Controlled Atmosphere Storage of Fruits in Japan

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Controlled Atmosphere Storage (CA storage) is a method where fruits are refrigerated and stored in the air of which the composition has been changed within the refrigerator.

As fruits are alive or respirating the components are consumed by the respiration of fruits. In order to store fruits for a long period it is necessary to reduce the consumption of components by controlling the respiration.

It may be possible to get longer storage life by lowering the temperature as a method for controlling the respiration than that by means of keeping at the normal temperature, but it could get much longer storage life by changing the atmospheric composition.

Normally the air contains 78 per cent nitrogen (N_2), 21 per cent oxygen (O_2) and 0.03 per cent carbon dioxide (CO_2).

When apples, for example, are stored in the atmosphere of which composition has been changed into low O_2 and high CO_2, it is possible to control the respiration to approximately 30 to 60 per cent and to store them longer and more fresh than preserved in just a refrigerated condition in normal atmosphere.

CA storage had been initiated as a new storage method for apple by Franklin Kidd and Cyriel West, both of England, in 1919, and it has been recently applied to apple and pear in the United States, Canada, Australia and Western countries.

In Japan the study has been made by Shimizu in 1929, but it has not been put into practice. Around 1960, CA storage of apple, however, had reached the stage for practical application by conducting again the study and trial of CA storage of apple, although it has been on a small scale.

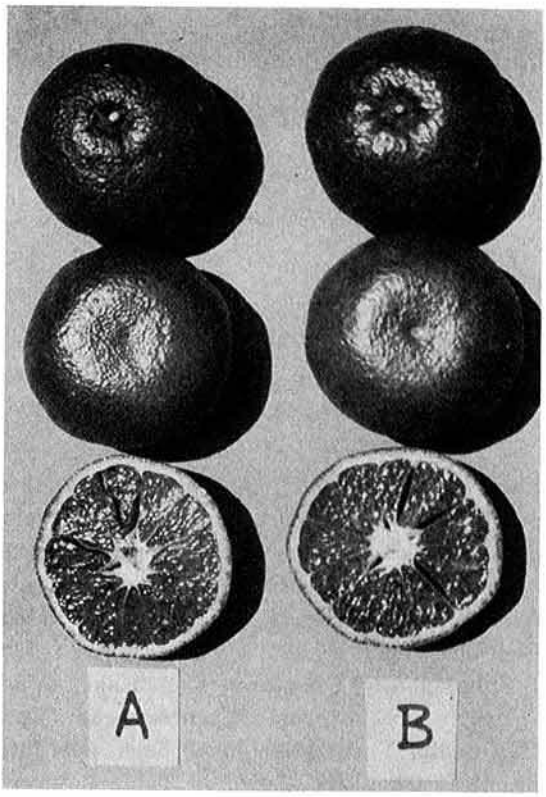
Subsequently, CA storages of "Kaki" (Var. "Fuyu") in 1968 and Japanese pear (Var. "Nijusseiki") in 1969 have been put into practice. They are shown in Table 1, where the storage quantity is increased. Studies on other fruits are in the making.

The major effects for keeping quality of CA storage are (1) ripening control (2) firmness maintenance of flesh (3) maintenance of green color (4) maintenance of organic acid, and some fruits and vegetables show sprout inhibition or disinfestation.

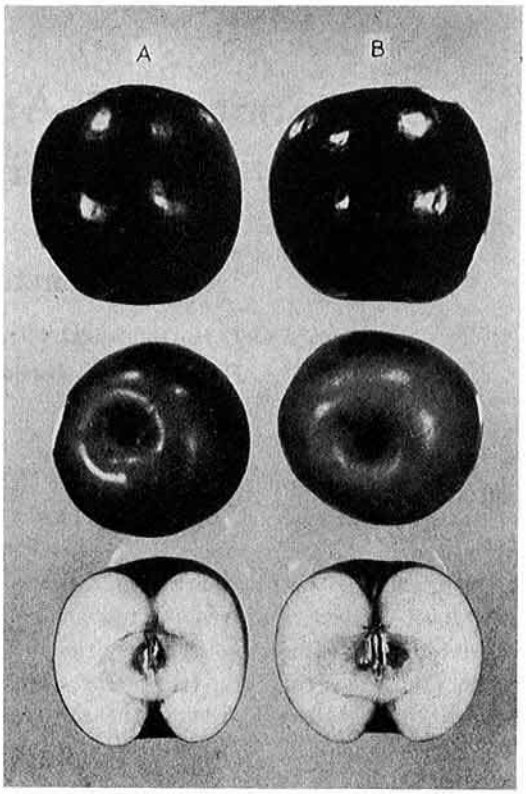
The method is especially effective to fruits which these effects depend upon the quality of fruits.

