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Davis

Factors Influencing the Keeping Qualities of
Apples in Cold Storage

FACTORS INFLUENCING THE KEEPING QUALITIES OF
APPLES IN COLD STORAGE

BY

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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE
DEGREE OF Bachelor of Science in Horticulture

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Factors Influencing the Keeping Qualities of
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FACTORS INFLUENCING THE KEEPING QUALITIES OF APPLES IN COLD STORAGE.

One of the most important factors in the rapid rise of American fruit growing has been the application of the principles of refrigeration to warehouses. One of the chief problems which makes apple growing a doubtful occupation is the instability of the market. Often, when a good crop is secured throughout the country, or even when there is a good crop in only one section with fair yields in the others, the apples in the sections of heavy yield are hardly worth harvesting.

Mr. Roy D. Antony (20,a)* of New York (Geneva) Experiment Station gives the cost of producing a barrel of apples as \$1.48. He states that where better management is used, this can be reduced to \$1.21. Allowing \$0.50 per barrel for freight and commission charges (which is low, as Wilkinson (20,a) allows \$0.22 per bushel for this when New York growers place their fruit on the New York market), the cost of putting a barrel of apples onto the market would range from \$1.71 to \$1.98. Table I (after Wilkinson) gives the yearly average price per barrel received for apples on the New York market, the table covering a period of twenty years.

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* (20,a) refers to a corresponding number in the bibliography.

Table I.

Average Price of Apples in New York for Twenty Years.

Year	Total receipts (barrels)	Average Price per barrel
1893-1894	234,863	\$3.43
1894-1895	526,338	2.60
1895-1896	736,487	2.21
1896-1897	1,426,546	1.41
1897-1898	877,077	2.66
1898-1899	650,686	3.25
1899-1900	921,648	2.33
1900-1901	895,967	2.50
1901-1902	593,816	2.72
1902-1903	1,540,005	2.08
1903-1904	2,043,606	2.39
1904-1905	1,865,459	2.09
1905-1906	1,566,855	3.30
1906-1907	2,227,577	2.64
1907-1908	1,687,719	3.05
1908-1909	1,858,267	3.22
1909-1910	1,898,268	3.18
1910-1911	1,932,327	3.57
1911-1912	1,875,168	2.68

Subtracting the cost as given above, from the New York average prices for the last ten years given in this table, shows a profit of from \$0.89 to \$1.16 per barrel.

Let us turn to Table II taken from the 1915 Yearbook of the Department of Agriculture (21). These figures are estimates by the Bureau of Crop Estimates.

Table II

Production and Farm Price per Bushel for Apples, 1910-1915.

Year		1910	1911	1912	1913	1914	1915
U.S.	*	47213000	71340000	78407000	48470000	84400000	76670000
"	o	\$0.95	\$0.80	\$0.68	\$0.99	\$0.62	\$0.74
N. Y.	*	5666000	13000000	14667000	6500000	16533000	8528000
"	o	\$1.10	\$0.59	\$0.50	\$0.95	\$0.45	\$0.77
Pa.	*	3867000	6833000	4233000	3400000	7700000	5085000
"	o	\$0.75	\$0.54	\$0.70	\$0.89	\$0.50	\$0.67
Ill.	*	267000	3533000	1933000	2733000	1233000	4716000
"	o	\$1.15	\$0.68	\$0.79	\$0.94	\$0.84	\$0.55
Mich.	*	1400000	4100000	5733000	2967000	5733000	3150000
"	o	\$1.02	\$0.70	\$0.50	\$0.82	\$0.49	\$0.72

* Production in barrels of three bushels each.

o Farm price per bushel.

According to this table the yearly average prices for apples at the orchard, throughout New York state, during the years from 1910 to 1915 inclusive, have ranged from \$0.45 per bushel in 1914 to \$1.10 per bushel in 1910, which equals \$1.35 to \$3.30 per barrel. The averages for apples at the orchard, throughout the United States, during this period, ranged from \$0.62 per bushel in 1914 to \$0.99 per bushel in 1913; this equaling \$1.86 to \$2.95 per barrel. Subtracting the costs of production as given by R. D. Antony, shows results ranging from a loss of \$0.13 to a gain of \$1.82 per barrel during this period in New York. Subtracting these costs from the average orchard prices throughout the country, shows a gain varying from \$0.38 to \$1.76 per barrel.

