Apple Preservation in Controlled Atmosphere (CA)

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The yearly consumption of fruits per capita in Japan is about 30 kilograms and this is considerably small in quantity compared with that of the United States (80 kg), according to the latest data on the supply and demand of food.

The annual yield of apples in Japan is about 1,200,000 tons though it varies every year.

This is a large yield next to that of mandarin oranges. But the production of apples in France is about 3,600,000 tons per year which is the largest yield of the world—three times as much as the output of Japan—and about two-thirds of this yield or 2,400,000 tons are consumed for cider (the varieties for the processing of apple wine are used and the other one-third is used without any processing, most of which are Golden Delicious and Starking Delicious.

The Japanese consumption of apples is quite different from that of France; that is, the amount of processing is less than one-tenth of the whole yield and about one million tons of apples are used in raw so it means that the yearly consumption per capita is about 10 kilograms.

Generally, the apple fully ripened on the tree gives the best relish but it is difficult to maintain it for a long time because respiration and metabolism of the fruit continue even after the harvest but any more nutrient comes up to fruit from outside. Consequently, the consumption of fruit ingredients and the aging of cells proceed progressively.

Therefore, the decline of ingredients and quality change of the fruit may be restricted if it is possible to control its respiration and metabolism.

Subsequently, the preservation method by low temperature of about 0°C is utilized for this purpose. But the low temperature preservation during more than several months also brings about quality decline depriving acidity and firmness from fruit.

So the atmosphere controlling method was developed. This is the method to change artificially the concentration of oxygen and carbon dioxide in the air of the refrigerated room. For instance, in the air containing oxygen and carbon dioxide at the concentration of three per cent respectively, fruit respiration was restricted to one-half of that kept in cold storage and high freshness was maintained with the fruit.

The controlled atmosphere storage (CA) restricts fruit metabolism more effectively with the cooperative effect of cold temperature and prevents fruit evaporation to keep freshness with high relative humidity (about (100 per cent).

About 20 per cent of raw apples have been preserved by this CA storage in the U.S., but in Japan, the percentage is less than one per cent so future expansion is desired.

Some of the experimental results of CA storage are described as follows:

Varieties

The present major varieties of apple in Japan are as follows; Ralls (Kokko), Jonathan (Kôgyoku), Starking Delicious, Golden Deli-

cious, McIntosh (Asahi) and American Summer Pearmain (Iwai). And the production of new excellent varieties—Mutsu, Fuji and Megumi—are also developing progressively.

Table 1 shows the results of small scale experiment on CA storage carried out in Aomori Prefecture. It indicates that the greater part of apples can be kept in good quality for a considerably long period provided that fruit is harvested at the adequate stage of ripening (a little before the complete ripening stage) and storage conditions (temperature and air composition) are well maintained.

CA storage is also effective for controlling physiological disorder in addition to maintening freshness and good quality of fruit. For example, internal breakdown which occasionally occurs in Jonathan apples can be prevented by CA storage. This disease usually appears on the over-ripened fruit harvested too late at the end of a long term storage. The flesh of the affected fruit begins to decay entirely turning brown. CA storage can protect Jonathan effectively from the attack of this disease compared with common storage under low temperature[1].

On the contrary, sometimes internal breakdown is apt to break out in Starking Delici-

Table 1. CA storage of apple fruit

Varieties	Ripeness	Harvest	Storage Period		Remarks
			Initial	Final	
American Summer Pearmain	ripe	1960. 8. 29	1960. 9. 10	1961. 3. 9	0°C, O_2 5~2%, CO_2 2~5%
Jonathan	ripe	1961. 10. 19	1961. 10. 25	1962. 9. 19	0°C, O_2 5~2%, CO_2 2~5%
Jonathan	unripe	1962. 10. 5	1962. 10. 10	1963. 6. 27	0°C, O_2 5~2%, CO_2 2~5%
	ripe	10. 15	10. 20	6. 27	
	overripe	10. 25	10. 30	6. 27	
Ralls	ripe	1960. 11. 14	1960. 11. 17	1961. 9. 27	0°C, O_2 5~2%, CO_2 2~5%
Starking Delicious	unripe	1963. 10. 1	1963. 10. 7	1964. 9. 7	0°C & 4°C, O_2 5~3%,
	ripe	10. 9	10. 15	9. 7	CO_2 2. 5~3%
	overripe	10. 17	10. 23	9. 7	
Golden Delicious	unripe	1962. 10. 13	1962. 10. 18	1963. 7. 30	0°C, O_2 5~2%, CO_2 2~5%
	ripe	10. 18	10. 23	7. 30	
	overripe	10. 27	11. 1	7. 30	
Mutsu	unripe	1962. 10. 11	1962. 10. 16	1963. 7. 30	0°C, O_2 5~2%, CO_2 2~5%
	ripe	10. 22	10. 27	7. 30	
	overripe	11. 7	11. 12	7. 30	
Megumi	unripe	1963. 10. 15	1963. 10. 21	1964. 9. 11	0°C, O_2 5~3%, CO_2 2. 5~3%
	ripe	10. 25	10. 31	9. 11	
	overripe	11. 5	11. 11	9. 11	
Fuji	unripe	1964. 10. 20	1964. 10. 22	1965. 9. 16	0°C, O_2 5~3%, CO_2 2. 5~3%
	ripe	10. 30	11. 4	9. 16	
	overripe	11. 9	11. 14	9. 16	
Indo	unripe	1964. 10. 30	1964. 11. 4	1965. 9. 16	0°C, O_2 5~3%, CO_2 2. 5~3%
	ripe	11. 9			
	overripe	11. 19			