It can be said that the method is a supplementary means effective to fruits of which storage temperature cannot be reduced because of the occurrence of low temperature injury.

Although CA storage is expected to be developed in the future as an effective storage method for fruits and vegetables, it is necessary to select them for which the method is suitable, and to establish the optimum storage condition, since it is not fitted to all fruits and vegetables, and studies on many fruits are pending.



Satsuma mandarin stored for 5 months at 3°C, R.H. 88%. Atmosphere A: $O_2$10% and CO_2 2%, B: air



Apple (Var. Jonathan) stored for 5 months at 0°C, R.H. 95%. Atmosphere A: $O_2$3% and CO_2 2.5% B: air (Photo by A. Ito)

Fig. 1. Fruits stored in controlled atmosphere and in air

Apple

The standard of storage temperature of apple is 0°C, but in cases of Starking Delicious, Jonathan and "Fuji", the internal breakdown is apt to occur at 0°C, about which studies are under way.

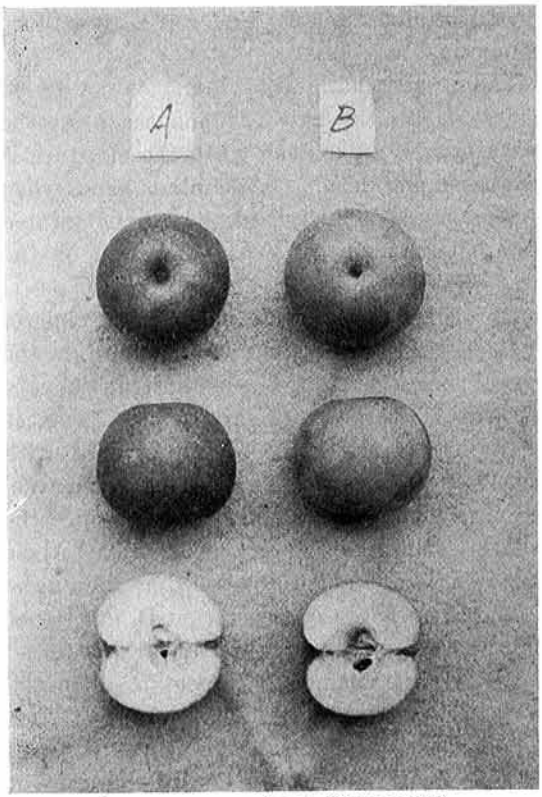
The proper humidity (R.H.) for apple is 90 to 95 per cent. Under 90 per cent of humidity, apples are dried and the quality will be damaged. Therefore, it is necessary to pay strict attention that they should not be dried, since there will hardly be an excess of moisture during storage.

The major varieties to which CA storage is applied in Japan are Starking Delicious, Golden Delicious, Jonathan, Rallus Janet and "Fuji", and all of them are stored in the atmosphere of 3 per cent O_2 and 3 per cent CO_2, but it is still indispensable to conduct studies on some varieties.

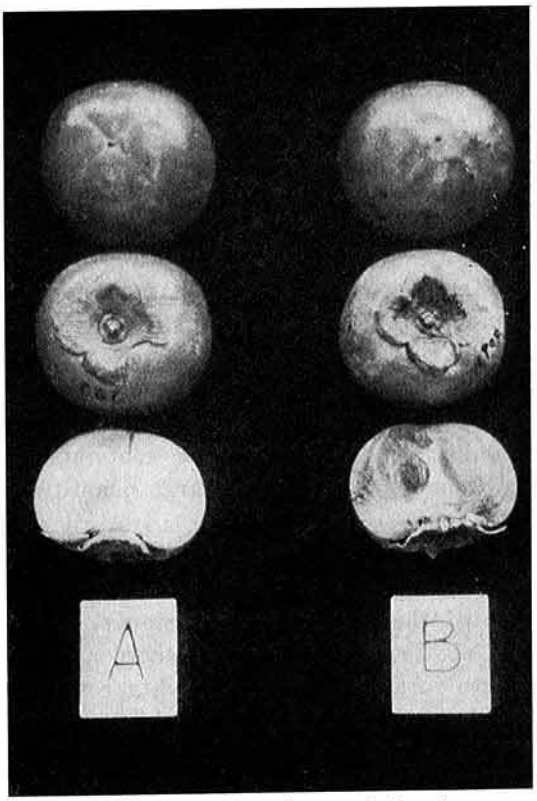
Generally, softening of the flesh is apt to be accelerated when the concentration of O_2 is over 5 per cent, and browning of the core is likely to increase when it is under one per cent.