These figures look very favorable to the grower. However, not all of the crop is fit for barrel stock and it costs nearly as much to raise the poor fruit as it does the good. Estimates of commercial apple crops are given by Mr. E. J. Glasson (8,a) (8,b) in the American Year Book. His figures for commercial crops are: 31,000,000 barrels in 1913; 50,000,000 barrels in 1914; and 40,000,000 barrels in 1915. Comparing these figures of production with the ones given above from the United States Department of Agriculture Year-book for 1915, for the same years, we find that the commercial crop was in 1913 only 64 per cent of the total crop, in 1914 only 59 per cent, and in 1915 only 52 per cent. Part of the remainder of the fruit can of course be sold for something as evaporator and cider stock where plants for the use of such fruit are available, but much of it goes to waste. An article on apple by-products by H. C. Gore (9) in the 1914 Yearbook states that twenty-five per cent of the apples grown in America never figure in the food supply of the nation. It goes on to say, "These waste apples are either good fruit for which the farmer can find no profitable market and therefore allows them to rot under the tree, or are surplus culls left after demands for vinegar and cider have been met." Even the fruit which is sold for these by-products brings a price much below the cost of its production.

The reason why such a large part of the crop is not worth marketing is because so much of the fruit is thrown onto the market just following harvest instead of being distributed more evenly throughout the year. Table III (after H. B. Knapp) (20,b) shows the distribution throughout the year, of apple shipments to New York, and covers a period of twenty years.

Table III.

Monthly and Yearly Receipts of Apples in New York City

(In Barrels)

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1893-1894	4,632	20,461	57,068	66,160	25,678	18,692	15,462
1894-1895	17,046	33,800	125,000	159,527	58,419	33,032	27,942
1895-1896	33,510	75,394	152,419	164,463	110,638	50,327	58,782
1896-1897	51,947	188,135	263,491	273,052	165,494	115,096	134,113
1897-1898	38,713	71,433	203,538	196,477	81,695	70,649	62,560
1898-1899	30,428	76,807	161,876	117,608	89,251	49,578	37,323
1899-1900	47,918	102,955	206,216	185,785	113,277	75,164	72,156
1900-1901	23,116	82,426	176,411	189,521	101,193	99,087	69,548
1901-1902	18,379	53,611	127,191	106,371	57,021	51,597	36,013
1902-1903	68,007	154,475	287,936	255,942	166,971	130,626	122,687
Yearly average for 10 yrs.	33,370	85,950	176,115	171,491	96,964	69,385	63,659
1903-1904	95,142	246,684	435,950	399,130	193,206	144,919	165,102
1904-1905	85,332	284,112	309,135	337,336	168,721	143,071	122,565
1905-1906	143,052	252,056	367,638	281,482	152,945	119,309	82,084
1906-1907	174,637	255,600	478,323	413,566	223,554	223,469	145,847
1907-1908	60,488	137,729	350,529	364,490	171,099	168,649	117,938
1908-1909	121,641	310,289	447,895	337,580	217,601	137,683	92,688
1909-1910	64,305	183,892	393,288	406,772	248,797	131,709	138,119
1910-1911	78,678	196,597	538,630	416,374	208,490	127,015	115,654
1911-1912	75,922	199,039	320,569	314,330	301,257	176,639	171,219
1912-1913	41,335	171,788	636,626	464,450	223,096	201,154	193,846
Yearly average for 10 yrs.	94,053	223,780	427,858	373,551	210,877	157,362	134,506

Table III (Cont'd).

Monthly and Yearly Receipts of Apples in New York City.

(In Barrels)

Year	March	April	May	June	July	Total
1893-1894	12,451	8,845	5,414	971	1,430	237,264
1894-1895	36,522	24,608	10,442	2,193	20,177	548,708
1895-1896	45,293	30,209	13,955	1,497	12,017	748,504
1896-1897	125,945	74,936	24,654	9,683	19,813	1,446,359
1897-1898	71,913	47,521	25,532	7,046	5,396	882,473
1898-1899	36,752	33,148	16,368	1,547	11,276	661,962
1899-1900	60,291	38,498	16,528	2,860	3,517	925,165
1900-1901	69,917	55,282	25,959	3,507	5,443	901,410
1901-1902	36,671	43,463	18,328	5,171	10,576	564,392
1902-1903	160,567	96,626	62,503	33,665	23,721	1,563,726
Yearly average for 10 yrs.	65,632	45,314	21,968	6,814	11,337	847,996
1903-1904	166,698	108,761	56,203	31,811	8,016	2,051,662
1904-1905	193,460	130,367	70,923	20,437	22,236	1,787,695
1905-1906	80,466	49,034	27,802	10,987	7,688	1,574,543
1906-1907	173,133	87,412	39,442	12,594	1,917	2,229,494
1907-1908	160,210	108,194	75,719	33,162	13,839	1,762,046
1908-1909	87,198	61,486	32,369	11,837	5,470	1,863,737
1909-1910	162,011	98,764	51,063	19,548	6,403	1,904,671
1910-1911	105,385	47,361	48,107	23,036	5,556	1,937,883
1911-1912	138,045	102,727	52,757	22,664	5,335	1,880,503
1912-1913	217,240	191,250	93,969	45,177	16,706	2,496,647
Yearly average for 10 yrs.	148,385	101,236	54,835	23,125	9,317	1,958,884

Using the average for the ten years from 1893 to 1903, we find an average shipment for the three months of September, October, and November of 433,556 barrels, which leaves only 414,440 barrels to be shipped during the remaining nine months of the year. Using the average from 1903 to 1913, we find the average shipment for these three months to be 1,025,189 barrels, leaving only 933,686 barrels distributed over the remaining nine months.

