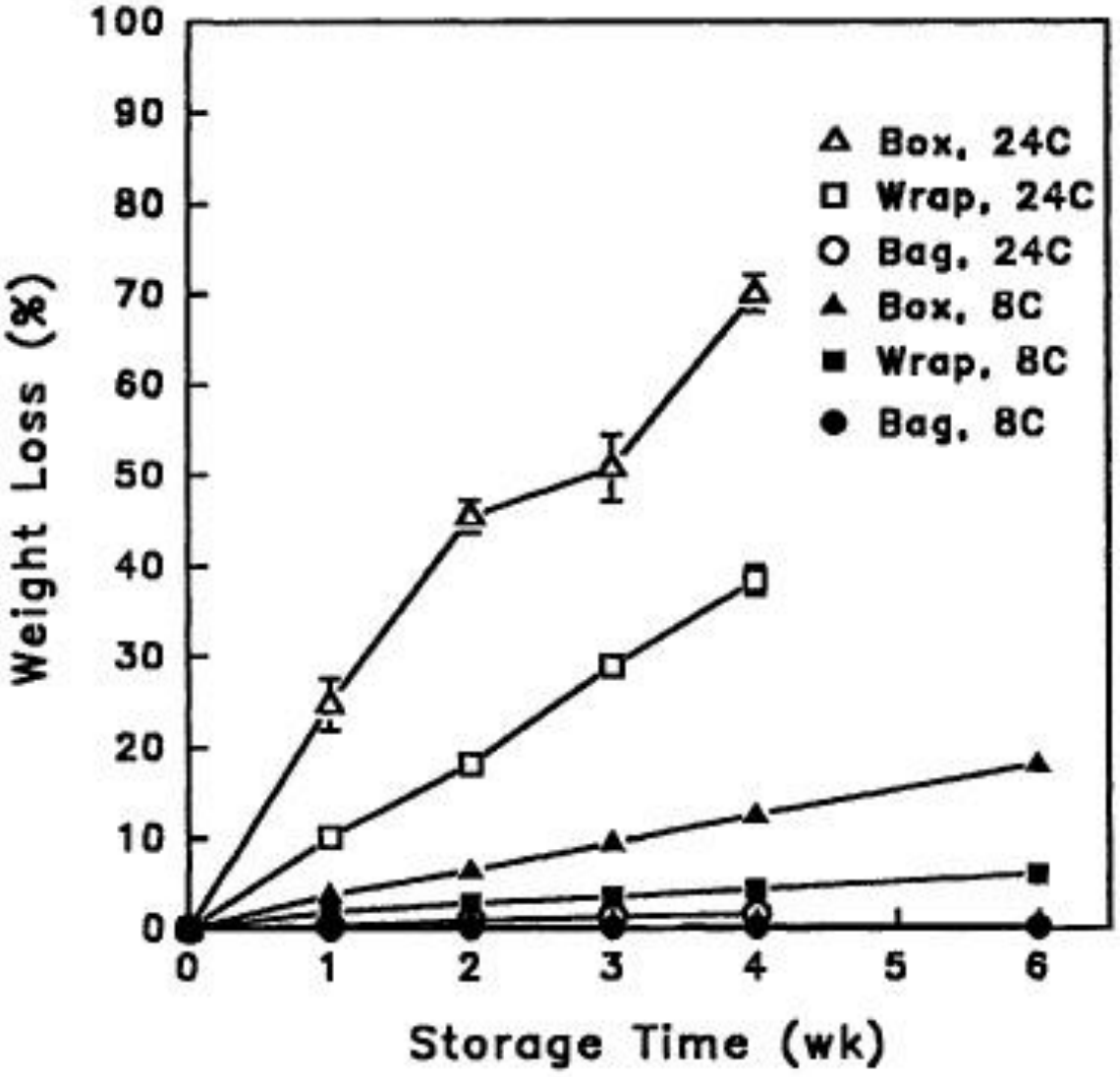
The potential for improvement or damages depends on the following aspects:

- Type of fresh produce
- The cultivar
- Atmospheric composition
- Temperature
- Storage period

Modified atmosphere

Potential improvement

- **Reducing water loss**
- **Maintaining high moisture**
- **Delaying aging**
- **Lowering ethylene sensitivity**
- **Reducing sensitivity to chilling injury**
- **Reducing physiological defects**
- **Reducing decay**
- **Improving pest control**



Weight loss in pomegranate fruit stored with or without packaging, at 8 or 24 degrees C

