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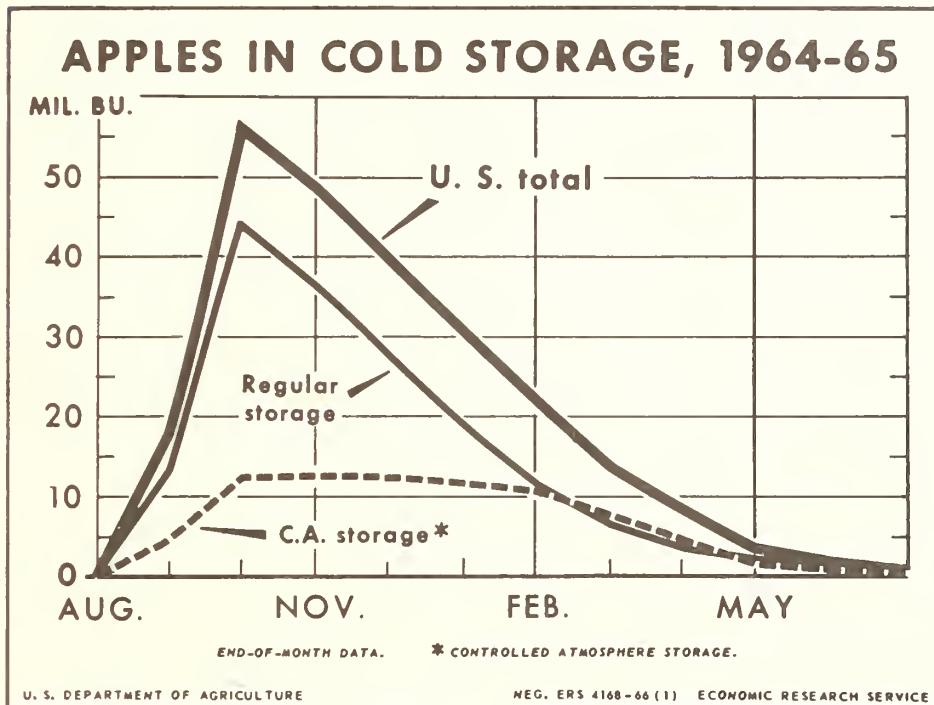
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CONTROLLED ATMOSPHERE STORAGE OF APPLES

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More than a fifth of the apples in cold storage on October 31, in both 1964 and 1965, were in controlled atmosphere(CA)storage. Over the next 4 months of 1964-65, the volume sealed in CA storage changed little while the volume

in regular cold storage declined with shipments therefrom. Thereafter, stocks in and shipments from both types of storage followed similar courses. The storage pattern for 1965-66 appears to be close to that for 1964-65.

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Nature of Controlled Atmosphere Storage

Modification and control of the atmosphere in fruit storage plants is a method used increasingly in recent years to hold the condition and extend the storage life of fruit, especially apples. This is in addition to the maintenance of artificially cooled temperatures and high relative humidity, basis requirements for regular cold storage.

All fresh fruits continue to respire after harvest--that is, they take in oxygen and give off carbon dioxide. Many fruits, including apples, ripen after harvest. This ripening process may be greatly retarded by the usual cold storage methods, which reduce fruit metabolism including the rate of respiration. Under controlled atmosphere (CA) methods, respiration and ripening may be reduced further by lowering the oxygen content of the air, which normally consists of 21 percent oxygen, 78 percent nitrogen, and 1 percent other elements.

Two principal techniques are employed to reduce the percentage of oxygen in the apple storage rooms. The first involves the use of oxygen, and its displacement by carbon dioxide, in natural respiration of the fruit. In this process, however, provision must be made to prevent excess accumulation of carbon dioxide, which could be harmful. The second method involves the circulation of atmosphere of the desired composition (produced by commercial generators) through the storage rooms to replace normal air. By this method the oxygen content may be lowered sufficiently in a matter of hours, or at most a few days, much faster than by the first method.

Many fruits have been tested in CA storage to determine the most suitable atmospheric conditions and temperatures for prolonging their life. They include apples, pears, peaches, grapes, strawberries, bananas, and oranges. Results have been most successful with apples. For apples in CA storage, levels of 2 to 3 percent oxygen and 1 to 7 percent carbon dioxide together with the appropriate minimum temperature, usually 30 to 38 degrees (depending on the variety), and 95 percent relative humidity, are the most satisfactory for minimizing respiration and the ripening process. Each apple variety differs slightly in requirements for oxygen and carbon dioxide, temperature, and relative humidity for optimum results.