These figures for the New York market are the only ones obtainable, but it would be rather phenomenal if the habits of New York growers in regard to disposing of their fruit at harvest time were materially different from the habits of apple growers in other sections of the country. In fact (though no exact data have been obtained on this point) it is the general opinion that growers throughout the country dispose of most of their fruit at harvest time, as they have no place to hold it. Therefore, it seems permissible to use these New York figures as representing general marketing conditions throughout the country.

This habit of the growers of throwing the greater part of their crop onto the market during the late fall causes difficulties to arise. There is a period of over supply followed by more or less of a shortage of apples during the remainder of the year. This unevenness in distribution throughout the year causes relatively low prices to prevail at the time when the growers are disposing of the greater part of their crops. These low prices are a direct result of the temporary oversupply on the market, and they put the growers at a disadvantage; especially those growers who have no suitable place to store and hold their fruit. With

over half of the apples disposed of in three months, the prices can not, of course, be satisfactory. The unevenness of distribution also decreases consumption. One might think that if the prices received were as a whole lowered, the consumption would be increased. However, for the greatest use of any article, an even supply over long periods is required rather than a fluctuating supply.

Another difficulty which rises from the marketing of so much fruit in so short a time is the inability of the distributive machinery of the country to handle it efficiently. This results in considerable deterioration and loss. All through the marketing process delays occur. Trouble is experienced in securing cars, and even when they are promised, they may not arrive as expected. In such a case, the fruit waits in the heat (if the weather is at all warm) at the station or at the packing shed, for it would hardly pay to store it when the cars are expected at any time. Usually there is no fit place to store it anyway. Even after the fruit is started rolling the delays are not over. In the confusion of the harvest season it may lie on a side track for several days, waiting to be shifted from one railroad line to another; or the consignee may be so rushed that the fruit will have to lie on the tracks for a day or two even after it has reached its destination. The conditions surrounding the fruit during this time, if the weather is warm, are ideal for rapid ripening and deterioration. Waiting in the heat for the cars causes the life history of the fruit to advance rapidly, but much worse conditions are found in the cars. The hot, close, moist air in addition to ripening the fruit rapidly, is very favorable to the spread of disease. As a result much of the fruit when

it reaches the market is in poorer condition than what was left on the ground in the orchard. The poor quality of this fruit on the market makes it act as a drag, decreasing the consumption of apples and cutting down the prices received for them.

The difficulties mentioned above would be largely overcome by the cold storage of considerable quantities of apples by the growers. Shipments would then be more evenly distributed throughout the year, and the railroads and commission men would be better able to handle them. The fruit being less delayed in transit would arrive on the market in better condition, even when it was shipped during the warmer months; while that which was held in cold storage during the warm season and shipped during cold weather would be much superior to that which at present is taken out of common storage for winter sale, or to that which is held in the store rooms of brokers after a railroad shipment in warm weather. This added quality, together with the more even supply on the market, would lead to an increased consumption, and would make the apple better able to compete with such long season, tropical fruits as the banana and orange.

By holding fruit in cold storage better prices may be secured. Table IV (after H. B. Knapp) (20,b) gives the average prices per barrel by months, for apples in New York; the table covering a period of twenty years.

Table IV

Average Prices per Barrel of Apples in New York
by Months for Twenty Years.

