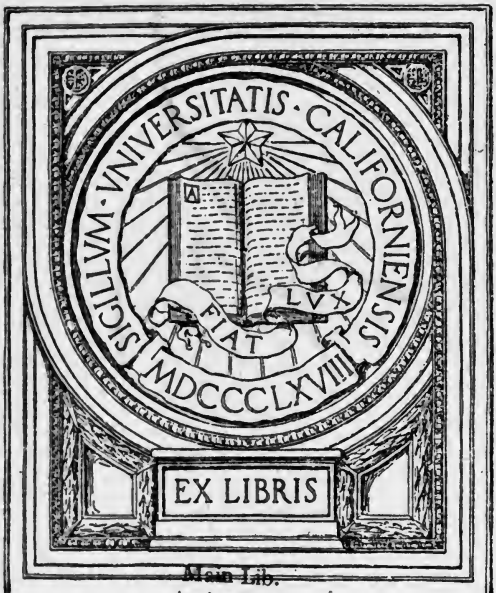

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H. W. WILEY, Chief of Bureau.

THE COLD STORAGE OF APPLE CIDER.

By H. C. Gore.

INTRODUCTION.

This report gives the results of the first season's work on the cold storage of apple cider. It is hoped that these investigations may later become the basis of definite recommendations for commercial practice. The plan of the work has been to prepare cider in the laboratory, cool quickly to 0° C. (32° F.), then store at 0° C., and examine from time to time during storage.

Mr. W. A. Taylor, pomologist in charge of field investigations, Bureau of Plant Industry, has cooperated in suggesting the varieties of apples used and in selecting the localities from which the fruit was obtained, with a view to giving the results a wide application. Mr. Taylor, Mr. George C. Husmann, and Mr. W. N. Irwin, of the Bureau of Plant Industry, have also furnished valuable organoleptic notes on the ciders at intervals during storage.

THE FRUIT USED FOR THE EXPERIMENT.

The fruit purchased was of the grade commercially known as "seconds." Upon delivery at Washington it was stored in a warehouse in a room kept at 32° F., as it was not practicable to begin the experiments when the apples were received. Considerable decay occurred during cold storage in the case of the first five varieties of apples mentioned in Table I. This was to be expected, because the apples were not of the first grade; but very little decay was found among the last four varieties mentioned.

The following facts should be noted in connection with the composition of the juices as given in the table. The content of sugars is probably higher than if the apples had been ground as soon as received. This is particularly true of the three late winter varieties, Baldwin, Golden Russet, and Roxbury Russet, on account of the well-known fact that most fall and winter apples contain starch at

picking time, which disappears rather rapidly in common storage, and slowly in cold storage. On the other hand, the acid content is probably much lower than if the apples had been ground at once, because acid is lost rapidly during cold storage. These facts have been repeatedly demonstrated.[a] The composition of the first six juices is fairly typical of average American varieties.[b] The last three juices were exceptional products and show what may be produced should the demand arise. They were very rich in sugars and in acid, and in every way were of very high quality. The high sucrose content of the Roxbury Russet is noteworthy.

TABLE I.—*Localities where the apples were grown and the intervals for which they were held in cold storage, together with analyses of the freshly prepared apple juices.*

Variety.	Where grown.	Interval in cold storage.	Corrected brix.	Analysis of fresh juice.			
				Acid as malic.	Reducing sugar as invert.	Total sugar as invert.	Sucrose.
		Days.	*Degrees.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Tolman	Carlton Station, N. Y.	47	14.86	0.12	9.98	13.11	2.97
Wilfesap	Waynesboro, Va.	84	11.56	.42	9.04	9.92	.84
Yellow Newtown	do	84	12.71	.47	7.82	10.67	2.71
Ralls (syn. *Rawles Janet*)	do	84	13.79	.37	9.88	11.85	1.87
Gilpin (syn. *Little Red Romanite*)	do	84	12.53	.28	9.34	10.93	1.51
Baldwin	Halls Corners, N. Y.	99	14.71	.48	8.19	12.51	4.10
Golden Russet	Carlton Station, N. Y.	71	18.23	.53	11.77	15.12	3.18
Roxbury Russet	do	71	18.80	.70	8.02	15.16	6.78
Kentucky Red	Mitchell, Ind.	108	18.02	.74	10.42	15.09	4.44
Average			15.02	.46	9.38	12.71	3.15
Average of first 6 varieties.			13.36	.35	9.04	11.50	2.50

PREPARATION OF THE CIDER.

The quantity of apples made into cider amounted to 2 barrels of each of seven varieties, to 6 barrels in the case of the Baldwin apples, and to 1 barrel of the Kentucky Red. All rot was removed from each lot of apples before grinding. The method of preparing the juice closely approximated standard commercial practice. The fruit was ground in a rotary apple grater of the type usually employed in grinding apples, and was pressed in a powerful hand power press. Racks and cloths were used, following in this respect the usual American method. The racks were 36 inches square, and each cheese was 32 inches square and about 3 inches thick. One cheese held the grated pulp from a barrel of apples. For the cold-storage experiments, 5-gallon kegs were used as containers for the juice from eight varieties, and a 50-gallon barrel was used for the Baldwin cider. These containers were well steamed, and rinsed with clear, cold water immediately before use.

[a] U. S. Dept. Agr., Bureau of Chemistry Bul. 94.