ous apples which have been preserved by CA storage for a long time[2]. Therefore, it must be remembered that CA storage is not always suitable for every case. It is necessary to shift minutely the environmental conditions, temperature and air composition, according to each case.

Time of harvest

The quality of apples stored in controlled atmosphere depends much upon the time of harvest independently of varietal difference.

As for apple acidity, generally much acidity brings much freshness and green fruit has more acidity than a ripened one. Table 2 shows that the fruit preserved by CA storage has more acidity than that of by common storage so the former is superior to the latter with its freshness.

Therefore, it is better to harvest fruit a little before the ripening stage to keep preserved apples in fresh condition. After all, it is very important to determine the right time to harvest the fruit for CA storage.

The suitable harvest time has been determined by focusing attention to the change of size, hardness, color and soluble solid substances of fruit.

The climacteric change of fruit respiration during the growing stage on the trees is also reasonably available to determine harvesting time. In this case, it is better to use highly sensitive non-dispersive infra-red analyzer for carbon dioxide[3].

Preservation method

There are two ways to change the air composition for CA storage. One is to make air of suitable composition which was made by artificial combustion flow into the storeroom. This is the method currently used for only experiment in Japan.

The second method is to regulate the air composition to get suitable components (O_2–3%, CO_2–3%) by the respiration of fruit which was packed into the airtight storeroom. This is the method now used practically in Japan. In this case, it is very effective to use the dry scrubber method which is able to eliminate excessive carbon dioxide by using

Table 2. Acidity (% as malic acid)

Varieties	Storage	Ripeness	Harvest	Storage period					
				Initial**	1965				
					Feb.	April	June	Aug.	Sept.
Jonathan	CA	unripe	1964. 10. 7	0. 75	0. 62	0. 62	0. 55	0. 55	
		ripe	10. 16	0. 65	0. 63	0. 63	0. 53	0. 50	
		overripe	10. 27	0. 59	0. 55	0. 52	0. 38	0. 36	
	Common refrigerated	unripe	1964. 10. 7	0. 75	0. 61	0. 62	0. 43	0. 27	
		ripe	10. 16	0. 65	0. 60	0. 47	0. 29	0. 22	
		overripe	10. 27	0. 59	0. 59	0. 46	0. 25	0. 18	
Ralls	CA	unripe	1964. 10. 30	0. 54	0. 54	0. 47	0. 35	0. 29	0. 21
		ripe	11. 9	0. 53	0. 44	0. 44	0. 34	0. 23	0. 18
		overripe	11. 19	0. 54	0. 42	0. 39	0. 23	0. 14	0. 11
	Common refrigerated	unripe	1964. 10. 30	0. 54	0. 45	0. 37	0. 28	0. 18	0. 16
		ripe	11. 9	0. 53	0. 45	0. 38	0. 23	0. 13	0. 11
		overripe	11. 19	0. 54	0. 44	0. 36	0. 23	0. 11	0. 06

* 0°C

** immediately after harvest

slaked lime.

In the second method, it is necessary to keep the storeroom almost airtight and galvanized iron, plywood and bubbled polyurethane are used for this purpose.

Change of fruit ingredients

Chemical ingredients are closely related to the qualitative change of fruit and the related ingredients are as follows; water[4], pectic substances[5], L-malic acid[6),7] and sugar (especially sugar phosphate)[8),9].

Thus, the apples preserved by CA storage according to the proper storing program can maintain high freshness with good quality for a long time provided there is no mistake on the performance of the following matters; selection of varieties, determination of harvest and storing time, maintenance of adequate temperature, relative humidity and air composition.

Moreover, on the storage of tropical fruits such as mango and pineapple, the author recommend reading Hulme's writings[10].

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