U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY—BULLETIN NO. 88.
H. W. WILEY, Chief of Bureau.

The Chemical Composition of Apples and Cider.

I. The Composition of Apples in Relation to Cider and Vinegar Production.

II. The Composition of Cider as Determined by Dominant Fermentation with Pure Yeasts.

BY

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Special Agent, U. S. Department of Agriculture, and Mycologist of the Virginia Agricultural Experiment Station.

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WASHINGTON:
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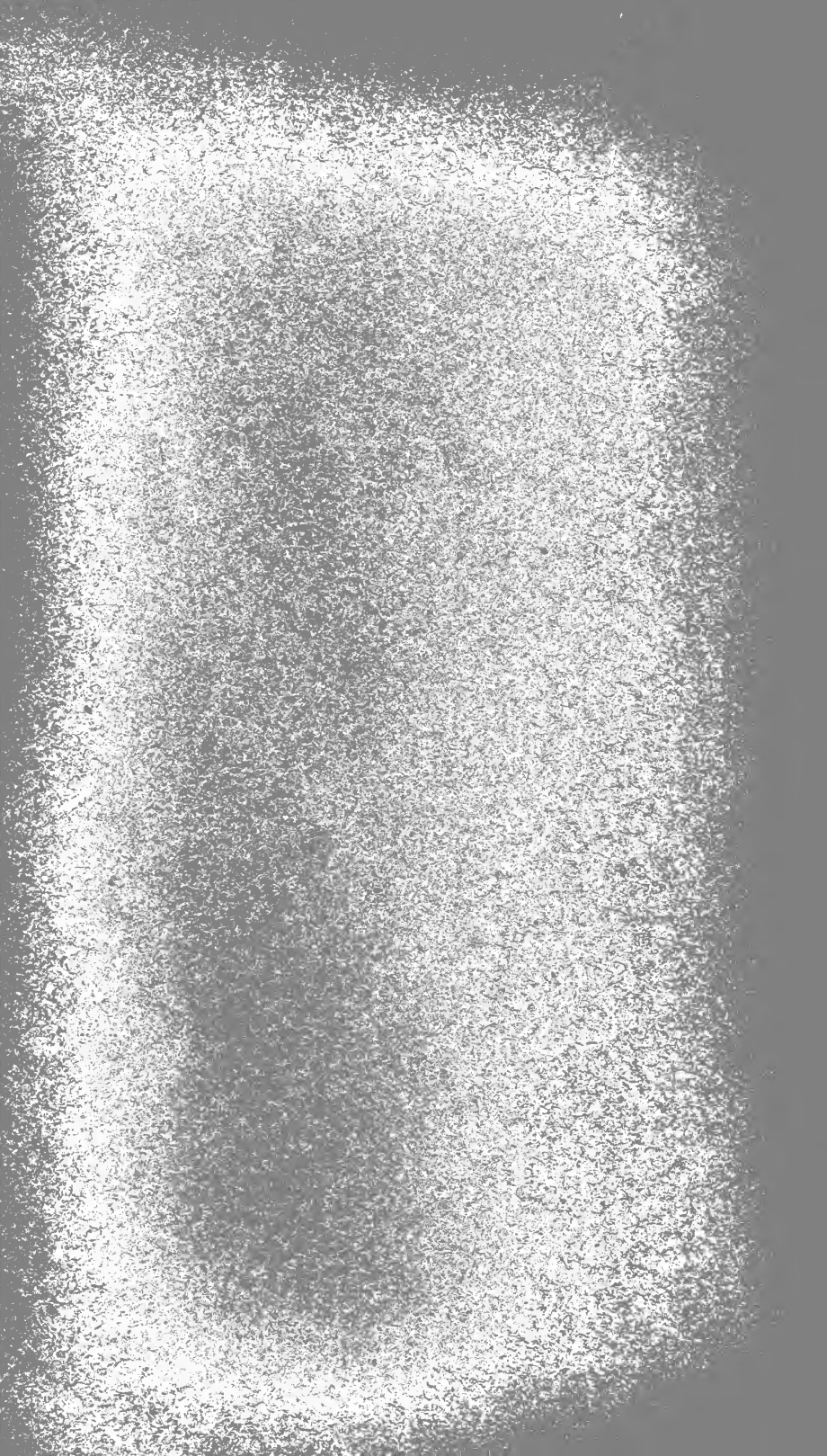

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Chemistry,
Washington, D. C., August 20, 1904.