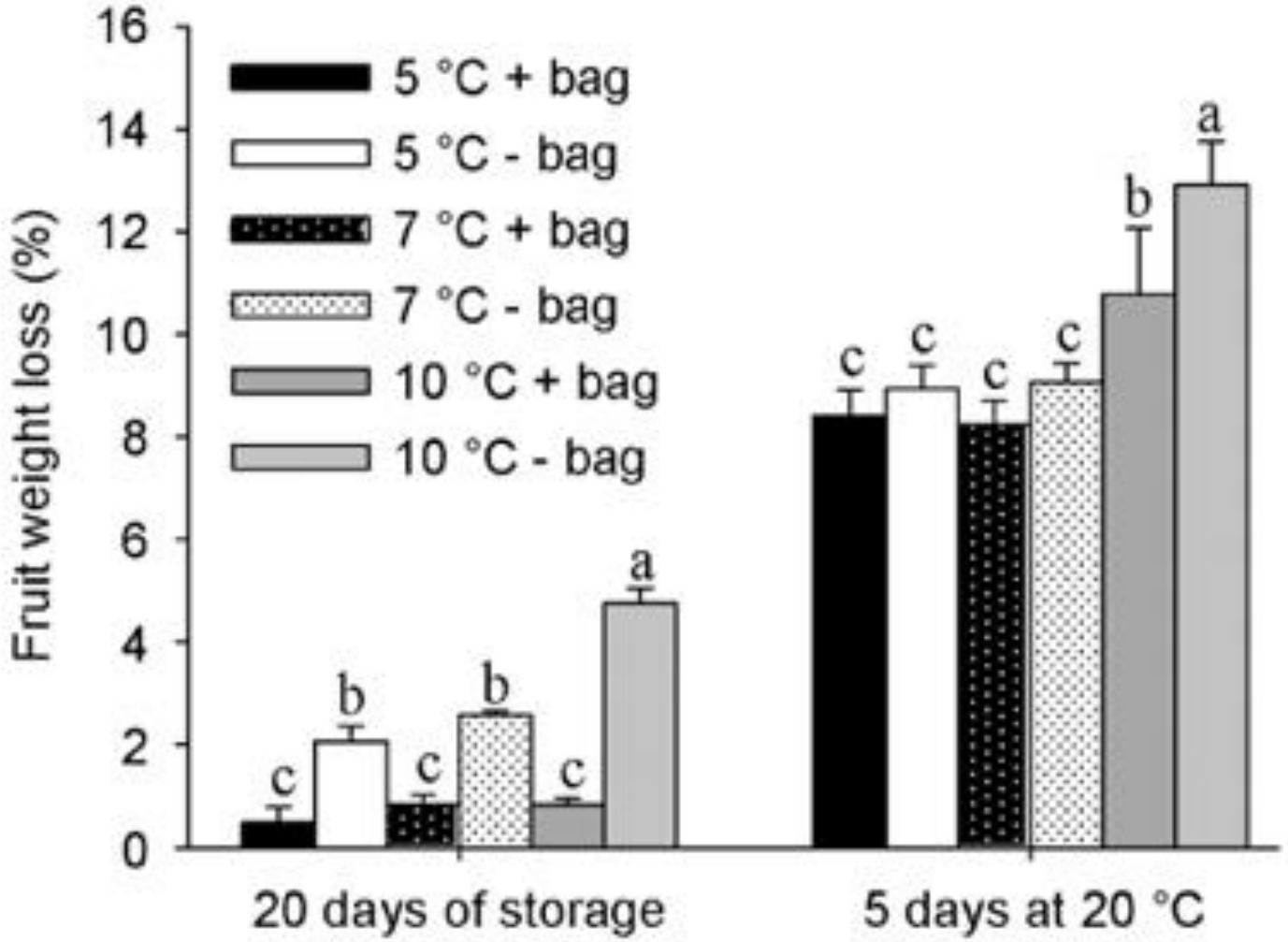
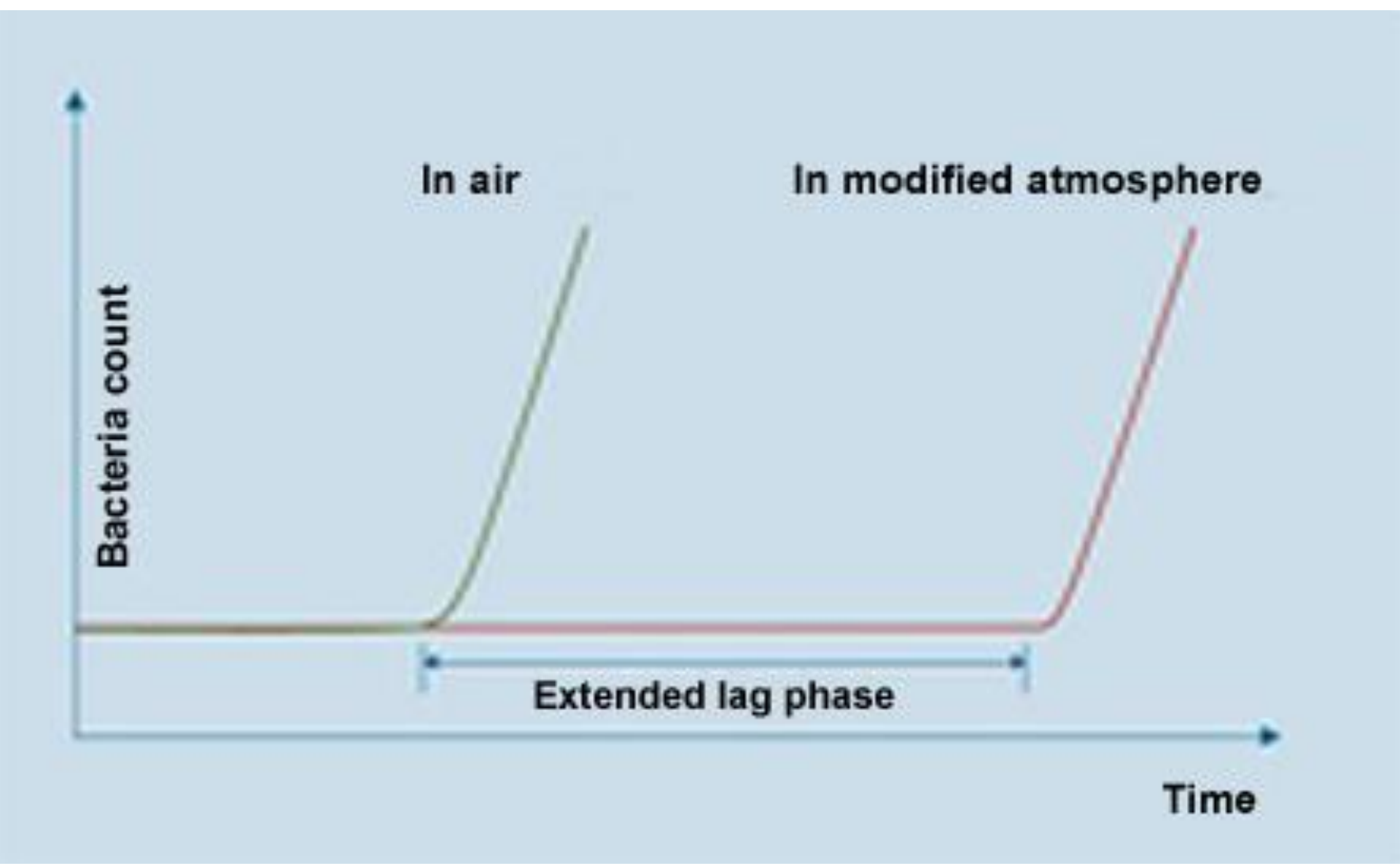