CA storage has been unusually successful with McIntosh apples, allowing storage for 7 to 8 months at 38 degrees F. When held under 38 degrees in regular storage, McIntosh are susceptible to internal breakdown, particularly "brown core". But at 38 degrees in CA storage, internal breakdown is avoided and storage life is prolonged. Other varieties in regular storage

can be safely held at temperatures of 30 to 32 degrees. Even for these apples, CA storage has been reported as beneficial in prolonging storage life when held in such storage beyond a 60- to 90-day period.

Essentials for CA storages include practically air-tight rooms and special equipment to achieve and maintain satisfactorily the desired atmospheric conditions. This is in addition to the requirements for adequate refrigeration and air circulation for regular cold storage. Accordingly, construction and operating costs are somewhat higher for CA storage than for regular cold storage. Over time, the additional costs should be recovered through increased revenues resulting from superior quality fruit.

To maximize results from CA storage, several precautions should be observed. The apples to be stored should be picked at the proper stage of maturity consistent with the desired color. CA storage cannot correct over-maturity; it can only aid in holding the firmness or condition of the fruit as it is at the time of storage. Once picked, the apples should be quickly placed in the CA rooms, the oxygen content lowered within the required 20 to 30 days, and then the apples kept under optimum atmospheric control until the rooms are opened for movement of the fruit. For these apples to be in the best possible condition when they reach consumers, the fruit should be kept under refrigeration, insofar as practicable, during transportation, handling, and display by retailers.

Extent of CA Apple Storage

The commercial application of controlled atmosphere in the storage of apples in the United States began over a quarter century ago. Growth of this kind of apple storage has been rapid over the past 5 to 10 years, and further gains are in prospect. The location and capacity of such storage was surveyed for the first time by the U. S. Department of Agriculture in 1963, covering data for October 1, 1963. A like survey on CA storages for October 1, 1965, was started last fall and is still underway. Monthly data on apples in CA storage were collected initially for the volume so stored at the end of January 1963. Since then, similar data have been collected monthly and published in the Department's Cold Storage Report.

The 1963 survey disclosed that 265 storage plants had CA rooms on October 1, 1963, with a capacity of more than 11 million bushels of apples. This was 12 percent of the total usable space of the 1,612 apple houses in the United States. Although substantial increases in CA storage capacity have been made since October 1, 1963, capacity data from the 1965 survey are not yet available to show the gains. However, over 12 million bushels of apples were reported in CA storage on November 30, 1965. Furthermore, not all available CA space was filled. It is estimated that present capacity slightly exceeds 13 million bushels.

Of the 265 plants having controlled atmosphere storage rooms on October 1, 1963, 159 plants (60 percent) were in the Eastern States. The other 106 plants were nearly equally divided between the Central and Western States. The total

capacity of all plants (11,125,000 bushels) was divided among these 3 regions as follows: Eastern, 48 percent; Western 34 percent; and Central, 18 percent. Capacity per plant in the Western States (77,612 bushels) was more than twice that in each of the other 2 regions. Among States, New York, Washington, and Michigan (in that order) led in capacity (table 2).

The quantities of apples in storage--CA, regular, and total--by months, 1963-65, are shown in table 3. Total U. S. stocks build up rapidly during late summer and early fall when harvesting is most active, reach a peak usually by the end of October, then decline over the rest of the marketing season ending the following midyear.

Total apples handled by apple houses in a season is greater than the top volume reported at the end of October. During harvest, apples move out of, as well as into, apple houses. This applies particularly to regular cold storage operations, because apples sealed in CA rooms usually are held a minimum of 90 days to qualify for CA sales. This time period accounts mainly for the small increase in CA stocks at the end of November and the slight change over the next few months. Meanwhile, apples from regular storage account for most of the sales. Stocks of apples in the 2 types of storage at the end of each month of the 1964-65 season are shown in the cover chart.