[b] See compilation of analyses by Van Slyke, N. Y. Agr. Exper. Sta. Bul. 258, p. 449.

After filling the kegs they were placed either out of doors or in a freezing room at the cold-storage warehouse, thus cooling the cider rapidly. The data in regard to the cooling are as follows:

Temperature changes of the ciders from the time of pressing until placed in storage at 32° F.

Tolman: Temperature when pressed, 15° C. Stored out doors over night; temperature then 3° C. Then sent to cold storage.

Winesap: Temperature when pressed, 15° C. Stored out doors over night; temperature then 12.5° C. Sent to freezing room, storage warehouse (temperature 11° F) for nineteen hours. The juice had cooled to —1.5° C with slight formation of ice; removed to storage at 0° C.

Yellow Newtown: Temperature when pressed, 14.5° C. Sent at once to freezing room. In nineteen hours had cooled to —1.5° C, with some formation of ice. Sent to storage at 0° C.

Ralls: Temperature when pressed, 16.5° C. Kept out doors over night; temperature 15.7° C. Then sent to freezing room; six hours later the juice was found to have cooled to 6.5° C. It was then removed to storage at 0° C.

Gilpin: Temperature when pressed, 18.5° C. Held out doors over night; temperature then 15.8° C. Sent to freezing room; six hours later juice had cooled to 6.5° C. Then removed to storage at 0° C.

Baldwin: Temperature when pressed, 13.5° C. Held out doors over night; in the morning, temperature was 12.5° C. Juice then sent to freezing room and left for three days. During this time the temperature of the juice fell to 2° C, and much ice formed in the barrel. Juice was now removed to storage at 0° C.

Golden Russet, Roxbury Russet, Kentucky Red: These three varieties were pressed on the same day. Temperature when pressed, 14.5°, 14.0° and 14.5° respectively. Sent to freezing room and removed after twenty-four hours. Temperature, —2° C. Some ice formation had occurred. The three lots of juices were sent to storage at 0° C.

After the casks had been placed in their final positions in the room at the warehouse, a $\frac{3}{8}$-inch hole was bored in the head of each, to serve as a vent in case of gas formation, and through which samples could be withdrawn. Except when samples were being taken the holes were kept plugged with cotton.

The ciders were sampled frequently during the first weeks of storage and somewhat less often thereafter. Organoleptic tests and chemical analyses were made of these samples.

ORGANOLEPTIC TESTS.

The following notes are compiled from the observations of W. A. Taylor, George C. Husmann, and W. N. Irwin:

Tolman: A very dark brown juice, flavor sweet and lacking in acid, and therefore rather too insipid for use as a beverage. There was no particular character to the juice. It was moderately clear. When fermented considerably it was still very insipid and unpalatable.

Winesap: Juice clear and thin; not up to the standard expected of the variety, lacking both sugar and acid. There was an off flavor, somewhat musty.

Yellow Newtown: A fairly clear, well balanced, palatable juice. Slightly off flavor, and it was doubtful whether the tests were fair to this variety.

Ralls: Juice beautifully clear, but not up to standard, lacking in acid and distinctive flavor.

Gilpin: Juice clear, but quite brown, standing next to Tolman in that particular. Heavy and sweet, but lacking in sprightliness and refreshing quality; had a good apple flavor and a fairly good aroma. It was improved by the slight fermentation noticeable after fifty days of storage.

Baldwin: Juice clear, slightly astringent, but palatable and refreshing. At the end of forty-eight days a very slight trace of fermentation was noticed. At a period of eighty-six days this variety approached its maximum in quality for consumption as a sweet, slightly fermented cider. It was better than any of the above juices.

Golden Russet: A beautifully clear, sweet, rich juice, possessing the cleanest and purest taste of any juice so far tried. After eighty-three days storage it was found to be very palatable, still rich and sweet and possessing enough "bite," due to the dissolved carbon dioxid gas, to be very palatable as a sweet cider.

Roxbury Russet: Much browner and less clear than Golden Russet, but with an excellent apple taste and aroma. A heavy, satisfying juice, with a slight earthy taste such as is frequently found in Roxbury fruit as it approaches full ripeness. On examination after a period of forty-three days the earthy flavor was found to have almost entirely disappeared. While at this time it did not appear to be as sweet and rich as Golden Russet, which was tried at the same date, it was still a very rich juice. At the eighty-three day period, the juice was found to be still sweet, but to need a little more fermentation in order that its palatability as sweet juice should be at its maximum.

Kentucky Red: Beautifully bright and clear, very light in color. Less heavy and rich than Roxbury and Golden Russet, but an exceedingly palatable juice. Less fruity in flavor than Roxbury Russet. A trace of fermentation was noted after eighty-three days, the juice being very palatable at that time.

CHEMICAL ANALYSES.

The chemical data secured are shown in Table II and are platted graphically in figures 1 to 9. Certain errors were introduced in collecting the data, due to varying conditions not at first noted, which can be avoided in future work, but no attempt has been made to correct the figures themselves, the data being published just as they were obtained. The formation of ice in the casks of cider which had been kept in the chill room led to the incorrect determination of the readings by the Brix spindle. This ice melted very slowly in the cider. As it loosened from the sides of the casks it rose to the surface, and the water formed from the ice also probably remained near the surface. Fortunately, these facts were apparent before the Brix readings of March 24 and the analyses of April 8 were made; and the contents of each cask was well mixed before taking the samples, except in the case of the 50-gallon barrel of Baldwin cider. This barrel was well shaken by rocking, but the contents were not sufficiently agitated, as the Brix reading and other determinations made on April 8 are too low, with the exception of the sucrose, which was too high, probably due to analytical error.