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1893-1894	\$2.18	\$2.45	\$2.65	\$3.10	\$3.88	\$4.65	\$5.10	\$4.37	\$5.00	\$4.98	
1894-1895	1.83	1.95	2.17	2.34	2.58	3.00	3.84	3.69	4.00	3.52	
1895-1896	1.56	1.59	1.99	2.13	2.28	2.30	2.64	2.95	3.19	3.16	\$3.25
1896-1897	1.49	1.32	1.31	1.20	1.20	1.40	1.53	1.56	2.22	2.60	2.89
1897-1898	1.98	2.11	2.22	2.54	2.99	3.27	3.23	3.16	3.08	3.26	3.47
1898-1899	2.13	2.43	2.27	3.48	3.93	4.12	4.00	4.61	4.33	3.92	4.14
1899-1900	1.69	1.81	1.78	2.05	2.51	2.61	2.91	3.38	4.19	4.07	3.37
1900-1901	1.63	1.84	1.87	2.32	2.70	2.74	3.11	3.23	3.36	3.52	4.31
1901-1902	3.08	3.23	3.80	4.45	4.10	2.59	3.21	3.68	3.87	3.69	3.37
1902-1903	2.00	1.72	1.99	1.77	1.76	2.56	2.35	2.37	2.37	2.50	2.56
1903-1904	2.38	2.02	2.18	2.42	2.36	2.40	2.85	2.67	2.66	2.66	2.55
1904-1905	2.15	1.85	1.75	1.95	2.19	2.22	2.34	2.41	2.20	3.72	3.31
1905-1906	2.54	2.56	2.90	3.32	3.53	3.50	4.51	4.77	5.10	5.24	5.48
1906-1907	2.67	2.48	2.34	2.38	2.18	2.26	2.80	3.82	3.94	5.23	5.64
1907-1908		2.91	2.94	3.06	2.95	3.08	3.71	3.04	3.33	3.05	1.93
1908-1909	2.93	2.59	2.75	3.00	3.58	4.11	4.33	4.25	4.29	4.60	4.93
1909-1910	3.15	3.31	3.04	3.27	3.20	3.00	3.23	3.10	3.14	3.58	3.88
1910-1911	3.17	3.27	3.28	3.40	3.37	3.77	4.19	4.48	4.85	4.81	4.33
1911-1912	2.34	2.22	2.51	2.63	2.59	2.87	2.66	3.03	3.44	3.16	3.11
1912-1913		2.66	2.48	2.40	2.38	2.53	2.69	2.44	2.69	4.04	4.09
Averages for period											
1893 to 1903	1.96	2.05	2.20	2.54	2.79	2.91	3.19	3.30	3.56	3.52	3.42
	2.67	2.59	2.62	2.78	2.83	2.97	3.33	3.40	3.56	3.96	3.92

During the last ten years shown in this table, the average price for the three months of greatest shipment (September, October, and November) ranges from \$2.59 per barrel in September to \$2.78 per barrel in November. By the end of the commercial storage season (the last of March or the first of April) the average price has risen to \$3.40 or \$3.56. At a cost of \$0.50 per barrel for storage, it would have been a paying practice, during this ten year period, to store for sale in February, March, or April. Storage would not only have paid the storer, but would have helped the grower who

did not store by keeping the market steadier. The greatest direct benefits to the apple producer probably come through the prompt withdrawal from market at harvest time of a large part of the best fruit. In this way prices of good fruit are less likely to be depressed, and the average price of good apples is undoubtedly higher than would have been possible without refrigeration. However, the consumer gets fruit which is in so much more perfect condition that he is more than satisfied to pay the slightly higher price, and there is so much less waste that he gets more for his money.

Food conservationists are inclined to attribute the loss of much good fruit to defects in existing marketing systems and to the failure of orchardists to avail themselves fully of cold storage as a means of keeping fruit to the season of scarcity and high prices.

Cold storage does not, as so many believe, injure the quality of apples or other fruits, nor does it reduce their value for food. The apple is a living, breathing organism. In its respiration it takes in oxygen and gives off carbon dioxide and water. At the same time there are changes and losses in the constituents of the fruit; chemical actions take place which are entirely independent of disease and decay. These changes have been shown to be mainly a transformation of starch into cane sugar in the first stage after picking; next, a changing of this sugar into invert sugar; and finally, a slow decrease in the total quantity of sugars. At the same time, there is from the first a slow decrease in the amount of acid, there being most acid in the unripe fruit (14,a). If apples are held until these changes are complete, the result is a fruit of poor quality, dry, mealy, tasteless, and perhaps withered.

Fruits such as winter apples and pears are not in a fit condition for consumption when picked and stored. They must pass through some of the ripening processes outlined above to develop proper maturity. In cold storage they pass through just the same stages in ripening and deterioration as they would in cellar storage, but the stages pass more slowly. By proper handling of apples in cold storage, so as to control this ripening process, the highest quality may be developed.

Cold storage preserves fruit by slowing down its life processes. Low temperatures hinder the changes outlined above, while higher temperatures hasten them. Taking the amount of carbon dioxide given off as a measure of the speed of the reaction, it has been found that changes of composition take place from four to six times as fast at summer temperatures and from two to three times as fast at cellar temperatures as at cold storage temperatures. However, the life processes can not be stopped entirely even at the lowest temperature at which it is safe to store fruit. Apples can not be kept indefinitely but keep about twice as long in cold storage as in cellar storage.

Another important way in which cold preserves fruit is by slowing down the life processes of fungi which attack it. The three fungi causing most of the apple rots are *Sphaeropsis malorum* (black rot), *Glomerella rufomaculans* (bitter rot), and *Penicillium glaucum* (soft rot) (13,b). The development and spread of these fungi is favored by heat and moisture. Cold storage temperatures retard their development but can not stop it entirely.

In an experiment by the New Hampshire Station (13,b), apples were stored both at the station and at a commercial cold storage plant in Boston. During the first year, the temperature in the station storage room stood at 40 degrees Fahrenheit through most of the winter but rose to 50 degrees in April. At the Boston storage plant, a temperature of 34 degrees was maintained throughout the year. The experiment showed considerably less decay in the lot of fruit held in cold storage. By June 1, only 5 per cent of the apples held at the station were free from decay while more than 50 per cent of those held at Boston were sound.