When the concentration of CO_2 is under one per cent, softening of the flesh is quickened. Over 5 per cent, browning of the core is increased.

Unripe fruits after storage have bad flavor and texture, and overripe fruits are apt to lose the freshness; injury may very possibly



Japanese pear (var. Nijusseiki) stored for 8 months at 0°C, R.H. 90%. Atmosphere A: $O_2$5% and $CO_2$4%, B: air (Photo by A. Sato)



Kaki (var. Fuyu) stored for 4 months at 0°C, R.H. 95–100%. Atmosphere A: $O_2$2% and $CO_2$8%, B: air (Photo by Y. Tanaka)

Fig. 2. Fruits stored in controlled atmosphere and in air

occur in both cases.

Time of picking differs with cultivated area, weather condition and variety. The standard of the optimum date of picking for Starking Delicious in the northern part of Tohoku district is around 155 days after bloom when considered to be intermediate between climacteric minimum and climacteric maximum.

Compared with refrigeration, CA storage of apple has the following advantages: (1) less change in firmness and acidity, (2) storage time can be prolonged for additional 2 to 3 months, (3) shelf life after storage is longer and can be kept for one to two weeks at normal temperature, (4) and not much physiological disorders such as scald, internal breakdown and Jonathan spot occur.

Prolongation of storage life and retention of quality are effective especially for apples, for example, McIntosh which has low temperature injury.

"Kaki" (Japanese persimmon, var. "Fuyu")

Suitable storage temperature for "Kaki" is 0°C. Injury will occur when the temperature is below minus 1.5°C, and long-term storage will be difficult when it is over 3°C.

The proper humidity (R.H.) is 95 to 100 per cent, which will be more proper with the rise of humidity, and when the weight loss

during storage is increased to over 5 per cent, the quality will be damaged.

The atmosphere of 2 per cent O_2 and 8 per cent CO_2 will be suitable for "Kaki". There exists a relation of concentration balance between O_2 and CO_2, and the atmosphere of one per cent O_2 and 5 per cent CO_2 will be also appropriate for storage. It could be thought that there are several combinations for the O_2 and CO_2 atmosphere. Over 10 per cent of CO_2 will be dangerous.

"Kaki" will be one of the most suitable fruits for CA storage, since it is excellent in durability to the atmosphere containing a small quantity of O_2 and a large quantity of CO_2.

The approximate storage life is two months by refrigeration, while it is six months, three times of the former, by CA storage. Even after six months of storage, there are few changes in appearance and quality compared with those immediately after picking, and the shelf life after delivery is four days at 15°C.

As "Fuyu" is a non-astringent variety, the storage condition of astringent variety differs with the former. In the case of astringent variety, astringent cannot be removed during bad condition of storage. Consequently, the problem is whether it is stored as it is, or is stored after removal of astringent. Such condition as astringent is naturally removed during storage and is investigated. The results are shown in Table 2.

Japanese pear (Var. "Nijusseiki")

The storage temperature for Japanese pear should be 0°C to 1°C. Under 0°C, it will be dangerous.

The proper humidity (R.H.) is 88 to 92 per cent. In the case of Japanese pear, the texture will be damaged when the moisture is decreased and dried. On the other hand, when the moisture is increased, it will be tainted with microorganisms from the stem of the pear.

In order to prevent invasion of microorganisms from the stem and to maintain the green color, the stem is cut short at delivery without cutting before storage. Japanese pears are stored as they are covered with envelopes to protect them during cultivation or wrapped in papers after picking, since the peel is soft and is apt to be bruised. (Apple and "Kaki" are generally stored as they are.)

The atmosphere of 5 per cent O_2 and 4 per cent CO_2 is suitable for Japanese pear.

By refrigeration, 50 per cent of abnormal fruits are produced after six months of storage, while by CA storage, brown core occurs below 10 per cent even after nine months of storage. It is possible to store for one year yet the green of the peel is hardly damaged and the quality is extremely good.

Time of picking is important to store it for a long period. In Tottori Prefecture, pears are generally picked about 126 days after bloom when they are slightly immature. But it is desirable to store pears matured moderately in order to improve the quality and in this respect investigation is being conducted on storage condition.

