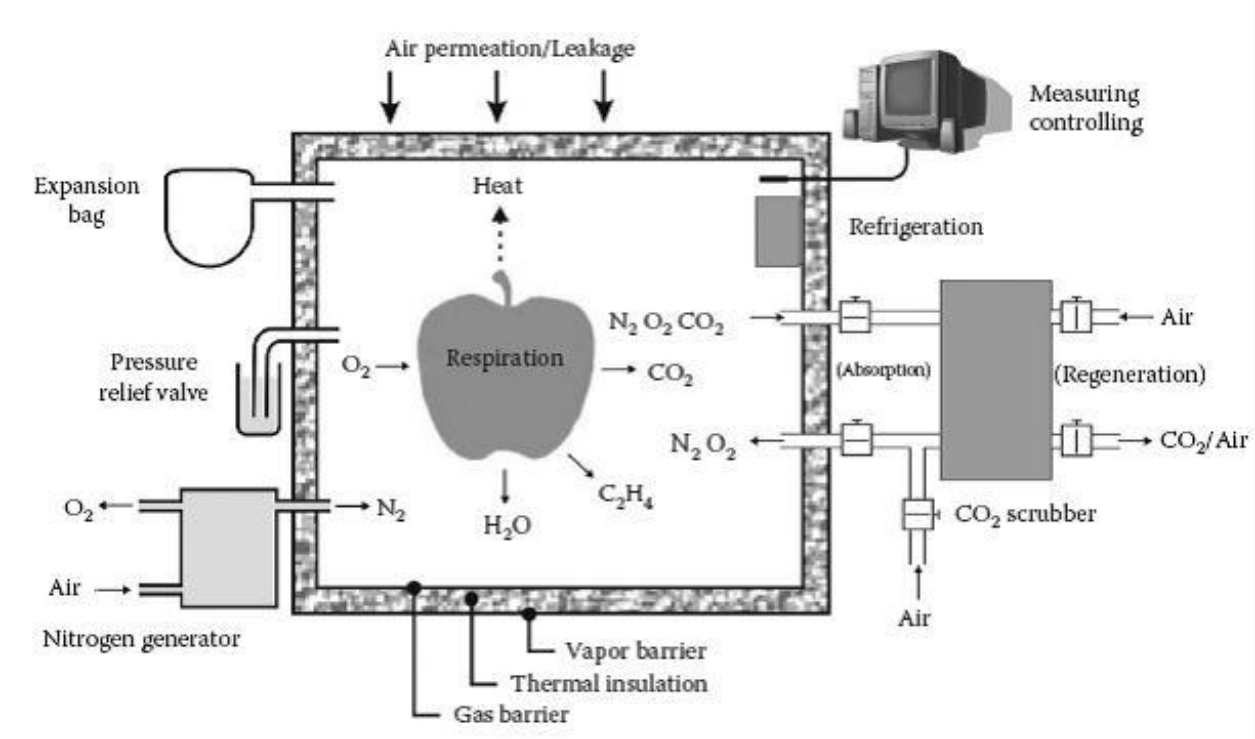
# Lesson 46. CA And MAP Storage Conditions for Various Fruits and Vegetables

## 46.1 Fruits

Conditions for the optimal storage of fruits and vegetables are influenced by a variety of factors such as crop species, cultivar, growing conditions, maturity, quality, temperature, relative humidity, packaging, and duration of storage. Storage under CA and MA is influenced by the concentration of O2, CO2, ethylene, and other gases in the atmosphere immediate to product. Storage life quality and susceptibility to disease and physiological disorder can be modified considerably by production practices, weather, soil, and other factors. Delay in cooling after harvest of apples, for instance, can result in reduced storage life because of accelerated softening and ripening process, and increased probability of scald development, breakdown, and decay. Most apple cultivars benefit from storage at temperatures just above the freezing point of the fruit, a relative humidity in the range of 90 to 95%, O2 concentration in the range of 1 to 2%, and CO2 level in the range of 1 to 2%. For apples as well as for most other fruits, it is important that whenever O2 concentration in the store space is low, CO2 concentration must also be low enough (Tables 46.1 and 46.2). This is to prevent physiological alterations and to secure organoleptic characteristics of the fruits to a great deal.