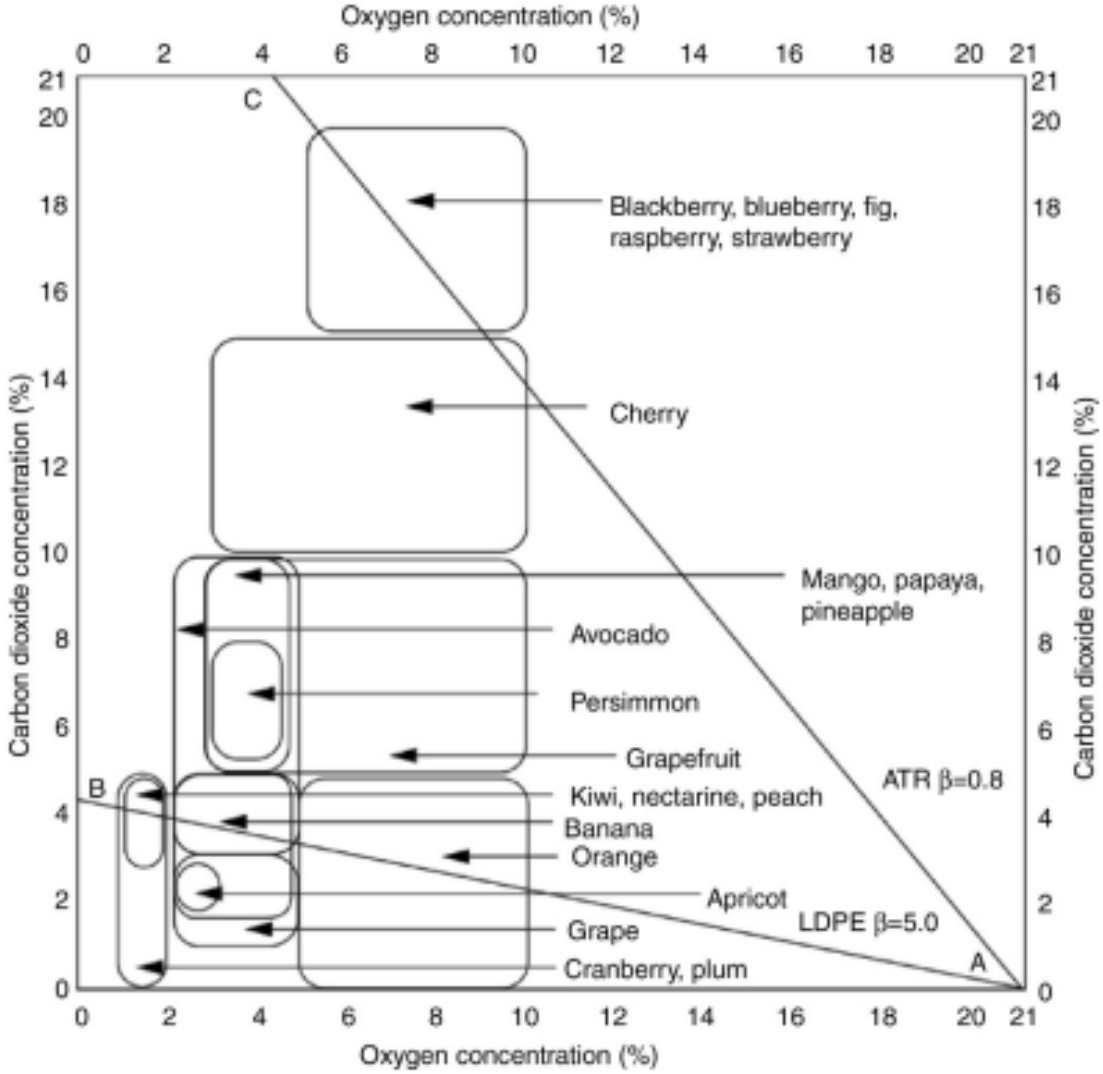