TABLE II.—*Changes in composition of ciders during storage at 0° C.*

Date. (1909.)	Interval.	Brix at 17.5° C.	Corresponding specific gravity.	Analysis of juice expressed as grams per 100 cc.					
				Total acid as malic.	Volatile acid as acetic.	Alcohol.	Reducing sugar.	Total sugar.	Sucrose.
	Days.	*Degrees.*							
TOLMAN.									
February 3	0	14.86	1.0607	0.13	.....	.....	10.59	13.91	3.15
February 25	22	14.95	1.0611	.....	.....	.....	.....	.....	.....
March 8	33	14.66	1.0598	.....	.....	.....	.....	.....	.....
March 24	49	14.30	1.0583	.....	.....	.....	.....	.....	.....
April 8	64	13.75	1.0559	.24	0.006	0.69	9.71	12.51	2.66
May 17	103	9.3	1.0372	.....	.....	.....	.....	.....	.....
June 28	145	4.8	1.0189	.33	.....	4.13	4.60	4.95	.33
August 26	204	2.6	1.0101	.29	.02	5.31	2.68	2.80	.11
WINESAP.									
February 10	0	11.56	1.0467	0.44	.....	.....	9.46	10.38	0.87
February 25	15	10.08	1.0404	.....	.....	.....	.....	.....	.....
March 8	26	10.3	1.0413	.....	.....	.....	.....	.....	.....
March 24	42	10.5	1.0422	.....	.....	.....	.....	.....	.....
April 8	57	10.7	1.0430	.46	0.006	0.40	8.39	9.20	.77
May 17	96	9.4	1.0376	.....	.....	.....	.....	.....	.....
June 28	138	8.1	1.0322	.54	.....	1.69	6.40	6.57	.16
August 26	197	5.8	1.0229	.50	.04	2.72	4.85	5.08	.12
YELLOW NEWTOWN.									
February 10	0	12.71	1.0514	0.49	.....	.....	8.22	11.22	2.85
February 25	15	10.91	1.0439	.....	.....	.....	.....	.....	.....
March 8	26	11.2	1.0451	.....	.....	.....	.....	.....	.....
March 24	42	12.2	1.0493	.....	.....	.....	.....	.....	.....
April 8	57	11.50	1.0464	.53	0.012	0.50	7.23	10.08	2.71
May 17	96	8.4	1.0335	.....	.....	.....	.....	.....	.....
June 28	138	4.5	1.0177	.54	.....	3.46	2.57	2.68	.10
August 26	197	.9	1.0034	.54	.03	4.74	1.23	1.33	.10
RALLS (SYN. RAWLES JANET).									
February 16	0	13.79	1.0561	0.39	.....	.....	10.43	12.52	1.99
February 26	10	13.91	1.0566	.....	.....	.....	.....	.....	.....
March 8	20	13.9	1.0566	.....	.....	.....	.....	.....	.....
March 24	36	13.7	1.0557	.....	.....	.....	.....	.....	.....
April 8	51	12.75	1.0516	.45	0.02	0.64	10.66	11.10	.42
May 17	90	8.5	1.0339	.....	.....	.....	.....	.....	.....
August 26	191	.9	1.0034	.47	.03	5.43	.97	1.04	.07
GILPIN (SYN. LITTLE RED ROMANITE).									
February 16	0	12.53	1.0507	0.29	.....	.....	9.81	11.48	1.59
February 26	10	11.95	1.0483	.....	.....	.....	.....	.....	.....
March 8	20	12.70	1.0514	.....	.....	.....	.....	.....	.....
March 24	36	12.60	1.0510	.....	.....	.....	.....	.....	.....
April 8	51	12.10	1.0489	.34	0.02	0.40	9.80	10.84	.99
May 17	90	9.9	1.0397	.....	.....	.....	.....	.....	.....
August 26	191	5.3	1.0209	.42	.02	3.34	4.47	4.50	.03
BALDWIN.									
February 19	0	14.71	1.0600	0.51	.....	.....	8.68	13.26	4.35
February 26	7	14.61	1.0596	.....	.....	.....	.....	.....	.....
March 8	17	14.40	1.0587	.....	.....	.....	.....	.....	.....
March 24	33	15.30	1.0626	.....	.....	.....	.....	.....	.....
April 8	48	10.50	1.0422	.40	0.012	0.52	6.10	9.55	3.28
May 17	87	13.50	1.0548	.....	.....	.....	.....	.....	.....
June 28	129	11.7	1.0472	.65	.....	1.90	8.37	10.32	1.85
August 26	188	7.7	1.0306	.59	.018	3.51	6.59	6.79	.19
GOLDEN RUSSET.									
February 23	0	18.23	1.0754	0.57	.....	.....	12.66	16.26	3.42
February 26	3	17.23	1.0710	.....	.....	.....	.....	.....	.....
March 8	13	15.86	1.0650	.....	.....	.....	.....	.....	.....
March 24	29	17.8	1.0735	.....	.....	.....	.....	.....	.....
April 8	44	17.0	1.0700	.59	0.006	0.20	12.04	15.24	3.04
May 17	83	14.8	1.0604	.....	.....	.....	.....	.....	.....
August 26	184	5.7	1.0225	.60	.02	5.58	4.47	4.66	.18

TABLE II.—*Changes in composition of ciders during storage at 0° C.*—Continued.