Sir: The manuscript offered for publication herewith contains the results of elaborate studies made on the composition of apples, apple juices, and the fermented products thereof, conducted by this Bureau in collaboration with the agricultural experiment station at Blacksburg, Va., during the past two years. The chemical work was done partly in the Bureau of Chemistry, but chiefly in the laboratories of the Virginia station, while the fermentation experiments were made solely at the experiment station. In regard to the authorship, William B. Alwood is solely responsible for the plan and direction of the work herein presented, and the report has been prepared by him. To R. J. Davidson should be accredited the chemical work done at the Virginia station, while W. A. P. Moncure had charge of the fermentation room and kept the records of that part of the work. The data obtained throw a great deal of light upon the processes of fermentation and the methods which should be used to secure the highest grade of products from the juices of apples and other fruits. The researches reported here form a sequel to Bulletin No. 71 of this Bureau, entitled "A Study of Cider Making in France, Germany, and England," and I recommend the publication of this manuscript as Bulletin No. 88 of the Bureau of Chemistry.

Respectfully,

H. W. Wiley, *Chief.*

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

THE CHEMICAL COMPOSITION OF APPLES AND CIDER.

I.—THE COMPOSITION OF APPLES IN RELATION TO CIDER AND VINEGAR PRODUCTION.

By Wm. B. Alwood and R. J. Davidson.

INTRODUCTION.

As special work on the study of orchard problems and orchard products has progressed, the fact has become more and more patent that for all but the most temporary results we must turn our attention more to a thorough study of elemental principles. Thus in regard to the subject in hand, the study more particularly of the fruit of the apple, it appears that without a careful and comprehensive examination of the composition of the varieties of this fruit safe conclusions on many important points which govern the future of varietal selection and breeding for special purposes can not be reached.

A complete study of the composition of the apple fruit would include the determination of other data than those derived solely from a chemical analysis, but a study of the physical characteristics of varieties has not yet been undertaken with any accuracy. This is, however, planned for the future, when the condition of the work and the equipment will permit. That these studies will contribute data for the guidance of students of varieties there is every reason to believe, but this will only be true when they have been brought to such technical perfection that the elemental data presented can be relied upon for the making of safe deductions. Owing to the short period of time covered and the local character of the work, very few deductions are attempted in this paper. Chemistry and physics must be brought more fully to bear upon the problems of pomology, and thus aid in determining those factors which should guide us in the breeding and selection of varieties for special climatic and soil conditions. When

all the factors of the problem are properly determined, who can say that the horticulturist shall not, within a reasonable time, breed apples that are more resistant to frost and to disease?

As a continuation of the work begun in 1901,[a] during 1903 a further investigation was made upon the composition of the more important varieties of apples fruiting in the experiment station orchards at Blacksburg, Va., in that year. This investigation includes the consideration of the quantity of juice which was secured from a given weight of each kind or variety of apple, and also a chemical analysis of both juice and pomace, so as to obtain accurate data as to the quality of the varieties and their relative value when used for the manufacture of various secondary products.

PREPARATION OF THE SAMPLES.

The station orchards have been described and the character and growth of the varieties sufficiently noted in bulletins Nos. 128 and 130 of the Virginia Station to render further descriptive matter under these heads unnecessary.

The samples of fruit for the technical examination were selected from the trees when fully mature and placed in ordinary 10-pound grape baskets. Care was taken to select representative samples as to variations in size and to select fruit from all parts of each tree. These samples were labeled as picked and placed in a cool room, or, if necessary to hold them for analysis, they were placed in cold storage. As far as could be determined with such a range of varieties, each one was ground when in the best condition to yield the maximum amount of juice, but in the case of a few varieties the fruit was held until decidedly overripe and mealy, and because of this fact the juice percentage is low in these varieties, which are indicated in Table I.