Figure 4 – Weight loss of pitaya fruit after 20 days storage at 5, 7, or 10 °C with and without perforated plastic bags and after five days of shelf-life at 20 °C without bags. Mean values (means ± standard deviation) with different letters at each evaluation time are different (Tukey's test, $p = 0.05$).

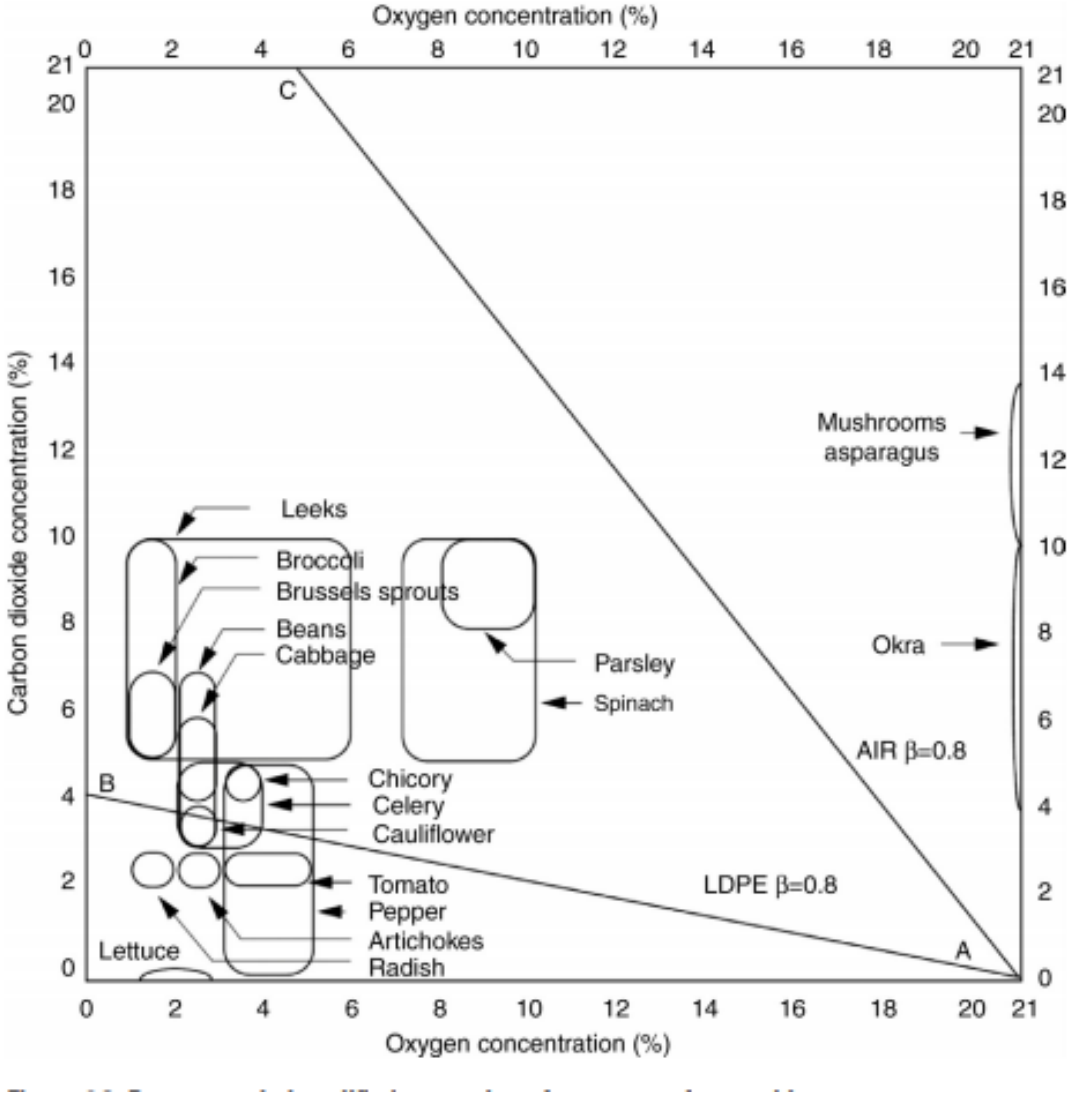


The development of bacteria over time in a normal atmosphere and in a modified atmosphere



Optimal concentrations for modified atmosphere of different fruits

From Mannapperuma, J.D., et al., 1989. In Proceedings of 5th Controlled Atmosphere Research Conference, Wenatchee, WA, p. 225