| Table 46.1 Controlled Atmosphere Storage Conditions for Apple Cultivars | | | | | |
|---|---|---|---|---|---|
| **Cultivar** | **Temperature (ºC)** | **Relative Humidity (%)** | **$O_2$ (%)** | **$CO_2$ (%)** | **Approximate Storage Life (Months)** |
| Belle de Boskoop | 3 | 92 | 2 | 1 | 5–6 |
| Cox's Orange Pippin | 3.5 | 92 | 2 | 1 | 5–6 |
| Delicious | –0.5 | 90 | 2 | 1 | 6-7 |
| Elstar | 3 | 90 | 3 | <1 | 5–6 |
| Empire | 0 | 90 | 2.5 | 3 | 4-6 |
| Gala | 0.5 | 90 | 2 | 2 | 5–6 |
| Gloster | 0.5 | 90 | 3 | 3 | 4–6 |
| Golden Delicious | –0.5 | 92 | <3 | 5 | 5–7 |
| GrannySmith | 0 | 90 | 2 | 1 | 5–6 |
| Idared | 0 | 90 | 3 | 5 | 6–8 |
| Jonagold | 0 | 90 | 3 | 5 | 5–7 |
| Jonathan | 0 | 88 | 2 | 2 | 5–6 |
| Laxtons | 2 | 92 | 3 | 3 | 5–6 |
| McIntosh | 3 | 90 | 3 | 5 | 6–7 |
| Mutsu | 0.5 | 92 | 3 | 2 | 8–9 |
| Rome Beauty | 0 | 90 | 2 | 2.5 | 8–9 |
| Spartan | 0 | 90 | 2 | 2.5 | 6–8 |
| Stayman | 3 | 92 | 2 | 2 | 6–7 |

| Table 46.2 Controlled Atmosphere Storage Conditions for Selected Fruit Species | | | | | |
|---|---|---|---|---|---|
| **Cultivar** | **Temperature (ºC)** | **Relative Humidity (%)** | **$O_2$ (%)** | **$CO_2$ (%)** | **Approximate Storage Life (Months)** |
| Avocado | 7–12 | 90 | 2–3 | 3–10 | 2 months |
| Cherry | 0 | 95 | 3–10 | 10–12 | 30 days |
| Chestnut | 0 | 90 | 3 | 10 | 3 months |
| Kiwifruit | 0 | 98 | 2 | 4–5 | 7 months |
| Nectarine | –0.5–0 | 95 | 2 | 5 | 50 days |
| Peach | –0.5–0 | 95 | 2 | 4–5 | 40 days |
| Anjou | –0.5–0 | 90 | 1–2 | 0.5–2 | 6–7 months |
| Bartlet | –1.0–0 | 90 | 2–3 | 4–5 | 4–5 months |
| Plum | 0 | 95 | 2 | 5 | 45 days |

The severity of flavor loss depends on the atmospheric composition and duration of storage. The higher the CO2 concentration, the lower is the O2 concentration; and the longer the duration in CA storage, the greater is the flavor loss. Disorders in apples likely to occur during storage include bitter pit, scald, shrivelling, water core, chilling injury, core flush or core browning, decay, and breakdown. Of these disorders, scald, core- flush, breakdown, and decay can be controlled by handling and storage practices.

Delays in storage, high temperature, hot weather before and during harvest, immaturity, high fruit nitrogen, and extended storage periods all tend to increase scald. Controlled atmosphere and low $O_2$ storage reduce scald. Coreflush, or core browning, a common storage disorder of McIntosh apples is associated with low storage temperature and senescence. This disorder, which is accentuated by immaturity and excess fruit nitrogen level, generally appears in apples after 3 to 4 months of storage at –1 to 0°C and is intensified by a further 5 to 6 days at room temperature.

Apricots, peaches, cherries, raspberries, strawberries, and plums have a short storage life. In air at –1 to 0°C and 85 to 95% relative humidity, sweet cherries have a storage life of about 3 weeks, sour cherries only a few days. Mature soft fruit normally has a maximum 2-week storage life, whereas firm fruit can be stored for 2 to 4 weeks. Fresh strawberries can be held for a maximum of 10 days and rasp- berries can be held for a maximum of 5 to 7 days at 0°C and 85 to 95% relative humidity. Controlled atmosphere storage of soft and stone fruits can provide additional storage life. Controlled atmosphere storage of apricots using 3 to 5% CO2 and 2 to 5% O2 at –1 to 0°C can extend the storage life from 12 to 14 days to 18 to 20

days. Similarly, storage of sweet cherries in atmospheres containing 20% CO2 and 21% O2 at –1 to 0°C can extend storage life for 5 to 6 weeks. Recommendations for CA storage of pears, peach, nectarine, plum, avocado, cherry, chestnut, and kiwifruit are given in Table 46.2.

## 46.2 Vegetables

Recommended storage temperature, gas concentration, and storage life expectancy of selected vegetables are given in Table 46.3. For vegetables, such as potatoes, carrots, garlic, and horseradish, which can be successfully stored in air, controlled atmosphere storage is not an economical option. For most other vegetables, the benefits of CA are generally low and consequently the level of application is slight.