Of total stocks of apples in cold storage at the end of October 1964, apples in CA rooms comprised about 21 percent and those in regular storage the other 79 percent. By the end of March, when CA rooms were opened in increasing numbers, CA apples constituted about half of total stocks, because of the large reductions in regular storage over the preceding months. Movement and stocks of both types of apples followed similar pathways over the next few months.

Total cold storage stocks of apples on October 31, 1965, were approximately 56 million bushels, about 1 percent larger than a year earlier. CA stocks again comprised about 21 percent of the total. For the entire 1965-66 season, the pattern of stocks probably will fairly closely match that of 1964-65.

State Regulation of CA Apple Storage

State storage regulations for CA apples are in force in at least 12 States: Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Virginia, Michigan, Washington, Idaho, and California. For CA-stored apples to be certified for marketing as "CA apples", all 12 States except Michigan require that the oxygen in the storage rooms be reduced to a maximum of 5 percent within 20 days after the rooms are sealed. In Michigan, the period is 30 days. Moreover, all 12 States require that most varieties of apples be kept a minimum of 90 days with the oxygen level no higher than 5 percent. Michigan, New Jersey, and Virginia allow a minimum of 60 days for Jonathans.

All 12 States require that daily records be kept of temperature and of oxygen and carbon dioxide percentages. They also require annual registration or licensing of storage facilities, and registration or license number stamped

Table 2.--Controlled atmosphere storage: Number and capacity of plants with controlled atmosphere storage rooms, United States, October 1, 1963

Region	Plants		Capacity		Capacity per plant
	Quantity	Percentage	Volume	Percentage	
	Number	Percent	Bushels	Percent	Bushels
Eastern States	159	60.0	5,376	48.3	33,811
Central States	57	21.5	1,946	17.5	34,140
Western States	49	18.5	3,803	34.2	77,612
United States	265	100.0	11,125	100.0	41,981

Data derived from "Capacity of Refrigerated Warehouses in the United States, October 1, 1963". SRS, USDA, August 1964.

on all CA apple containers. In addition, some States specify inspection to assure that U. S. condition standards and other requirements are met.

Economic Importance of CA Apple Storage

Apples properly stored in CA rooms hold their condition well from fall until the following summer. This allows growers and others engaged in storing and selling the apples an extended period for marketing their fruit. Moreover, it permits more orderly marketing, especially at harvest time. Flexibility in choice of time to market is perhaps the greatest after January 1. During late winter and spring, when stocks of both types of apples are about equal, both types are highly competitive for the buyers' dollar. In the past, CA apples, especially the McIntosh, have usually brought premium prices. The CA method of storing permits increased opportunities for apple marketers to maximize their returns from the fruit.

Consumers also benefit from CA apple storage. It provides them with increased quantities of firm, crisp, juicy apples late in the season. They have shown their preference for such apples by paying top or premium prices.

Selected References on Controlled Atmosphere Storage

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2. Olsen, Kenneth L., and Schomer, Harold A. 1964. Oxygen and Carbon Dioxide Levels for Controlled Atmosphere Storage of Starking and Golden Delicious Apples. Mktg. Res. Rpt. No. 653. U. S. Dept. of Agr., Washington, D. C.
3. Agricultural Research Service. 1965. A Review of Literature on Harvesting, Handling, Storage, and Transportation of Apples. ARS 51-4. U. S. Dept. of Agr., Washington, D. C.

Table 3. --Apples: Cold storage stocks, by type of storage,
end of month, 1963, 1964, and 1965, U. S.

Month	1963			1964			1965		
	Controlled: atmosphere:	Regular: bu.	Total: bu.	Controlled: atmosphere:	Regular: bu.	Total: bu.	Controlled: atmosphere:	Regular: bu.	Total: bu.
January	8,303	17,208	25,511	9,353	20,604	29,957	11,618	18,901	30,519
February	7,413	10,612	18,025	8,409	11,966	20,375	10,265	11,833	22,098
March	5,413	5,698	11,111	6,269	6,247	12,516	7,255	6,744	13,999
April	3,170	2,742	5,912	3,284	2,868	6,152	4,323	3,835	8,158
May	914	1,129	2,043	1,000	1,387	2,387	1,584	1,961	3,545
June	269	424	693	280	455	735	540	976	1,516
July	85	150	235	133	213	346	207	522	729
August	45	151	196	30	297	327	71	300	371
September	3,182	11,615	14,797	4,082	13,011	17,093	6,375	16,188	22,563
October	9,708	49,418	59,126	11,977	43,924	55,901	12,026	44,343	56,369
November	9,734	39,441	49,175	12,331	36,407	48,738	12,323	37,953	50,276
December	9,702	30,514	40,216	12,226	27,256	39,482	12,312	26,549	38,861