During the second year the temperature in the station storage room ranged as follows: from the beginning of November to the middle of December, 45 degrees Fahrenheit; from the middle of December to the middle of March, 40 degrees; from the middle of March to the Middle of April, 45 degrees; from the middle of April to the middle of May, 45 to 50 degrees; and from the middle of May to the first of July, 50 to 65 degrees. The Boston storage held the temperature of the previous season, 35 degrees. At intervals through the season, boxes were removed from storage and examined. By January there was a slight difference in the way that the two lots of fruit had kept, this difference being in favor of cold storage. By March 15 this difference amounted to 35 per cent and by June to 69 per cent. "In general it may be said that cold storage is the most practical method of controlling the rots which we at present have" (13,b).

Cold storage rooms in different experiments have been

maintained at temperatures from 42 to 32 degrees Fahrenheit. The results in all cases have been in favor of the lower temperature. Lower temperatures not only keep the fruit longer by slowing down to a greater extent the ripening process and the spread of fungus diseases, but also allow the development of the highest quality, aroma, and flavor.

In an experiment at the Michigan Agricultural College (4,b), Baldwin apples were held at 35 and at 42 degrees Fahrenheit. By May 22 those stored at the higher temperature were worthless, while only 2 per cent of those held at 35 degrees had spoiled. An experiment by the United States Department of Agriculture (1b,a) showed very similar results. Fruit held at temperatures of 36 and 40 degrees ripened and deteriorated more rapidly, both in storage and after removal from storage, than did that held at 32 degrees. Because fruit which is held at 31 or 32 degrees keeps longer than that held at 35 or 36 degrees, Cooper (4,b) recommends that fruit which is to remain in storage for only a short time and which should ripen somewhat before being removed, be held at the higher temperature.

A temperature of 31 degrees should be considered critical. Below this it is unsafe to store apples. Apples are sometimes frozen in cold storage, but this does not necessarily injure them. In freezing, the water in the cells is withdrawn and frozen in the intercellular spaces. If the fruit is thawed slowly and the freezing has not been too severe, the cells may regain the water without injury and resume their living functions. If freezing is too severe, however, the tissues are forced apart by the formation

of ice in the intercellular spaces and the fruit breaks down quickly.

Absolute cleanliness is necessary in a storage. No matter can be allowed to accumulate which gives off offensive odors. Moreover, a room should be used for the storage of only one kind of product. For example, apples should not be stored in the same room with cabbage or cheese for the fruit would absorb the odors of these products. To keep the air of a storage house clean and sweet, there must be ventilation. In a storage which is cooled by circulating air much of the odor may be removed by freezing out the moisture from the air. From time to time, however, fresh air must be introduced. This is usually done whenever the temperature out of doors drops to about the same point that is maintained in the storage. Odors are absorbed rapidly by warm fruit just after it enters the storage. As the fruit cools and its respiration becomes slower, it absorbs them less rapidly. For this reason, rapid cooling of fruit after it enters storage tends to develop its highest quality.

The keeping quality of apples varies greatly with different varieties. The chemical changes in summer and early winter varieties take place more rapidly than in late winter kinds. They, therefore, ripen and deteriorate more quickly, and as a rule, are not so valuable in cold storage. As a rule, courser, drier sorts such as the Ben Davis keep better than finer grained and better quality fruit such as the Jonathan.

The keeping quality of apples also varies with the cultural, soil, and climatic conditions under which they are grown. Anything which keeps the tree in vigorous growth and which keeps it growing late in the fall, develops large apples which are late

in maturing but which ripen and deteriorate very quickly in storage. Large apples from rapidly growing, young trees are less valuable for storage than medium sized, mature, bright colored, but firm fruit from older, more slowly growing trees. Apples from older trees grown on rich, heavy soil where frequent cultivation is given, where nitrogenous cover crops have been turned under year after year, and where there is plenty of rain, behave much the same as those from young trees. Lack of pruning, by cutting out sunlight, may keep the fruit too green for the best results. These difficulties, where they exist, may be overcome by severe pruning and by seeding down the orchard for a time. When only medium sized bright colored fruit is selected for storage, there is little difference between apples grown in cultivated and in sod orchards. Not only do overgrown, immature apples keep poorly, but apples which are grown in rather dry, sandy orchards where the apples mature relatively early, have only a short storage season.