Optimal concentrations for modified atmosphere of different vegetables

From Mannapperuma, J.D., et al., 1989. In Proceedings of 5th Controlled Atmosphere Research Conference, Wenatchee, WA, p. 225

Modified atmosphere

Possible negative effects:

- Encourage physiological defects
- Causing uneven ripening
- Causing aftertaste/odors
- Increasing decay
- High CO_2 damage
- Anaerobic respiration
- Reducing storage capacity

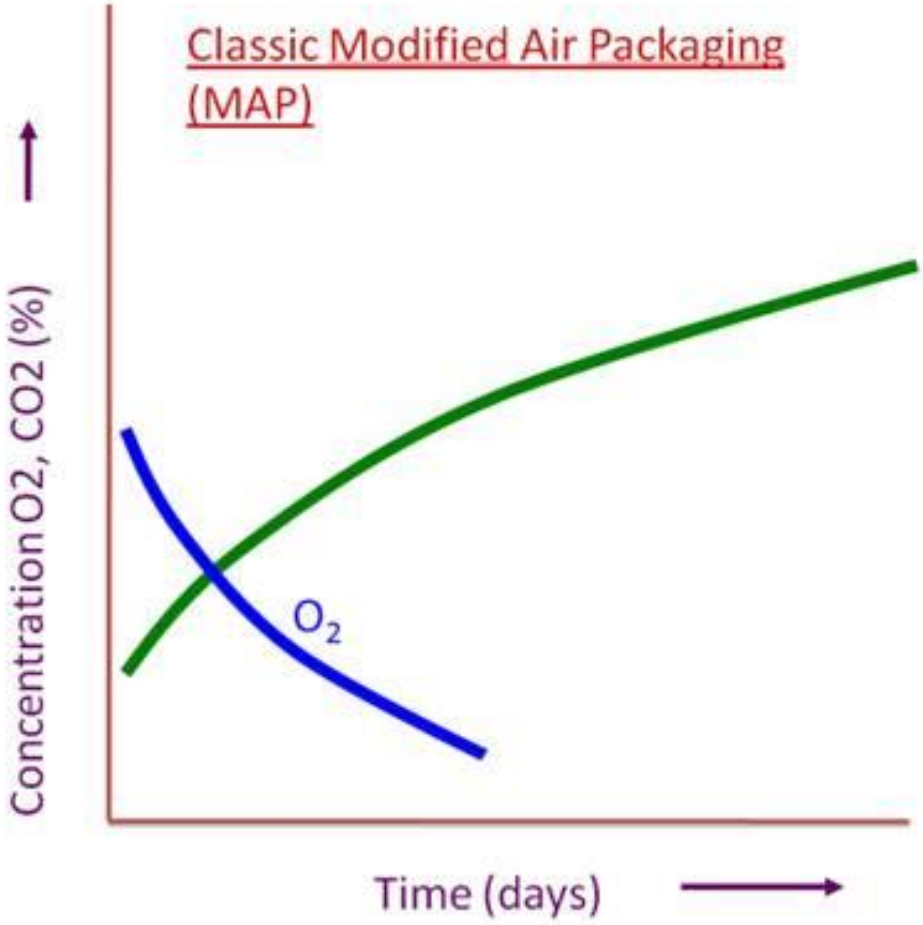
CO2 damage as a result of high CO_2 10% over two weeks

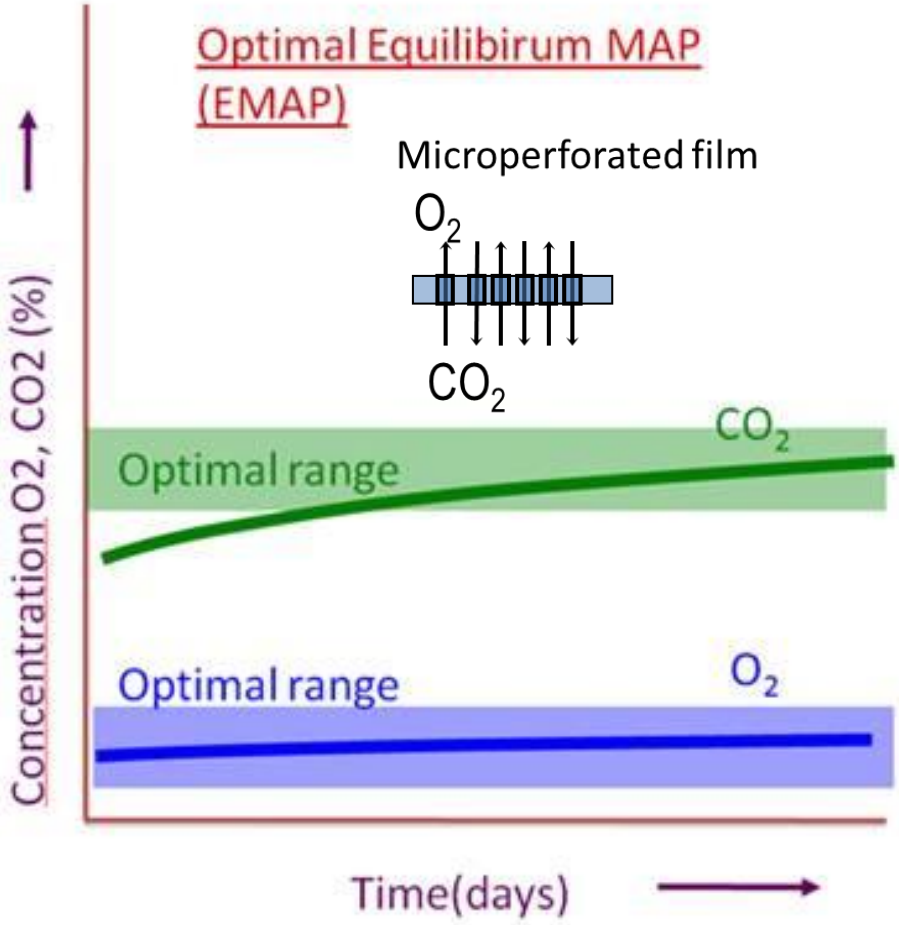
Tissue brown as a result of high ethylene

