# CURRENT STATUS AND RECENT TRENDS IN CA STORAGE IN WASHINGTON

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Controlled atmosphere (CA)[1] storage for apples and pears in the State of Washington has been developing over the past 25 years and now makes up more than half (about 55%) of the storage capacity. Initially, generation of the reduced oxygen ($O_2$) atmosphere was dependent on respiration of the fruit. The carbon dioxide ($CO_2$) was scrubbed out using caustic soda (sodium hydroxide solution).

Washington has loose storage capacity of approximately 47,800 and 58,280 carloads (1000 bu) of regular atmosphere (RA) and CA storage, respectively. During the 1983-84 season, a total of 51,503 carloads of apples were shipped of which half were stored under CA conditions. There were 3,243 carloads of pears shipped and nearly 40% of these were stored under CA.

The initiation of CA storage stimulated several warehouses to improve their RA storages. Good quality RA storage 'Red Delicious' became available later in the season due to better maturity at harvest time and careful temperature and humidity control along with good air circulation in the storage. This RA fruit was marketed as special storage and received prices comparable to CA fruit.

It became obvious that regulations were needed for CA storage operations as a practical measure against the marketing of fruit as CA but not from CA storage if consumer confidence was to be gained for a higher priced product. The following were the basic factors written into the Washington State CA law: Appropriate atmospheres must be reached within 20 days after the room is sealed; and fruit must be held in not more than 5% $O_2$ for a minimum of 90 days; determination of $O_2$, $CO_2$ and temperature must be made daily; 'Red Delicious' apples must be firmer than 11 lbs at time of shipment; and fruit must enter the channels of commerce within 2 weeks of a State horticultural inspection. Unless all of the foregoing criteria are met the fruit cannot be labeled as CA. Fruit not meeting these requirements go on the market as RA fruit.

[1]An atmosphere in which concentrations of $O_2$ and $CO_2$ are maintained at a specific level.

An additional regulation added to this law states a CA storage for 'Red Delicious' cannot be started after December 15 of each year. This precludes use of the same room for 2 loads of fruit in the same season.

Although the Washington State CA law has remained essentially unchanged, our recommendation for CA operation have become more specific. This is based primarily on work with 'Golden Delicious' apples which soften so rapidly in the first 4 months of storage even following very rapid hydrocooling. The first real retention of firmness in 'Golden Delicious' was obtained following a 17% $CO_2$ treatment on fruit directly after harvest (2). Many warehouses in Washington adopted this procedure but the danger of $CO_2$ burn was too great and this treatment was not used commercially in British Columbia (5,6). Moisture on the fruit in the presence of elevated $CO_2$ (3) and fruit with poorly developed natural cuticle contribute to this disorder.

Comparable results on retention of firmness were found when the fruit was exposed initially to a rapid reduction in $O_2$ (7). This procedure has subsequently been called rapid CA (RCA) (4). In the 1980 harvest, 4 commercial rooms were filled rapidly with 'Golden Delicious' and the $O_2$ was reduced artificially to 2% within 7 days after the first fruit in the room was picked. The retention of firmness was excellent. In following years it has been determined that some $CO_2$ burn may occur if the $CO_2$ level is permitted to rise above 3% during the CA generating period.

The response of 'Golden Delicious' to high $CO_2$ or RCA is dependent on the fruit not being completely physiologically mature and being placed under treatment quickly. Once the final organization of ripening has become complete, only small benefits in retention of firmness and acidity are derived from the high $CO_2$ or RCA treatments. The general softening pattern of 'Golden Delicious' and 'Red Delicious' is quite different. It appears that the final ripening organization in 'Red Delicious' may extend over a longer period and softening of this variety extends over the entire storage period. The rate of softening is greatly reduced if the fruit is placed under CA conditions prior to its initiation of the climacteric rise. Also, the rate of softening during marketing is reduced.

Maturity is very important to the storage life of fruit and must be taken into consideration for a successful CA operation. The Northcentral Washington Fieldmen's Association helped organize an industry funded maturity project. Fieldmen collect samples on the first of each week from the same trees in each test orchard starting about the middle of August. This fruit is brought to a central laboratory where examinations are made and the data is tabulated. Each Wednesday evening the fieldmen review the results. The absolute levels of the various measures are of interest but the rate of change that has been occurring in these measurements is of primary importance. Observations made at this meeting are distributed to the growers and is used to establish the initiation of harvest.

As harvest gets underway, knowledge of the fieldmen about each orchard as well as sampling of fruit at the warehouse identifies the maturity of the apples. Fruit of similar maturity is placed in the same room. In general the first fruit harvested is the last fruit sold. Warehouse management is able to develop an organized marketing pattern based on knowledge of the fruit condition and the potential storage life of apples in their various storage rooms. Several warehouses now employ a quality control person to help monitor the fruit at harvest and during storage for better marketing.