The sample actually pulped was selected from the specimens in the basket with a view to representing fairly the individual characteristics of the fruit. Only apples free from speck or injury were used, and the stems were left on. The fruits were pulped in a machine which consists of a circular rotating basin, in which the sample is placed, the pulping or chopping being accomplished by a geared device which operates a walking beam carrying a knife at one end, set so as to strike squarely on the wooden bottom of the vessel containing the fruit. When the crank is turned this machine chops or pulps the fruit very finely in the circular vessel as it rotates by a ratchet motion beneath the knife. While this operation is slow, it gives good results. The vessel carrying the fruit can be detached and the sample recov-

[a] U. S. Dept. of Agr., Bureau of Chemistry, Bul. No. 71: A Study of Cider Making.

ered with but slight loss. The comparatively high percentage of loss in some cases may lead to a misconception. In preparing a small sample the loss shown in the table is proportionately much greater than would occur when larger quantities are handled, as this rate of loss would not continue.

The tissues of the fruit are in much better condition for extracting the juice when pulped in this machine than when prepared by any small mill of the grater type which was tried. First, a small hand-grater was used, but it was found impossible to recover anywhere near the entire weight of the sample, and the fruit was so poorly pulped that the juice could not be expressed as completely as is necessary in technical work. In the machine used, however, the sample can easily be chopped too fine to give the best results under the press; therefore the desired degree of fineness should be determined before the sample is prepared.

After chopping the sample as fine as desired it was carefully transferred to a small hand press, known as a meat press, such as is commonly used for pressing small quantities of substances in laboratory work. The screw was tightened slowly but very firmly until no more juice could be extracted; then the pomace was broken up and repressed as at the first operation, until it was exhausted as completely as possible with this apparatus. The juice so obtained and the pomace were weighed for comparison with the original sample. The samples were prepared in this manner early in the morning, and the juice and pomace were then delivered fresh to the chemical laboratory for examination before changes could well occur. Table I sets forth in detail the results obtained in preparing the samples.

TABLE I.—*Weight and percentage of sample recovered after pulping (Blacksburg, Va., 1903).*

SUMMER VARIETIES.

Variety.	Sample No.	Weight of original sample.	Weight recovered after pulping.			Percentage recovered and lost.		
			Juice.	Pomace.	Total.	Juice.	Pomace.	Loss.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*
Benoni	251	1,814.40	992.25	737.10	1,729.35	54.68	40.62	4.70
Chenango	250	1,814.40	1,105.65	680.40	1,786.05	60.93	37.50	1.57
Jersey Sweet	263	1,814.40	878.85	878.85	1,757.70	48.43	48.43	3.14
Oldenburg	254	2,409.75	1,304.10	1,105.65	2,409.75	54.12	45.88	.00
Red June	253	1,814.40	850.50	907.20	1,757.70	46.86	50.00	3.14
Sops of Wine[a]	256	1,814.40	623.70	1,162.35	1,786.05	34.37	64.06	1.57
Summer Pearmain	265	1,856.92	1,020.60	765.45	1,786.05	54.96	41.22	3.82
Summer Rose	252	3,883.95	2,097.90	1,587.60	3,685.50	54.01	40.87	5.12
Westfield	258	1,814.40	935.55	765.45	1,701.00	51.56	42.18	6.26
Williams *Favorite*[a]	255	2,041.20	595.35	1,360.80	1,956.15	29.16	66.66	4.18
Average of all						48.91	47.74	3.35
Average omitting Nos. 255 and 256						53.20	43.34	3.46

[a] Samples overmature when pulped.

TABLE 1.—*Weight and percentage of sample recovered after pulping (Blacksburg, Va., 1903)*—Continued

AUTUMN VARIETIES.