Table 4.--Apples, commercial crop: Production, average 1959-63, annual 1964 and indicated 1965 1/

State and area	Average	Indicated	State and area	Average	1964	Indicated	
	1959-63	1964		1959-63	1964	1965	
	1,000	1,000		1,000	1,000	1,000	
	bu.	bu.		bu.	bu.	bu.	
Maine	1,818	1,950	2,200	Minnesota	332	430	290
New Hampshire	1,380	1,180	1,370	Iowa	274	300	370
Vermont	1,036	920	900	Missouri	1,248	1,600	1,600
Massachusetts	2,820	2,800	3,150	Kansas	206	290	280
Rhode Island	172	180	200				
Connecticut	1,312	1,280	1,370	N. Central	23,988	29,770	27,790
New York	20,860	21,500	23,500				
New Jersey	2,760	2,800	2,600	Kentucky	336	500	450
Pennsylvania	8,940	11,500	11,000	Tennessee	316	400	320
				Arkansas	215	205	210
N. Atlantic	41,098	44,110	46,290	S. Central	867	1,105	980
Delaware	296	240	280				
Maryland	1,422	1,560	1,450	Total Central	24,882	30,875	28,770
Virginia	10,090	9,800	10,500				
West Virginia	5,260	5,700	5,100	Montana	33	30	20
North Carolina	2,360	2,400	4,200	Idaho	1,090	1,450	1,350
				Colorado	1,130	1,600	1,600
S. Atlantic	19,428	19,700	21,530	New Mexico	481	1,200	650
				Utah	348	430	310
Total Eastern	60,526	63,810	67,820	Washington	22,280	25,500	24,000
				Oregon	2,086	1,920	2,200
Ohio	3,260	4,200	3,600	California	9,786	12,400	9,000
Indiana	1,726	2,300	1,850				
Illinois	2,240	2,500	2,500	Western	37,234	44,530	39,130
Michigan	13,160	16,500	16,000				
Wisconsin	1,542	1,650	1,300	United States	2/122,641	139,215	135,720

1/ Estimates of the commercial crop refer to the total production of apples in the commercial apple areas of each State. For some States in certain years, production includes some quantities unharvested on account of economic conditions.

2/ Average includes States for which estimates have been discontinued.

Table 5.--Apples, commercial crops 1/: Production by varieties, United States, average 1959-63, annual 1964-65

Variety	Average	1964	1965	Variety	Average	1964	1965
	1959-63				1959-63		
	1,000	1,000	1,000		1,000	1,000	1,000
	bu.	bu.	bu.		bu.	bu.	bu.
Summer:				Winter, cont'd:			
Gravenstein	2,419	3,334	1,110	Cortland	3,608	3,622	4,194
Other summer	2,444	2,820	2,382	Delicious	27,451	33,938	33,332
Total	4,863	6,154	3,492	Golden delicious	2/8,252	11,222	12,142
				McIntosh	17,102	17,479	18,335
Fall:				Northern Spy	2,912	3,436	3,510
Grimes Golden	1,160	1,156	1,059	R.I. Greening	2,877	3,591	3,424
Jonathan	8,292	9,768	10,078	Rome Beauty	8,781	11,061	10,762
Wealthy	1,376	1,248	1,217	Stayman	6,604	7,121	7,832
Other fall	1,755	1,686	1,939	Winesap	8,187	7,539	5,712
Total	12,583	13,858	14,293	Yellow Newtown 3/	4,054	4,046	4,114
				York Imperial	6,483	7,487	6,522
Winter:				Other winter	4,793	5,535	5,105
Baldwin	2,655	2,084	2,033	Total	105,196	119,203	117,935
Ben Davis and Gano	1,158	862	765				
Black Twig (Paragon)	279	180	153	Total all varieties	122,641	139,215	135,720

1/ Estimates of commercial crop refer to the total production of apples in the commercial areas of each State. 2/ Golden Delicious included with "other winter varieties" prior to 1960 in Colorado.

3/ Albemarle Pippin.