ROXBURY RUSSET.

Date. (1909.)	Interval.	Brix at 17.5° C.	Corresponding specific gravity.	Analysis of juice expressed as grams per 100 cc.					
				Total acid as malic.	Volatile acid as acetic.	Alcohol.	Reducing sugar.	Total sugar.	Sucrose.
	Days.	*Degrees.*							
February 23	0	18.80	1.0779	0.75	.....	.....	8.64	16.34	7.31
February 26	3	18.20	1.0753	.....	.....	.....	.....	.....	.....
March 8	13	16.91	1.0695	.....	.....	.....	.....	.....	.....
March 24	29	17.7	1.0730	.....	.....	.....	.....	.....	.....
April 8	44	17.7	1.0730	.74	0.006	0.08	8.29	15.79	7.13
May 17	83	16.5	1.0678	.....	.....	.....	.....	.....	.....
August 26	184	6.4	1.0253	.80	.02	5.50	4.55	4.74	.18

KENTUCKY RED.

February 23	0	18.02	1.0745	0.80	.....	.....	11.20	16.21	4.76
February 26	3	17.25	1.0711	.....	.....	.....	.....	.....	.....
March 8	13	14.92	1.0610	.....	.....	.....	.....	.....	.....
March 24	29	17.8	1.0735	.....	.....	.....	.....	.....	.....
April 8	44	17.0	1.0700	.74	0.006	0.35	10.69	15.25	4.33
May 17	83	16.3	1.0669	.....	.....	.....	.....	.....	.....
August 26	184	10.1	1.0405	.80	.02	3.66	8.66	8.65	.0

In addition the charts show when the ciders were fermenting perceptibly and when they had fermented too far to be considered sweet. The corresponding intervals, together with the alcohol content of the ciders, are given in Table III.

TABLE III.—*Alcoholic content of ciders before and after fermentation.*

Variety.	Interval before the cider began to ferment.		Interval before the cider fermented too much to be considered sweet.	
	Days.	Alcohol content.	Days.	Approximate alcohol content.
		Grams per 100 cc.		*Grams per 100 cc.*
Tolman	49	0.50	103	2.3
Winesap	57	.40	96	1.0
Yellow Newtown	57	.50	96	1.4
Ralls (syn. Rawles Janet)	36	.64	90	1.9
Gilpin (syn. Little Red Romanite)	51	.40	90	1.2
Baldwin	48	.52	119	1.8
Golden Russet	83	1.65	125	3.3
Roxbury Russet	83	1.50	125	3.2
Kentucky Red	83	1.20	125	2.3
Maximum	83	1.65	125	3.3
Minimum	36	.40	.....	1.0
Average	61	.8	107	2.0
Average of first six varieties	50	.5	99	1.6

At the time of preparing the ciders 5-gallon lots of each of the varieties, except Gilpin and Kentucky Red, were allowed to ferment spontaneously at laboratory temperatures in carboys previously well cleaned and kept stoppered during fermentation with clean cotton plugs. In all cases fermentation started promptly. The juices were practically completely fermented in from thirty-three to fifty-four days.

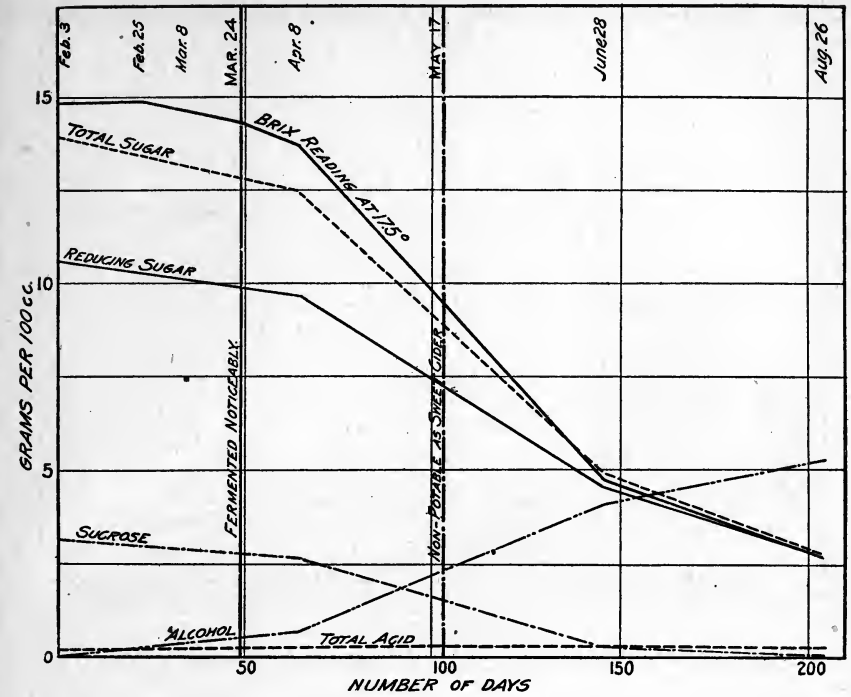

FIG. 1.—Changes in cider made from Tolman apples and stored at 0° C.