Variety.	Sample No.	Weight of original sample.	Weight recovered after pulping.			Percentage recovered and lost.		
			Juice.	Pomace.	Total.	Juice.	Pomace.	Loss.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*
Baltzby	283	1,304.10	708.75	567.00	1,275.75	54.34	43.47	2.19
Buckingham	271	1,360.80	793.80	567.00	1,360.80	58.33	41.67	.00
Fall Orange[a]	266	1,190.70	368.55	765.45	1,134.00	30.95	64.28	4.77
Fall Pippin	272	1,474.20	737.10	722.92	1,460.02	50.00	49.38	.62
Fanny	259	1,569.25	822.15	708.75	1,530.90	52.72	45.45	1.83
Maiden Blush	274	1,360.80	694.57	623.70	1,318.27	51.04	45.83	3.13
Mother	275	1,332.45	765.45	567.00	1,332.45	57.45	42.55	.00
Moulin à Vent[b]	268	340.20	212.62	127.57	340.19	62.50	37.50	.00
Plumb Cider	276	1,332.45	737.10	595.35	1,332.45	55.32	44.68	.00
Porter[a]	267	1,289.92	467.77	793.80	1,261.57	36.26	61.53	2.21
Smith *Cider*	288	1,289.92	652.05	637.87	1,289.92	50.54	49.46	.00
Tolman *Sweet*	281	1,360.80	680.40	623.70	1,304.10	50.00	45.83	4.17
Wealthy	278	1,360.80	680.40	652.05	1,332.45	50.00	47.91	2.09
Average of all						50.72	47.66	1.62
Average omitting Nos. 266 and 267						53.92	43.95	2.13

WINTER VARIETIES.

Albemarle Pippin [c]	284	1,360.80	737.10	567.00	1,304.10	54.16	41.66	4.18
Arkansas	298	1,247.40	623.70	623.70	1,247.40	50.00	50.00	.00
Baldwin	269	1,445.85	793.80	652.05	1,445.85	54.90	45.10	.00
Belle de Boskoop	270	1,502.55	822.15	623.70	1,445.85	54.71	41.50	3.79
Cannon	296	1,360.80	793.80	567.00	1,360.80	58.33	41.67	.00
Gano	295	1,360.80	595.35	737.10	1,332.45	43.75	54.16	2.09
Grimes *Golden*	273	1,474.20	666.22	779.62	1,445.84	45.19	52.88	1.93
Jonathan	294	1,360.80	623.70	708.75	1,332.45	45.83	52.08	2.09
Lankford	300	1,360.80	807.97	552.83	1,360.80	59.37	40.63	.00
Lawver	292	1,360.80	737.10	623.70	1,360.80	54.16	45.84	.00
Limbertwig	293	1,360.80	680.40	680.40	1,360.80	50.00	50.00	.00
Peck	291	1,474.20	793.80	680.40	1,474.20	53.85	46.15	.00
Ralls *Genet*	290	1,389.15	595.35	510.30	1,105.65	42.85	36.73	20.42
Roxbury *Russet*	289	1,530.90	680.40	822.15	1,502.55	44.44	53.70	1.86
Smokehouse	277	1,559.25	850.50	708.75	1,559.25	54.55	45.45	.00
Via	301	1,360.80	680.40	652.05	1,332.45	50.00	47.91	2.09
Winesap	297	1,360.80	793.80	538.65	1,332.45	58.33	39.58	2.09
Yellow Bellflower	279	1,360.80	850.50	510.30	1,360.80	62.50	37.50	.00
Yellow Newtown [c]	285	1,360.80	737.10	595.35	1,332.45	54.16	43.75	2.09
Average						52.16	45.59	2.25

CRAB APPLES.

English	287	1,360.80	737.10	623.70	1,360.80	54.16	45.84	0.00
Maiden Blush	280	1,360.80	822.15	538.65	1,360.80	60.42	39.58	.00
Queen *Choice*	264	1,360.80	907.20	453.60	1,360.80	66.67	33.33	.00
Red Siberian	261	1,559.25	793.80	765.45	1,559.25	50.91	49.09	.00
Soulard	286	1,360.80	765.45	538.65	1,304.10	56.25	39.58	4.17
Transcendent	262	1,615.95	963.90	652.05	1,615.95	59.64	40.36	.00
Whitney	260	1,814.40	963.90	765.45	1,739.35	53.12	42.18	4.70
Average						57.31	41.42	1.27

[a] Samples overmature when pulped.
[b] A French cider apple fruited from graft on Chenargo.
[c] See footnote on page 15.