The proper maturity of fruit at the time of picking and storing is very important. In recent years there has been a tendency to pick apples earlier than formerly. This has been done partly to avoid the congestion and car shortage of harvest time, and partly because of a belief that highly colored, mature apples are less able to stand the abuses of picking, packing, and shipping than are hard, green ones. It is not usually the case, however, that the immature apples keep better. The speed of ripening varies with the degree of maturity of the fruit when picked, and the less mature apple reaches the end of its life as quickly as, or even sooner than, the more mature fruit. Cooper (4,b) reports an

experiment in which overgrown Tompkins King and Sutton apples from young trees kept better when only one half or two thirds colored than when highly colored. However, apples from older trees have in all cases shown better keeping quality when fully grown and highly colored, but still firm, than when undercolored. In an Iowa experiment (1,a) hard, firm, well colored Northwestern Greenings remained in prime condition for a month longer than those poorly colored and prematurely picked.

On the other hand, if apples are not picked until over-ripe, they are already near the end of their life and will deteriorate quickly if not stored immediately in a low temperature. In an experiment with Spies at the Michigan Agricultural College (4,b), the first lot was picked and stored when fully matured and well colored, but perfectly firm. The second lot was taken from the same trees two weeks later. By May 22 only 18 per cent of the first lot were decayed as contrasted with 62 per cent of the second. A number of the late varieties of apples may be picked when they are beginning to mellow and will keep in prime condition for months if they are handled carefully and stored immediately at a temperature of 31 or 32 degrees. Mature fruit not only keeps longer in storage, but is also superior in flavor and texture, retains its plumpness better, and is more attractive to the purchaser.

Apples for storage must be carefully handled during the operations of picking, grading, and packing to prevent bruising or breaking the skin of the fruit. They must also be carefully graded so as to select only sound, mature, medium sized, firm fruit. It pays to store only perfect apples. The contents of a

package may be injured by the spread of a fungus disease from only one or two imperfect apples. Rots gain entrance to the fruit easily around worm holes, through scab spots, or wherever the skin is bruised or broken by rough handling or by nails protruding through the container. It is therefore essential that such injuries to fruits be reduced to a minimum by care in growing, grading, and packing the crop. All of the investigations of the Department of Agriculture emphasize the fundamental importance of well grown, carefully handled fruit for successful storage operations.

The style and size of the package and the method of packing have considerable influence upon the keeping quality of apples. A small package is especially useful when storing early, quickly maturing varieties, and is most important in the hottest weather. With a barrel the fruit does not cool down uniformly, and the apples near the center of it may continue to ripen rapidly for some time. With a small container such as the bushel box, the fruit cools down more quickly and the ripening continues more evenly throughout the package. The Iowa Experiment Station carried on an experiment (1,a) to determine what influence the kind of package and the wrapping of fruit has upon the speed with which the fruit at the center of the package cools down. The data in Table V show the results obtained.

Table V.

Effect of Wrapping and of Type of Package Upon
the Speed of Cooling of Apples.

Package	How Packed	Drop in Temperature of Air at Center of Pack- age.		Drop in Temperature of Fruit at Center of Package.	
		Temperature Drop	Time in Storage	Temperature Drop	Time in Storage
Slat Crate	Unwrapped	41°F	1 day, 14 hr.	43.5° F	1 day, 10 hr.
Bushel Box	" "	43	2 " 18 "	42.5	2 " 10 "
Barrel	" "	41.5	3 " 2 "	39	3 " 2 "
Slat Crate	Wrapped	43.5	2 " 18 "	44	2 " 18 "
Bushel Box	"	43.5	2 " 22 "	43	2 " 22 "
Barrel	"	37	3 " 2 "	37	3 " 2 "

Though fruit in a slat crate cools down most quickly, this type of package is suitable only in cases of short storage. Fruit in a crate shrivels and loses its attractiveness much more quickly than in a closed package. There is also more danger of bruising the fruit against the edges of the slats. For these reasons ventilated containers should not be used where long storage is intended.

At present the bushel box seems to be the most satisfactory container. In it the fruit cools quickly and is protected from the excessive evaporation shown in ventilated crates. Moreover, fruit can be held in storage in the bushel box until riper than it could be held in a barrel. As soon as apples in barrels begin to mellow, they must be sold to prevent bruising by their own weight, but apples in boxes may sometimes be carried for several weeks longer.

Though wrappers as shown in the above table, delay slightly the cooling of fruit, they are more beneficial in other ways than they are harmful in this. They prevent much of the bruising of fruit due to improper packing, and they prevent its withering due to excessive transpiration. For these purposes a double wrapper has proven most efficient. A satisfactory combination consists of an absorbant, unprinted, newspaper next the fruit, with a more impervious paraffin wrapper outside. Wrapping also prevents the spread of decay through the package. Each apple is isolated from the others by wrappers, and in this way is protected from any fungus spores which may develop upon a chance diseased fruit. Wrapping retards somewhat the ripening of fruit; and this in conjunction with the decay prevention holds wrapped fruit in prime condition several weeks longer than unwrapped fruit can be held. In commercial practice the wrapping of hard, late varieties is of little importance, but wrapping has a distinct advantage in extending the life of tender varieties and in preserving their bright, attractive appearance and firmness.