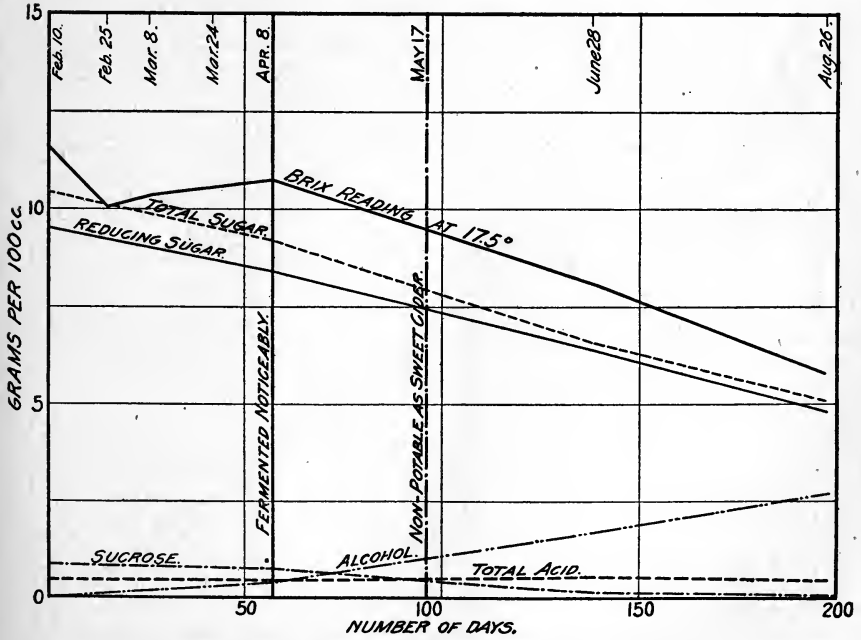

FIG. 2.—Changes in cider made from Winesap apples and stored at 0° C.

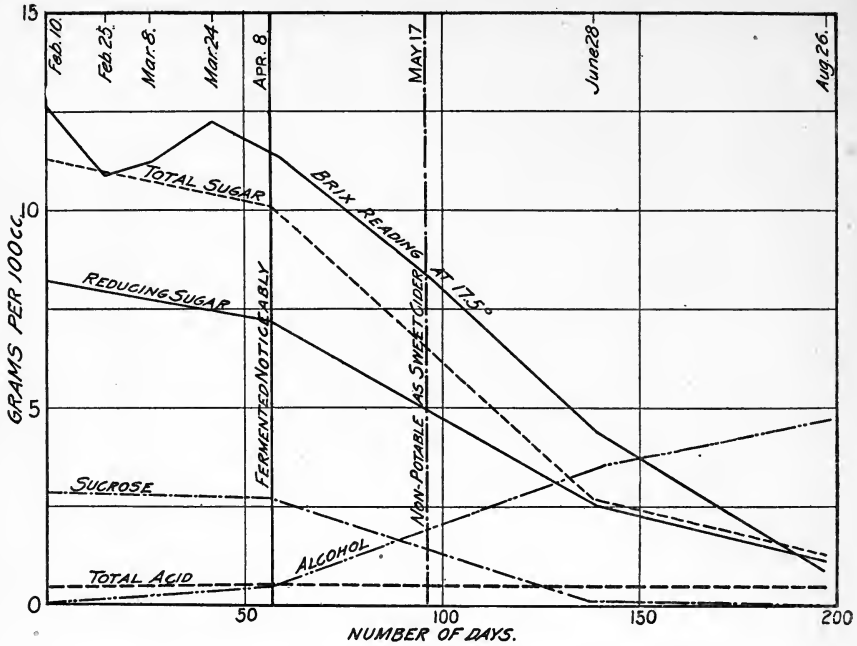

FIG. 3.—Changes in cider made from Yellow Newtown apples and stored at 0° C.

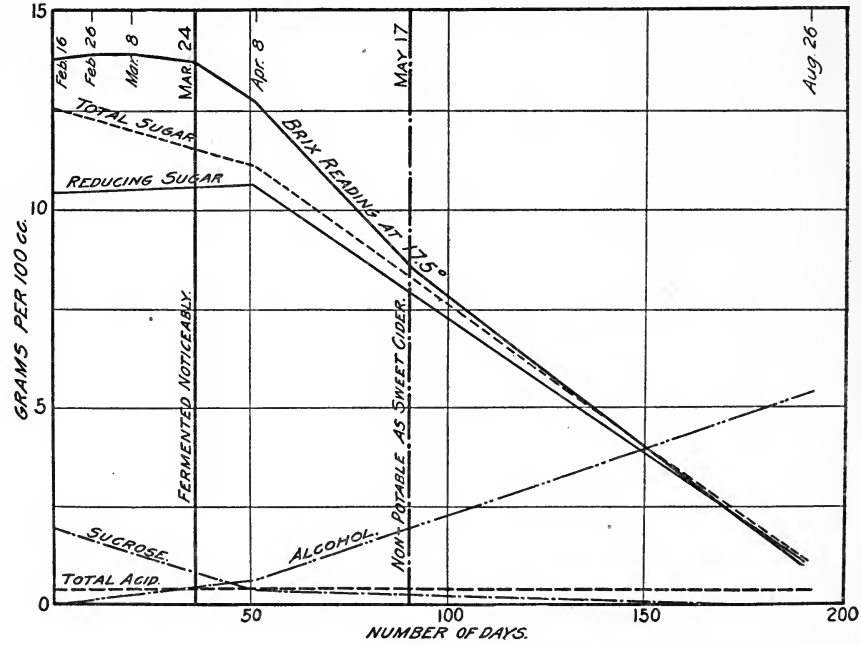

FIG. 4.—Changes in cider made from Ralls (syn. Rawles Janet) apples and stored at 0° C.