JUICE AND POMACE.

The average water content of the whole apples varies from 80 to about 86 per cent of their total weight, and the dry matter from about 14 to 20 per cent. These data were determined for several varieties of apples in this investigation and are given in Table VI. Everyone who has ground apples on grater or crushing machines and expressed the juice for cider with the ordinary hand press knows that these machines do not extract much over half the juice originally con-

tained in the fruit, and even the more perfect hydraulic presses do not recover nearly all of it. It is an impossibility to rupture all the cells of the fruit by grinding or to recover all the juice by any practical method of extraction by pressure. With the 80-ton hydraulic press of the Virginia station only about 74 per cent of the weight of fruit is recovered as juice when the conditions are the very best, and in practice this amount is not obtained, 70 per cent being a very high average.

It must be remembered that a very considerable percentage of the weight recovered as juice consists of solids (sugar, etc.) held in solution; hence the actual amount of juice left in the pomace is greater than appears from the percentage of weight recovered. The question of the more perfect grinding of the fruit and extraction of the juice belongs to the technique of cider making. The only phase of the question which concerns us at present is its bearing on the results obtained in preparing material for this investigation. Care was observed to recover the entire sample as nearly as possible, but occasionally slight losses occurred through errors of manipulation and imperfections of the apparatus used. The percentage of loss on each sample is given in the last column of Table I. The percentage of juice obtained in the preparation of these samples by a small hand apparatus approximates the average of custom work, except where the best modern cider-milling machinery is used.

In Table I the summer varieties, when all are considered, show an average of 48.91 per cent of juice obtained, but this average is influenced by the remarkably poor showing of Williams *Favorite* and Sops of Wine. These two varieties were overripe and so mealy that the juice could not be properly separated from the pulp. If they are omitted, the average of juice recovered is 53.20 per cent for summer fruit. The autumn varieties, omitting Fall Orange and Porter, which varieties became overripe for pressing, give an average of 53.92 per cent of juice. The average amount of juice recovered from the winter varieties is higher when all are considered, but here also one variety, Ralls, shows a poor result. This may be attributed partly to the fact that this variety does not properly mature until late winter or early spring and also to loss of material in making up the sample. The Ralls is, however, included in the report because of the value of the chemical analysis given in later tables. The Gano also yields a low percentage of juice, but this is characteristic of the variety. The crab apples show the highest juice content of any group, reaching an average of 57.31 per cent.

The analyses of the samples of juice and pomace are given in Tables II and III. These show the quality of the juice for manufacturing purposes and also the amount of useful substances not extracted from the pomace. The latter point is further developed in Table V by comparisons which bring out the actual loss of sugar caused by imperfect extraction of the juice.

TABLE II.—*Analyses of juice from the samples given in Table I (Blacksburg, Va., 1903).*

SUMMER VARIETIES.

Variety.	Specific gravity.	Grams per 100 cc.					
		Total solids.	Total sugar.[a]	Invert sugar.	Cane sugar.	Acids as sulphuric.	Tannin.
Benoni	1.046	11.73	9.68	5.24	4.22	0.35	0.053
Chenango	1.050	12.61	9.17	6.79	2.26	.29	.034
Jersey Sweet	1.053	13.28	10.94	5.61	5.06	.12	.034
Oldenburg	1.047	11.70	7.92	5.60	2.20	.71	.046
Red June	1.044	10.99	7.99	4.67	3.15	.48	.047
Sops of Wine	1.054	12.86	9.88	5.42	4.24	.29	.025
Summer Pearmain	1.062	16.05	12.44	8.50	3.74	.27	.060
Summer Rose	1.046	10.30	8.68	5.77	2.76	.44	.024
Westfield	1.045	10.87	8.85	5.50	3.18	.09	.016
Williams *Favorite*	1.051	12.89	9.75	5.36	4.17	.29	.062
Average	1.049	12.33	9.53	5.85	3.50	.33	.040

AUTUMN VARIETIES.