Methods for creating a modified atmosphere

- Passive modified atmosphere
- Active modified atmosphere
- Vacuum packing atmosphere

The atmosphere between the pack and the environment can be modified due to a micro perforation of the packaging film





External factors that modulate the formation of a modified atmosphere

- Harvesting conditions
- Treatment of produce
- Cleaning produce
- Temperature of the produce
- Water loss and humidity

Further factors that modulate the formation of a modified atmosphere

- Storage temperature
- The surface area of the plastic sheet.
- The thickness of the sheet and its physical components

Characteristics of different films used in fresh product packaging

Characteristics	Polyamide	Polyethylene terephthalate	Polyvinyl chloride	Polypropylene	Polyethylene films	
	Nylon-6	PET	PVC	PP	HDPE	LDPE
Water evaporation (WVTR)	4300-3900	510-390	15700-750	300-100	125	500-375
Oxygen	43-20	100-50	10000-154	4000-2000	3000-1670	8750-6700
CO2	180-85	510-255	61000-940	22000-11700	18200-9900	55000-41700
CO2\O2	4.2	5.1	6.1	5.62	5.99	6.25

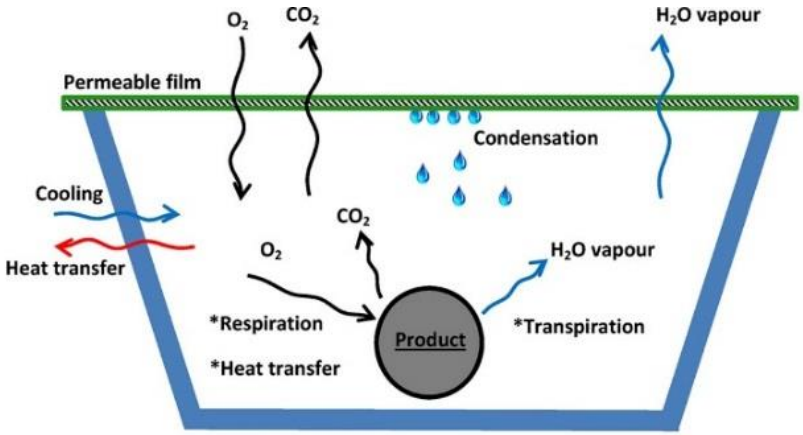
Every film must transfer better CO2 than oxygen.