The highest level of appreciation of CA in vegetables is with broccoli, cabbage, lettuce, asparagus, and Brussels sprouts. In broccoli, CA may extend the storage life by 1 to 2 weeks over that normally expected in cold storage. Optimum CA conditions (10% $CO_2$, 1% $O_2$ at 3 to 5°C) have been shown to retard chlorophyll loss, flower bud senescence, and toughening of broccoli. At $O_2$ levels below 0.5%, however, strong off-odor and off-flavor develop. Packaging of broccoli in polymeric films has been shown to extend shelf life and improve retention of color and nutrients, especially ascorbic acid.

Winter cabbage, held at 0°C and 90 to 95% relative humidity has a storage life of 3 to 7 months. In CA (5% $CO_2$; 2.5% $O_2$ at 0°C) cabbage can be stored for up to 10 months. This treatment is effective in preserving green color, maintaining succulence, and greatly retarding senescence. Cauliflower has a relatively short shelf life of only 4 weeks under optimal conditions of 0°C and 100% relative humidity. Storage life of this produce, however, can be extended with the use of CA. It is reported that under a CA of 3% O2 and 2.5 to 5% CO2 cauliflower was still commercially acceptable after 52 days of storage. Storage under higher CO2 levels, however, causes yellowing, softening, and microbial breakdown. Lettuce is also a short storage crop, and when its temperature is reduced rapidly to 0°C and held at this level while the humidity is kept very high, head lettuce can be stored for 2 to 3 weeks. Under CA of 2.5% CO2 and 2.5% O2 at 2°C head lettuce can be stored for up to 75 days. Studies of CA storage of minimally processed lettuce have shown that CA (3% O2, 10% CO2) can prolong the shelf life of shredded iceberg lettuce by limiting plant and microbial enzyme activity, without appreciably affecting microbial development.

**Table 46.3 Controlled Atmosphere Storage Conditions for Selected Vegetables**

| Vegetable | Temperature (°C) | $O_2$ (%) | $CO_2$ (%) | Level of application |
|---|---|---|---|---|
| Artichokes | 0 | 2–3 | 2–3 | Slight |
| Asparagus | 2 | Air | 10–14 | High |
| Beans, green snap processing | 7 | 2–3 | 4–7 | Slight |
| Broccoli | 0 | 1–2 | 5–10 | High |

| | | | | |
|---|---|---|---|---|
| Brussels sprouts | 0 | 1–2 | 5–7 | Slight |
| Cabbage | 0 | 2–3 | 3–6 | High |
| Cauliflower | 0 | 2–3 | 3–4 | Slight |
| Celeriac | 0 | 2–4 | 2–3 | Slight |
| Celery | 0 | 2–4 | 3–5 | Slight |
| Chinese cabbage | 0 | 1–2 | 0 | Slight |
| Cucumbers, fresh | 12 | 1–4 | 0 | Slight |
| Pickling | 4 | 3–5 | 3–5 | Slight |
| Leeks | 0 | 1–6 | 5–10 | Slight |
| Lettuce (crisphead) | 0 | 1–3 | 0 | Moderate |
| Cut salad | 0 | 1–3 | 0 | High |
| Lettuce (leaf) | 0 | 1–3 | 0 | Moderate |
| Cantaloupes | 8 | 3–5 | 10–20 | Slight |
| Mushrooms | 0 | Air | 10–15 | Moderate |
| Okra | 10 | Air | 4–10 | Slight |
| Onions | 0 | 0–1 | 0 | Slight |
| Onions (bunching) | 0 | 2–3 | 0–5 | Slight |
| Parsley | 0 | 8–10 | 8–10 | Slight |
| Pepper (bell) | 12 | 2–5 | 0 | Slight |
| Pepper (chili) | 12 | 3–5 | 0–5 | Slight |
| Radish (topped) | 0 | 1–2 | 2–3 | Slight |
| Spinach | 0 | 7–10 | 5–10 | Slight |
| Sweet corn | 0 | 2–4 | 5–10 | Slight |
| Tomatoes | 12 | 3–5 | 2–3 | Slight |
| Witloof chicory | 0 | 3–4 | 4–5 | Slight |

**References:**

- Gorini, F. L., Eccher Zerbini, P., and Testani, A., The controlled atmosphere storage of fruit and vegetables, Atti Istituto Speriment, Valorizzazione Tecnol. Prodotti Agri., 11, 139, 1988.
- Mazza, G. and Jayas, D. S., Controlled and Modified Atmosphere Storage.
- Meheriuk, M., Controlled atmosphere storage conditions for some of the more commonly grown apple cultivars, In: Controlled Atmospheres for Storage and Transport of Perishable Agricultural Commodities, Blankenship, S. M., Ed., North CarolinaState University, Raleigh, Hort. Rep. 126, 1985, 395.