Baltzby	1.050	13.04	10.00	6.40	3.42	0.11	0.050
Buckingham	1.045	11.01	9.22	7.00	2.11	.35	.041
Fall Orange	1.055	13.31	10.22	6.62	3.42	.37	.065
Fall Pippin	1.049	12.22	11.27	7.14	3.92	.42	.059
Fanny	1.053	12.84	11.22	6.78	4.22	.37	.068
Maiden Blush	1.051	12.70	9.99	6.34	3.47	.49	.058
Mother	1.060	14.77	11.69	7.31	4.16	.27	.074
Moulin à Vent	1.061	15.77	11.00	7.27	3.54	.21	.183
Plumb Cider	1.055	15.17	10.56	7.12	3.27	.62	.092
Porter	1.055	14.15	9.23	6.00	3.07	.39	.046
Smith *Cider*	1.057	14.44	11.64	7.44	3.99	.52	.054
Tolman *Sweet*	1.055	14.27	10.86	7.05	3.62	.14	.056
Wealthy	1.057	15.26	11.64	7.70	3.74	.48	.047
Average	1.054	13.76	10.66	6.93	3.53	.36	.069

WINTER VARIETIES.

Albemarle Pippin[b]	1.056	14.00	11.09	6.62	4.25	0.45	0.042
Arkansas	1.056	14.14	11.64	7.90	3.35	.52	.049
Baldwin	1.055	13.92	11.13	5.96	4.91	.50	.039
Belle de Boskoop	1.062	16.21	12.50	6.93	5.29	.78	.069
Cannon	1.054	14.52	11.50	5.32	5.87	.32	.057
Gano	1.056	13.92	11.32	6.96	4.14	.30	.047
Grimes *Golden*	1.063	15.39	12.52	6.95	5.29	.44	.066
Jonathan	1.056	14.62	11.60	7.00	4.37	.23	.049
Lankford	1.054	13.35	10.86	7.14	3.53	.41	.045
Lawver	1.057	14.42	11.27	8.10	3.01	.42	.063
Limbertwig	1.057	14.11	11.50	7.44	3.86	.45	.050
Peck	1.054	13.63	10.73	6.74	3.79	.39	.039
Ralls *Genet*	1.052	13.12	10.68	7.92	2.62	.36	.047
Roxbury *Russet*	1.065	16.91	13.20	6.74	6.14	.59	.066
Smokehouse	1.061	15.65	12.49	7.92	4.34	.48	.061
Via	1.044	10.88	8.95	7.57	1.31	.13	.054
Winesap	1.065	16.45	13.34	7.39	5.65	.42	.035
Yellow Bellflower	1.049	12.46	9.77	6.62	2.99	.43	.046
Yellow Newtown[b]	1.055	13.85	11.09	6.48	4.38	.47	.044
Average	1.056	14.29	11.43	7.04	4.16	.41	.050

CRAB APPLES.

English	1.057	14.17	11.60	8.60	2.85	0.47	0.045
Maiden Blush	1.070	18.56	14.78	10.00	4.56	.32	.078
Queen *Choice*	1.060	15.90	11.50	6.45	4.80	.39	.143
Red Siberian	1.070	17.54	11.83	9.54	2.17	.71	.214
Soulard	1.050	12.26	9.00	5.99	2.86	.67	.138
Transcendent	1.069	17.09	11.90	7.68	4.00	.70	.196
Whitney	1.060	14.16	11.39	8.27	2.96	.29	.040
Average	1.062	15.69	11.71	8.08	3.45	.50	.122

[a] Expressed as invert sugar.

[b] See footnote on page 15.