Delay in the storage of apples after picking seriously injures their keeping qualities, especially if this delay comes during hot, moist weather. The delay is more serious with quickly maturing varieties than with hard, late, winter sorts. An apple, after its growth is stopped by picking, ripens more rapidly than when on the tree, growing and ripening at the same time. The speed of ripening also varies with the temperature, being from four to six times as fast at summer temperatures as at cold storage temperature. The ripening should be slowed down by storing as quickly as

possible, as ripening is at the expense of cell contents and brings the fruit nearer the end of its life. Heat and moisture also favor the rapid spread of fungus diseases through piles of picked fruit. These diseases develop rapidly and cause much damage to fruit which becomes heated after picking.

The importance of immediate storage in warm moist weather is shown by an experiment which was carried on in New York in 1902 (15,b). During the latter half of September the temperature in eastern New York averaged about 62 degrees Fahrenheit, while there was about 84 degrees of humidity. During the first half of October the average temperature fell to 53 degrees and the humidity to 80 degrees. Rhode Island Greening, Tompkins King, and Sutton apples picked September 15 and stored within three days were firm until the following March, but fruit from the same trees which was not stored until two weeks after picking was badly scalded or decayed by the first of January. The commercial value of these varieties was reduced from 40 to 70 per cent by this delay. Apples from the same trees picked October 5 were less injured by delay in storing.

A serious trouble in storage, with which the owner must reckon, is apple scald. This disease causes a browning of the skin which injures considerably the market value of the fruit. It does not, however, affect the flesh, except that the apple may break down more quickly than a perfect one. "The disease as at present understood is a physiological disturbance not in any way connected with the action of parasitic or saprophytic organisms such as molds or bacteria. Briefly, it is the mixing of the cell contents, or the premature death of the cells and their browning due to oxidation

through the influence of normal oxidizing ferments of the cells" (15,b). The disease is not contagious but seems to be closely connected with the ripening of the fruit after picking. It is most serious as the fruit approaches the end of its life.

Though scald is worse with packed fruit as it advances in ripeness, it is not prevented by picking immature fruit. The scald first appears on the green side of an apple and is worse on poorly colored lots. Highly colored, mature, but firm apples are least affected by the trouble. Table VI (after G. H. Powell) shows the influence of maturity upon scalding.

Table VI.

Per Cent of Scald Developing on Mature and Immature Apples.

Variety	Locality Where Grown	Mature, Well Colored Fruit	Immature, Part- ly Colored Fruit
Baldwin	New York	3.1	29.2
Ben Davis	Illinois	2.6	15.8
" "	Virginia	13.1	41.6
Rhode Island Greening	New York	25.4	43.4
Winesap	Illinois	0.2	31.8
Yellow Newton	Virginia	2.3	9.4
York Imperial	Virginia	<u>2.0</u>	<u>18.2</u>
Average		6.9	27.0

From these facts it may be seen that late picking, or the use of cultural methods which will insure early maturity and high color, will decrease scald. Cultural methods which have these effects are heavy pruning to let light into the tree, and the use of a cover crop to ripen off the tree early in the fall.

Ripening during any delay in storing increases the susceptibility of apples to scald. Scald often develops seriously when storage is delayed in hot weather. In New York in 1902 (4,b), Rhode Island Greenings which were picked September 15 and stored within three days kept firm and free from scald until the following March; while those whose storage was delayed two weeks at an average temperature of 62 degrees were one-third scalded by the first of February. Similar results were reported by S. A. Beach in Iowa Bulletin 108 (1,a).

Different varieties of apples vary greatly in their susceptibility to scald and in the time at which the trouble attacks them. Some storage men state that greenish or yellow varieties are affected worse than red ones. However, this idea is not borne out in data presented by G. H. Powell (15,b). Of the thirteen red varieties reported by him, five were affected seriously; four, often seriously; two, sometimes seriously; and two, but slightly. Of these varieties, one was affected in early winter; seven, in midwinter; one, after midwinter; and four, late in the season. Of the seven greenish or yellow varieties reported, four were seriously and three slightly affected; the trouble attacking one in early winter, three in midwinter, and three late in the season. Not

enough difference is shown between these two groupings for anyone to draw the conclusion that either color is more susceptible. The susceptibility of a variety to scald does not seem to depend upon its physical characteristics. Yellow Newton, a moderately fine grained, juicy, yellow variety, is but slightly affected late in the season; while Smith Cider, a moderately fine grained, juicy, red apple, is seriously attacked in early winter. Willow, a coarse, juicy, red apple, is affected but slightly, late in the season; while Grimes, a moderately coarse, moderately juicy, yellow variety, is attacked seriously in early winter.

The development of scald upon a lot of apples comes suddenly. Table VII (after Powell) (15,b), shows the time at which scald developed on Baldwins.

Table VII.

Time of Development of Scald on Baldwin Apples.