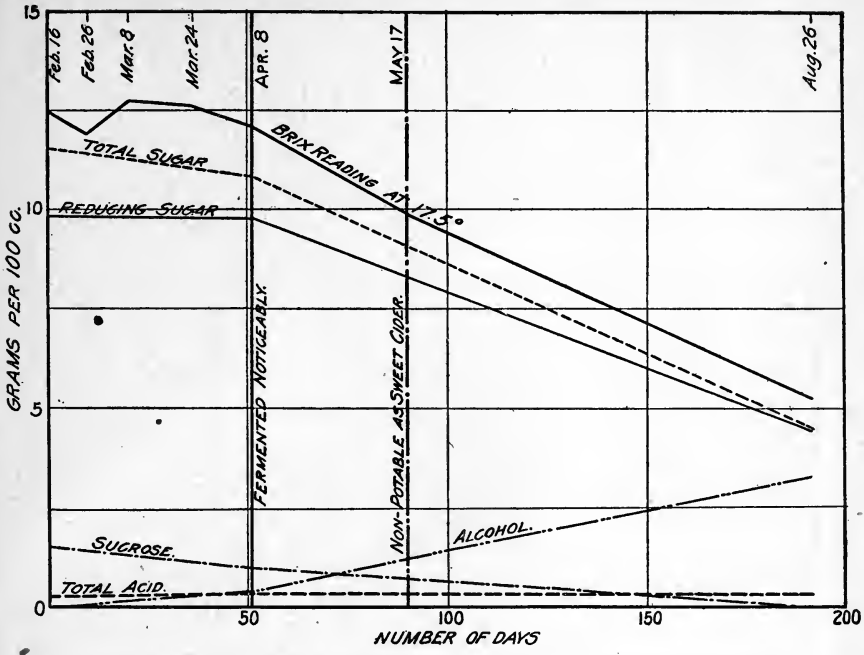

FIG. 5.—Changes in cider made from Gilpin (syn. Little Red Romanite) apples and stored at 0° C.

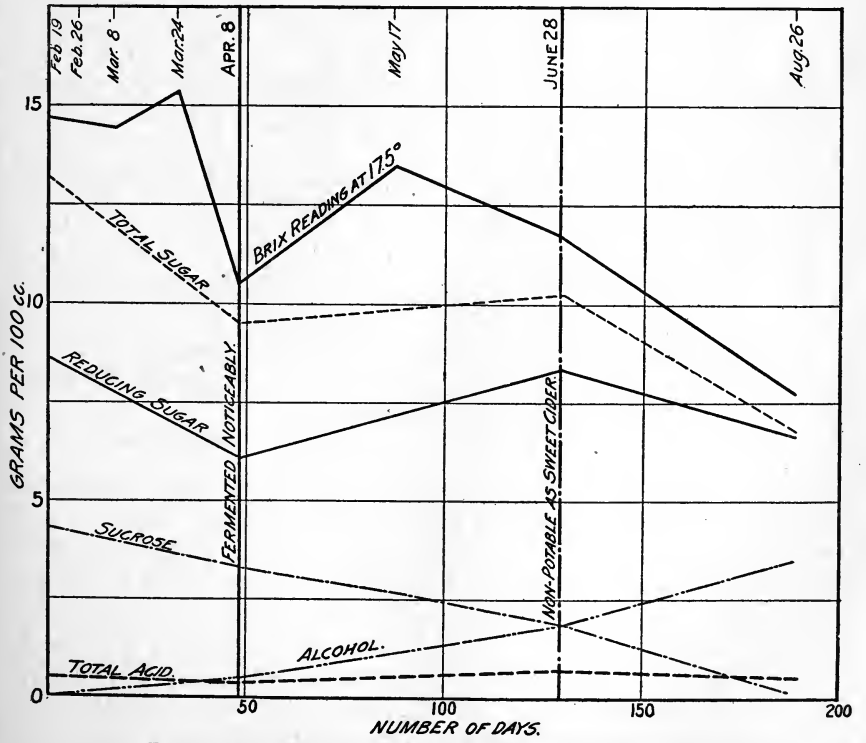

FIG. 6.—Changes in cider made from Baldwin apples and stored at 0° C.

DISCUSSION.