There are many varieties of Japanese pear, and the storage condition differs with each

Table 1. Present status of CA storage of fruits in Japan

Fruit (Var.)	Storage temp. °C	Relative humidity %	Atmosphere O_2%	Atmosphere CO_2%	Approximate storage life months	Capacity stored in 1970 (thousands of *boxes
Apple	0	90 ~ 95	3	3	6 ~ 9	150 ~ 200
Kaki (Fuyu)	0	95 ~ 100	2	8	5 ~ 6	15
Japanese pear (Nijusseiki)	0	88 ~ 92	5	4	9 ~ 12	20

* One box contains 18 kg of apples, 15 kg of either kaki or Japanese pear

variety. The result so far is shown in Table 2 and studies on other fruits are pending.

Satsuma mandarin

The standard of storage temperature for Satsuma mandarin is 3°C. Low temperature injury such as pitting will occur when it is under 1°C.

Moisture is the most important factor to store Satsuma mandarin, and the proper humidity for it is 85 to 90 per cent. Some injury will occur and decay will increase when it is over 90 per cent.

Under storage at high humidity, the weight loss is small but the flesh withers and "Ukigawa" (rind puffing: it indicates the state which the peel separates and floats from the flesh) will occur, resulting in multiplication of mold and reduction of the quality.

Conversely at low humidity there is few breeding of mold, but it is dried and the appearance and the flavor, in extreme case, are spoiled.

As the most suitable humidity for Satsuma mandarin is lower than that of other fruits, the weight loss is naturally large, of which 2 to 3 per cent per month is considered to be reasonable.

The atmosphere of 10 per cent O_2 and 0~2 per cent CO_2 is suitable for Satsuma mandarin.

"Yoso" treatment (pretreatment) is applied to Satsuma mandarin before storage. (It is to leave it at a condition of 7 to 8°C temperature and 75 to 80 per cent humidity for about three weeks in order to dry the peel. It is assumed that the weight loss during pretreatment is 3 to 4 per cent.)

Making a pretreatment (Yoso) at such condition seems unreasonable because of much change in quality during treatment but it could be considered to be effective since in the case of Satsuma mandarin, there are some effects such as prevention of "Ukigawa", control of decay, and keeping quality of flesh.

Although CA storage of Satsuma mandarin has such effects that there is much residual acidity and that there are few cases of decay, the extent of effect is smaller than that of "Kaki" and Japanese pear. The maximum storage life is 6 months.

Satsuma mandarin is one of the popular fruits in production in Japan. In 1970, 2,500,000 tons of mandarin were produced. Output is expected to increase so the technique of long-term storage must be urgently established.

As the existence of effects by CA storage of citrus fruits has been questioned also in foreign countries, many problems still exist even in the case of Satsuma mandarin. The experiment for practical application of five tons of Satsuma mandarin has been barely made, but it depends much to further study of CA storage.

Table 2. Requirements for some fruits for experimental CA storage in Japan

Fruit (Var.)	Storage temp. °C	Relative humidity %	Atmosphere		Approximate storage life months
			O_2%	CO_2%	
Satsuma mandarin	3	85 ~ 90	10	0 ~ 2	6
Pear (Bartlett)	0	95	4 ~ 5	7 ~ 8	3
Japanese pear (Kikusui)	0 ~ 1	90	10	below 3	6
〃 (Shinko)	0 ~ 1	90	6 ~10	below 3	6
Grape (Kyoho)	0	90	3 ~ 5	3	3
〃 (Alexandria)	0	90 ~ 95	5	5	3
Peach (Okubo)	0 ~ 1	90 ~ 95	3	8	4 weeks
Japanese chestnut	−1 ~ 0	90 ~ 95	3 ~ 5	3 ~ 6	4 ~ 6
Kaki (astringent)	−1 ~ 0	90 ~ 95	5	5 ~ 7	3

Other fruits

As the studies on other fruits except those mentioned above are in the stage of investigation, there is no definite condition, as shown in Table 2, which is the result of study in the laboratories of this country.

Although the system of CA storage of pear has been adopted in Western countries, CA storage has not yet been put into practice in Japan. The main product is Bartlett, and the production is small. The storage condition in Japan slightly differs from that in foreign countries.

Japanese chestnut is one of the most promising fruits for CA storage because the quality after storage is excellent and it has the effect of disinfestation.

Studies are now being conducted on the optimum storage condition and physiological mechanism of many fruits and vegetables such as citrus fruits, cherries, plums, loquats, Japanese apricots, tomatoes and strawberries, as well as grapes and peaches.

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