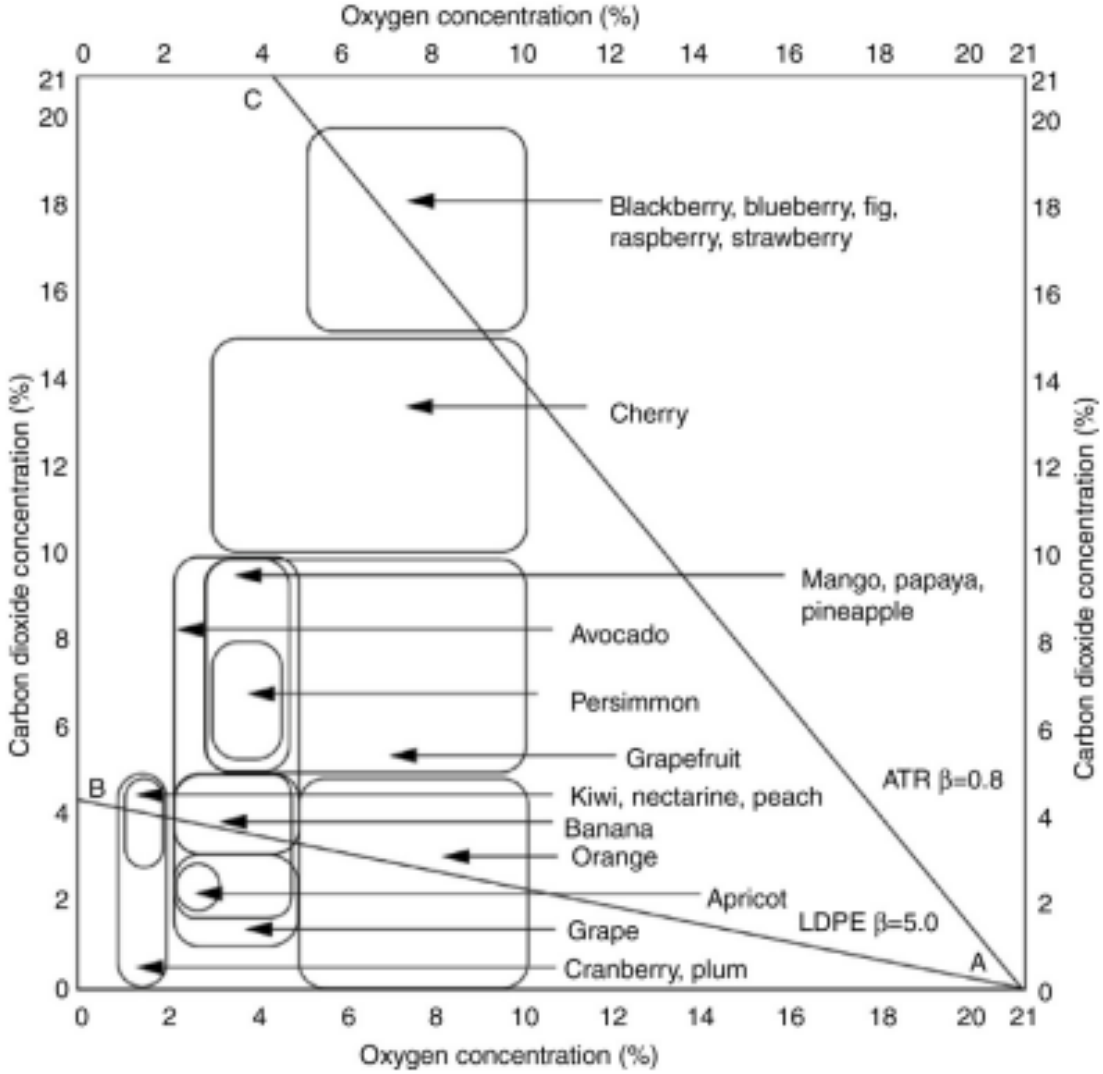
Water evaporation – at 37.8 C and 90% humidity (g µm/m2 day)
Oxygen and CO2 – Transfer at 25 C of oxygen and CO2 (cm3 µm/m2 h-atm)

What is the best film to create a modified atmosphere?

The important factors for choosing the best film:

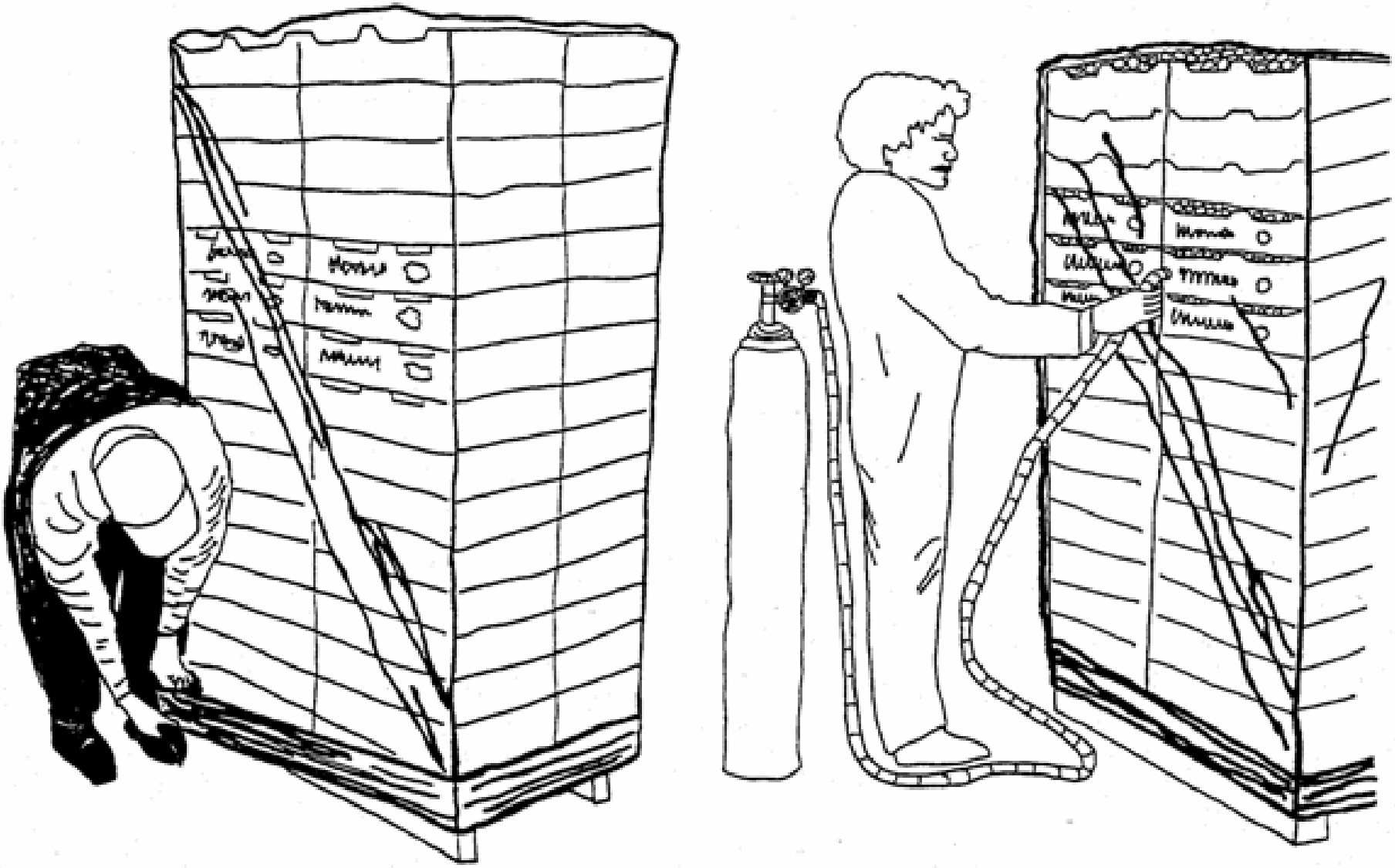
- **The type of packaging (flexible as a bit, rigid or semi-rigid).**
- **What are the characteristics of the prevention/transfer of each gas separately, the ratio of oxygen and CO_2 and water.**
- **The physical characteristic for creating the plastic packaging in the industry, the strength of the sheet, its transparency and its lifespan.**
- **The ability to close or seal with heat, or folding, preventing delay as a result of respiration.**
- **Effective sealing.**
- **Rate of water passage (evaporating of water).**
- **Resistance to chemical decomposition. No toxic residues in the plastic.**
- **Ability to print pictures and subtitles in the plastic.**
- **Commercial quality with reasonable costs**