The striking fact brought out in this experiment is that the cider is kept in storage from thirty-six to eighty-three days, an average of sixty-one days, before beginning to ferment noticeably. The average in the case of the first six varieties was fifty days. These varieties are mentioned separately because they are more typical of the usual American cider apples than the last three. The amount of alcohol developed

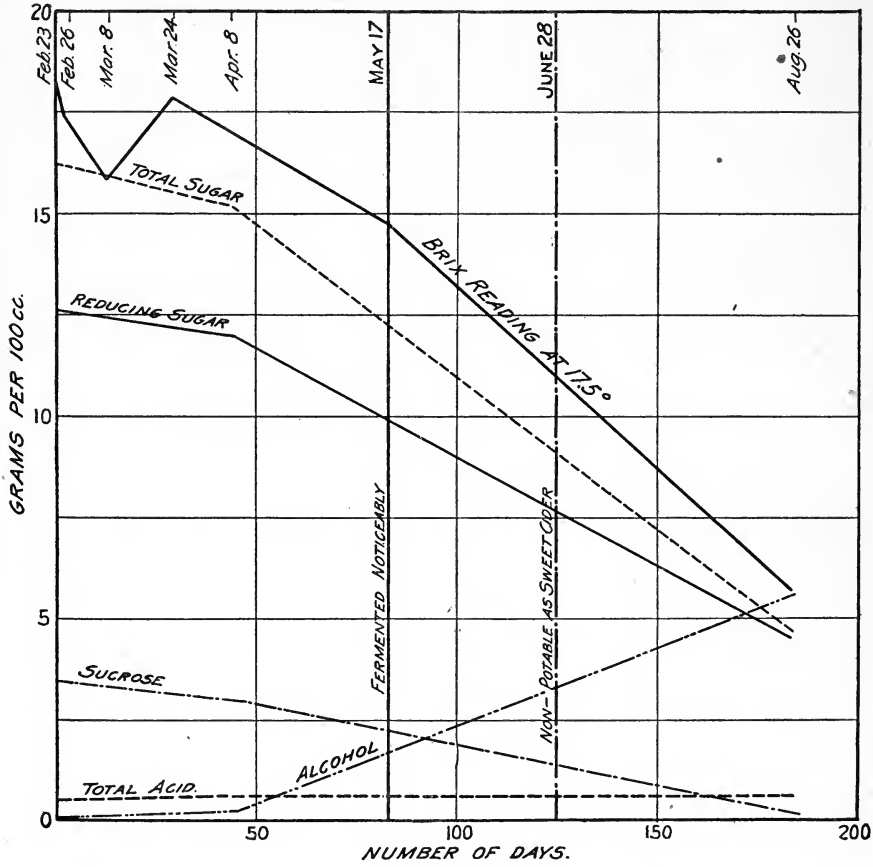

FIG. 7.—Changes in cider made from Golden Russet apples and stored at 0° C.

during this time varied from 0.40 to 1.65 grams per 100 cc, with an average of 0.8 gram. For the first six varieties the average was 0.5 gram. From ninety to one hundred and twenty-five days were required before the ciders had fermented too far to be called sweet, or an average of one hundred and seven days for all the varieties and of ninety-nine days for the first six. No deterioration in flavor during cold storage was noticed, except in the case of the Tolman variety, which is hardly a cider apple. No perceptible injury in flavor resulted from the slight freezing to which many of these ciders were

subjected before they were finally stored at 0° C. Not only were the characteristic flavors of the apples maintained, but an improvement was noted, due to the presence of carbon dioxid. The varieties giving the highest grade ciders were Baldwin, Golden Russet, Roxbury Russet, and Kentucky Red.

The charts show graphically the changes in the composition of the juices during cold storage. In each set of curves the upper line is the reading of the Brix spindle at a temperature of 17.5° C. While for

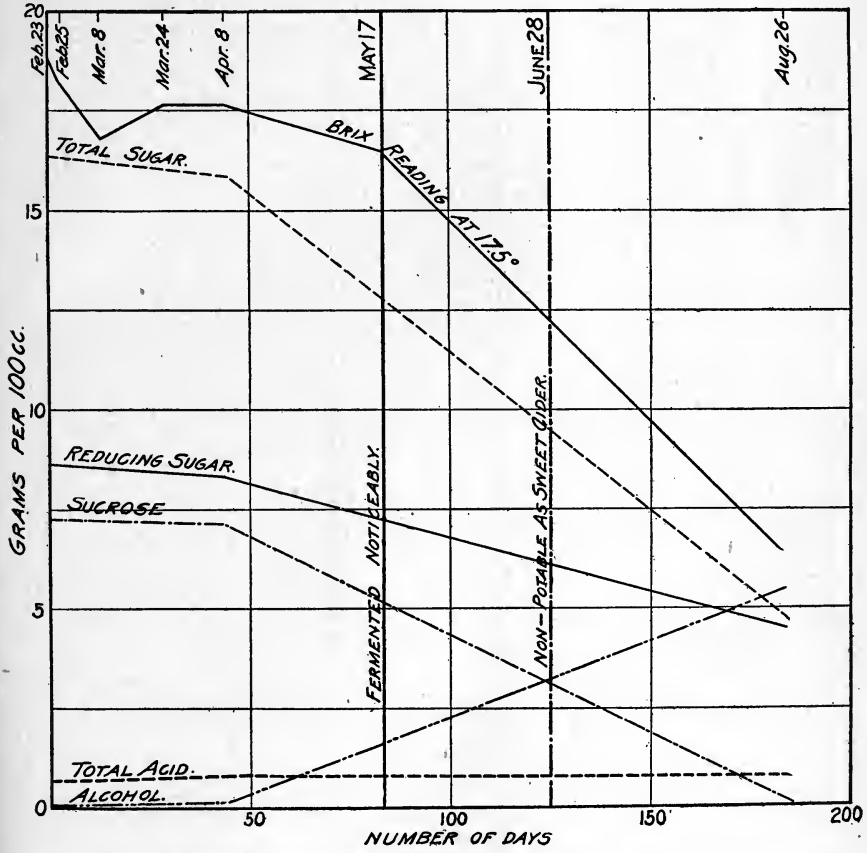

FIG. 8.—Changes in cider made from Roxbury Russet apples and stored at 0° C.