The general recommendations for RCA storage in Washington are as follows:
1. Only fruit of the same maturity should be placed in the same room.
2. The room should be filled quickly and the $O_2$ reduced to 2% within 7 days after the first fruit placed in the room was harvested.
3. Maintain $O_2$ at approximately 1.5% but not over 2%.
4. Maintain $CO_2$ below 2%.
5. CA storage temperature should not be below 31°F (-0.5°C). If $O_2$ goes below 1.5%, raise temperature to 32°F (0.0°C). Higher temperatures have not been adequately tested.
6. Monitor $O_2$, $CO_2$ and temperature daily. Use sampling pump to draw air through the meters to avoid possible leak in pump.
7. Sample rooms directly once per week to avoid small leaks in regular sampling procedure.
8. Check measuring equipment with a standard gas sample once per week.

The introduction of RCA has presented some problems for the industry. Better coordination of harvest by the growers is essential so that the storage rooms can be filled quickly with fruit of the same maturity. Generation of the low $O_2$ atmosphere has required an increase in the amount of generating equipment or a change to new equipment. The first equipment introduced in Washington was a flushing system known as 'Tectrol'. This equipment is no longer being manufactured but 'Gen-O-Fresh' is available which operates under the same principle. They burn natural or propane gas with outside air which lowers the $O_2$ and increases $CO_2$. Most of the $CO_2$ is removed in this system on carbon scrubbers before the atmosphere is directed into the CA room. A vent on the room must be opened to relieve the build up of pressure and thus a flushing system is established. This equipment became available in the 1962 season and is still being used in over half of the installations.

Another system was developed which recirculated the air from the room through a unit burning gas. This was called the 'Arcat' and became available in 1965. The atmosphere produced was returned to the room and a separate system was required to scrub out the $CO_2$ produced. This generator is now being manufactured in 2 locations in Washington and is called a "COB". It has been the other most popular unit.

Both of the above units are adequate to generate the CA atmosphere. However, additional or larger units were found necessary to comply within the frame work of RCA. The first major change in type of generator was the introduction of the 'Oxydrain' from The Netherlands in 1982. This uses ammonia fuel and is a closed system which produces $N_2$ and water

from the hydrogen of ammonia and oxygen from the room. There are 13 units installed in the Pacific Northwest at present. In one installation 2 'Oxydrain' units are used together with 4 'Tectrol' units supplying make up gas. With this system they are able to reduce the $O_2$ to 2% in a 55,000 bushel room in 36 hours.

Last year 3 'Isocell' units were installed and probably double that number or more will be installed this year. It is capable of producing 5000 SCFH of low oxygen air and has been very effective in developing RCA. There are 2 other mechanical units which are ready for testing this season. One is the pressure swing absorption (PSA) system which separates $O_2$ from $N_2$ in the air using a special activated carbon. The second is a membrane system which permits passage of water, $O_2$, $CO_2$ and some ethylene but retains $N_2$. This has been engineered into a modular system by the Dow Chemical Co., and it can be designed for whatever size is needed.

There is still another system which has been under study for the past 2 years and will be in commercial operation for the 1985 season. This is the use of liquid $N_2$ for initial $O_2$ pull down and purging out the $CO_2$ during storage. This will be automatically controlled for maintenance of desired $O_2$ and $CO_2$ levels. Humidification will be adjusted as necessary.

The newer systems have one common advantage in that no additional $CO_2$ is produced in the generation of reduced $O_2$ atmosphere. The 'Oxydrain' uses agricultural grade ammonia as a fuel. The PSA and membrane systems require a compressor but no fuel and both have the potential of removing $CO_2$ as well as $O_2$. Both of these systems require a capital investment but this can be amortized over several years. It is planned to test these units under commercial conditions during this coming 1985-86 season.

The liquid nitrogen system has been tested on commercial storages both for generating the initial low $O_2$ atmosphere and removal of $CO_2$ generated by the fruit. A desirable system will require some capital investment for the automated controls. As long as the nitrogen can be delivered at a competitive cost, this system will be simple to operate. The only mechanical parts will involve an air pump to inject outside air into the room as needed and a sampling pump to monitor the $O_2$ and $CO_2$ levels in the CA room.

Current research is directed toward lower $O_2$ levels. Promising results for control of storage scald have been obtained at 1% $O_2$ or lower (1). One commercial CA room was operated at an average 1.2% $O_2$ this past season with good results. It appears that some 'Red Delicious' can be stored near 0.5% $O_2$ at 32°F (0.0°C) or higher. Growing conditions and maturity of the fruit will probably affect the minimum safe $O_2$ level. The period of time in storage may also be another factor. Additional work needs to be done to determine if some additional volatile and flavor components can be increased without the loss in scald control or condition of the fruit by increasing the $O_2$ level after some initial period

in low $O_2$. This would increase the flavor of the fruit and result in better dessert quality and market acceptance.

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