Optimal concentrations of gases for a modified atmosphere of different fruits

From Mannapperuma, J.D., et al., 1989. In Proceedings of 5th Controlled Atmosphere Research Conference, Wenatchee, WA, p. 225



Wrapping a strawberry pallet in a polyethylene sleeve and injecting 10% - 15% CO2

“TransFresh” technology

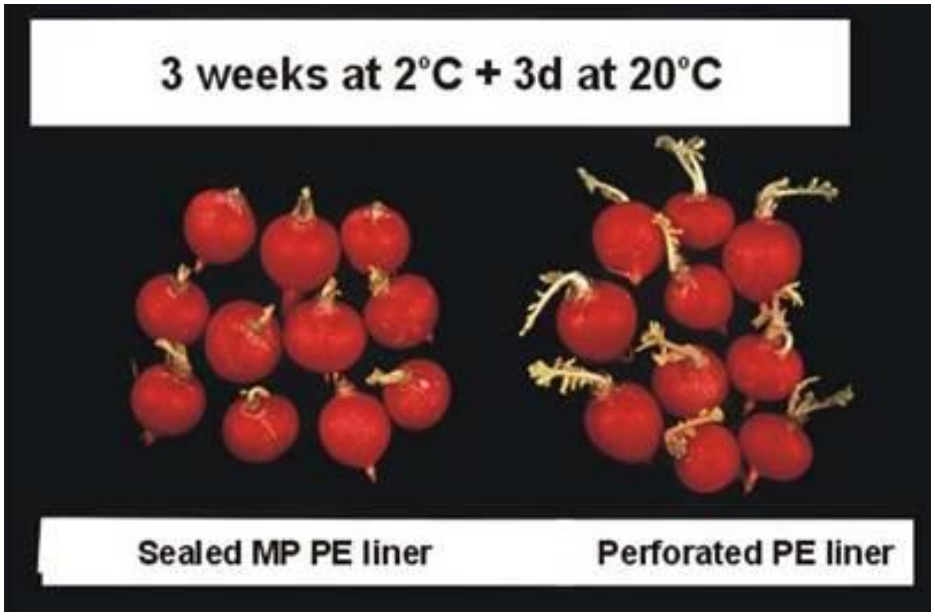
Effect of packaging on leek and other vegetable quality after 2 weeks at 1 C + 3 days in 20 C.

Sealed package

LDPE package

Xtend Package


RADISHES
SELECTED VEGETABLES


3 weeks at 2°C + 3d at 20°C
Sealed MP PE liner
Perforated PE liner


SEALED MP PE LINER
PERFORATED PE LINER


Bell Pepper Eden


Peppers
QUALITY GUARANTEED
TESCO VALUE
Peppers
500g
UNSIZED
WASH BEFORE USE
QUALITY GUARANTEED


No Perf.


ANTI FOG FILM


Microperf.


ANTI FOG FILM


Pomegranates
WAX-FLOWER
37201AMIRAN


Pomegranates


Pomegranates


Active modified atmosphere used commercially


Active modified atmosphere used commercially
71
142
207
96
29
95
210
187
183
28
94
185

Passive MAP

Active MAP

What is the future?

Intelligent packaging:

- ❑ **Decompose oxygen production/releases CO_2**
- ❑ **Eliminates odors**
- ❑ **Eliminates or removes ethylene**
- ❑ **Releases ethanol or a natural substance that has fungicidal activity**
- ❑ **Releases or maintains optimal moisture**
- ❑ **Alerts of oxygen lack or high CO_2**
- ❑ **Detects the development of decay (biosensor).**
- ❑ **Eatable**


HELP CURE
HUNGER IN
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