the fresh ciders this reading is practically equal to the content of total solid matter, in the fermented ciders it is merely useful in giving an idea of the progress of the fermentation. The total sugars remained practically constant during the first fifty days of storage for all of the varieties studied. The low value found for the Baldwin variety on April 8 has already been explained as due to the formation of ice (see p. 4). After approximately fifty days the total sugar values gradually declined. The reducing sugars followed in a general way the course of the total sugar, but the rate of loss was less rapid, owing

to the fact that inversion of the sucrose was taking place. The total acid readings are nearly constant and show a gradual increase during the fermentation, the increase being largely due in all cases, except the Tolman variety, to a very slight formation of volatile acid. The Tolman variety shows a slight increase in acid, of which a considerable portion was fixed acid. The rate of fermentation increased rather rapidly in all instances after about fifty days, but, on the whole, the changes were far slower than those occurring in common storage. As noted on page 6, the juices held at laboratory temperatures after

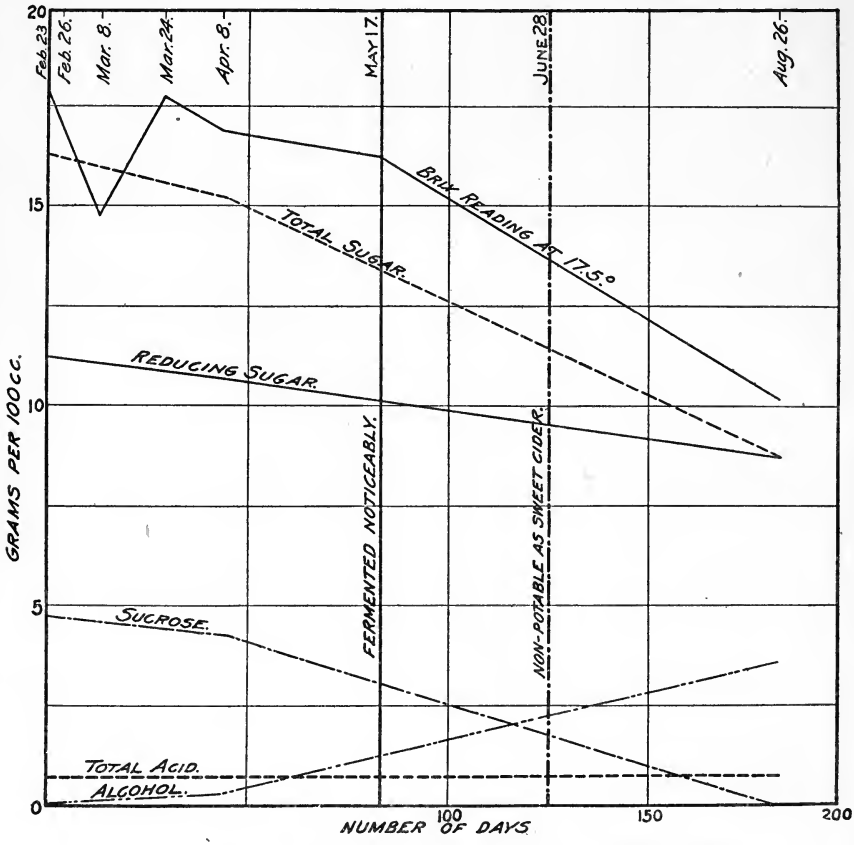

FIG. 9.—Changes in cider made from Kentucky Red apples and stored at 0° C.

pressing fermented rapidly, fermentation starting in all cases within a few days and being completed within thirty-three to fifty-four days.

A number of points remain to be determined before definite recommendations can be made as to storing cider. These points include:

(1) The influence of the number of yeasts and other organisms present on the storage of cider.

(2) The development of methods for controlling this infection if it is found to be a serious factor.

(3) The behavior of cider after its withdrawal from cold storage.

SUMMARY.

(1) Ciders prepared from apples free from decay chilled rapidly to the freezing point immediately after pressing, and then held in cold storage at 0° C. (32° F.) remained without noticeable fermentation for a period of from thirty-six to fifty-seven days, an average of fifty days for the Tolman, Winesap, Yellow Newtown, Ralls, Gilpin, and Baldwin varieties, and of eighty-three days in the case of the Golden Russet, Roxbury Russet, and Kentucky Red..

(2) These ciders were held for a period of from ninety to one hundred and nineteen days, an average of ninety-nine days for the first six varieties and of one hundred and twenty-five days for the last three, before they fermented sufficiently to be considered as becoming "hard" or "sour."

(3) The ciders were found to have suffered no deterioration (with the exception of the Tolman), but rather had become more palatable during storage.

O