Dated Examined	Per Cent of Scald
Jan. 29, 1903	0
Feb. 21, 1903	0
Mar. 20, 1903	20
Apr. 21, 1903	23

This table shows clearly the abruptness with which scald attacks a lot of fruit. A variety should be removed from storage before the time that it normally begins to scald, and only those varieties which do not scald should be held until late in the season.

The wrapping of apples has sometimes been claimed to decrease scald. However, though wrapping sometimes retards the trouble slightly, scald is often as severe or more severe with wrapped than with unwrapped fruit. When an increase of scald occurs it is attributed to the collection inside of the wrapper of carbon dioxide given off by the fruit. Good ventilation in conjunction with refrigeration is essential for successful storage.

The temperature at which apples are stored influences considerably the development of scald. Lower temperatures retard ripening to a greater degree, and also retard most the appearance of scald. Scald after the removal of apples from storage is increased by higher outside temperatures and by greater ripeness of the fruit at the time of removal, but is decreased by a higher moisture content of the air. Table VIII (after G. H. Powell) (15,b) shows the effect of removing apples into different temperatures.

Table VIII

Scald Development upon Apples Removed into Different Temperatures

Variety	Date Removed from Storage	Date Inspected	Per Cent of Scald			
			44°F	48°F	61°F	67°F
Baldwin	Jan. 29, 1903	Jan. 29	0	0	0	0
		Feb. 3	0	6	21	22
		Feb. 4	4	11	21	37
		Feb. 6	4	25	40	63
		Feb. 7	4	25	41	63

There was no increase in the amount of scald after nine days.

The fruit storer should not only aim to remove the fruit before the normal season of scald, but also to hold the apples, after removal, in the lowest possible temperature.

Fruit which has been taken from cold storage is thought by many dealers to break down more quickly than cellar stored fruit. When this appears to be the case it is probable that the fruit was held in cold storage until overripe. When removed to a warm temperature it would then complete its deterioration rather quickly. It is not probable that cold storage apples break down any more quickly than other apples of the same degree of ripeness when held at the same outside temperature. The temperature into which the apples are taken is, of course, a very important factor in determining the speed of deterioration. Table IX (after G. H. Powell) (15,b) shows the effect of removing Baldwin apples into different temperatures.

Table IX.

Decay Development upon Apples Removed into Different Temperatures.

Variety	Date Removed from Storage	Date Inspected	Per Cent of Rot			
			44°F	48°F	61°F	67°F
Baldwin	Jan. 29, 1903	Jan. 29	0	0	0	0
		Feb. 10	0	0	3	10
		Feb. 13	0	0	12	14
		Feb. 16	0	0	21	24
		Feb. 20	0	4	23	28
		Mar. 3	5	10	--	--
		Mar. 7	5	15	--	--
		Mar. 24	20	--	--	--
		Apr. 6	36	--	--	--

The speed of breaking down will also vary considerably with different varieties. Many of the best cold storage varieties are too tender for common storage, and should not be used in comparison with other varieties from common storage to ascertain the relative effects of the two storage systems upon the keeping quality of fruits. Cold storage has done a great service in bringing tender varieties of high quality into commercial significance.

The cold storage business has become important in stabilizing the fruit industry. It stores up the temporary oversupply at harvest time and distributes the fruit at home and abroad as it is needed. Though apple producers have been slower than citrous and tropical fruit growers to avail themselves of the opportunities offered by this comparatively young industry, they are beginning to recognize the importance of cold storage in caring for their product. The amount of apples in storage on December 1 (22) has increased rapidly in the last fifteen years, rising from 1,226,900 barrels in 1900 to 5,332,157 barrels in 1915. This growth of storage has had an important influence on the development of markets both at home and abroad. From 1890 to 1900 the average export of apples amounted to 575,548 barrels (23); between 1900 and 1910 it rose to an average of 1,213,388 barrels; and between 1910 and 1915 the average export reached 1,837,138 barrels. As the cold storage of apples becomes more firmly established the grower will feel the benefit of steadier conditions in the apple trade and of more uniform prices. The consumer will also be benefited by being able to secure apples throughout the year at more uniform prices, and by getting better fruit than that which is held in common storage.

Cold storage is increasing the commercial value of many tender but otherwise desirable varieties of apples. Formerly such varieties had to be sold soon after picking to prevent loss from decay. Early winter varieties such as the Wealthy, Grimes Golden, Jonathan, and McIntosh, may now be stored until midwinter or even later, adding varieties of high quality to the list of apples obtainable during that period. In this way cold storage has increased the use of high grade varieties that formerly had to be planted in restricted quantities.

Only the best grown and best handled fruit is stored successfully. This has caused dealers, when purchasing for storage, to discriminate against those orchardists who are careless in orchard management and in grading and packing their fruit. This discrimination has led apple producers in general, to improve their methods and to turn out fruit of higher quality. This education of orchardists has been one of the most important results of the growing use of cold storage.

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