TABLE III.—*Analyses of the pomace obtained from samples given in Table I (Blacksburg, Va., 1903).*

Variety.	Grams per 100 grams.						
	Moisture.	Ash.	Total sugar.[a]	Invert sugar.	Cane sugar.	Acid, as sulphuric.	Tannin.
SUMMER VARIETIES.							
Benoni	84.00	0.34	7.82	4.62	3.04	0.28	.....
Chenango	83.17	.39	8.69	6.52	2.06	.41	.....
Jersey Sweet	80.50	.39	10.50	5.46	4.78	.09	.....
Oldenburg	82.35	.37	7.27	5.48	1.70	.71	.....
Red June	85.10	.39	7.00	4.33	2.53	.41	.....
Sops of Wine	84.85	.41	9.57	5.67	3.71	.31	.....
Summer Pearmain	80.25	.44	9.60	6.69	2.76	.27	0.010
Summer Rose	84.46	.27	8.45	5.45	2.85	.41	.....
Westfield	83.45	.38	8.33	5.15	3.03	.10	.....
Williams *Favorite*	84.80	.33	9.40	5.60	3.61	.39	.....
Average	83.29	.37	8.66	5.49	3.00	.33	0.010
AUTUMN VARIETIES.							
Baltzby	82.50	0.31	8.74	5.54	3.04	0.10	0.073
Buckingham	83.50	.30	7.78	6.00	1.70	.35	.052
Fall Orange	84.30	.36	9.57	6.36	3.04	.18	.049
Fall Pippin	85.10	.31	8.24	5.85	2.27	.41	.054
Fanny	81.75	.37	8.37	6.17	2.09	.39	.....
Maiden Blush	82.65	.34	9.00	6.07	2.78	.45	.050
Mother	79.90	.38	10.90	6.85	3.85	.16	.070
Moulin à Vent	70.25	.61	7.92	5.68	2.13	.14	.017
Plumb Cider	80.80	.32	9.24	6.65	2.46	.59	.090
Porter	81.35	.35	9.68	7.55	2.02	.40	.054
Smith *Cider*	80.65	.39	9.92	6.64	3.12	.50	.014
Tolman *Sweet*	80.60	.38	10.03	6.36	3.49	.16	.060
Wealthy	77.25	.44	9.26	6.48	2.64	.42	.080
Average	80.81	.37	9.12	6.32	2.66	.32	.055
WINTER VARIETIES.							
Albemarle Pippin[b]	81.90	0.33	9.34	5.79	3.37	0.41	0.012
Arkansas	81.00	.39	10.32	7.00	3.15	.50	.091
Baldwin	81.40	.33	8.76	5.11	3.47	.47	.054
Belle de Boskoop	78.65	.39	10.21	5.91	4.09	.75	.054
Cannon	79.65	.36	5.19	3.65	1.46	.26	.069
Gano	80.50	.33	8.99	5.62	3.20	.28	.134
Grimes *Golden*	81.10	.23	10.26	5.50	4.52	.22	.043
Jonathan	82.30	.40	10.50	6.41	3.89	.20	.170
Lankford	79.25	.30	9.28	6.36	2.77	.39	.084
Lawver	81.25	.37	9.85	7.09	2.62	.40	.140
Limbertwig	82.15	.38	9.40	6.36	2.89	.41	.063
Peck	82.85	.27	10.04	6.41	3.45	.35	.080
Ralls *Genet*	80.75	.34	9.40	6.99	2.29	.33	.103
Roxbury *Russet*	80.40	.38	11.46	5.96	5.23	.59	.060
Smokehouse	80.65	.39	10.68	6.02	4.43	.50	.082
Via	84.65	.34	8.01	6.87	1.08	.14	.060
Winesap	79.15	.43	9.05	7.09	1.86	.41	.060
Yellow Bellflower	79.00	.41	8.09	5.43	2.53	.41	.060
Yellow Newtown[b]	82.00	.34	8.76	6.02	2.60	.46	.088
Average	80.98	.35	9.34	6.13	3.10	.39	.079
CRAB APPLES.							
English	76.40	0.41	10.15	5.84	4.09	0.31	0.091
Maiden Blush	76.65	.49	11.76	7.78	3.78	.35	.063
Queen *Choice*	77.35	.57	10.09	5.85	4.03	.47	.164
Red Siberian	90.00	.62	11.52	10.15	1.30	.75	.....
Soulard	77.40	.31	7.33	5.06	2.16	.63	.190
Transcendent	38.05	.43	10.36	5.70	4.43	.73	.....
Whitney	80.15	.52	10.58	7.62	2.81	.31	.....
Average	70.85	.48	10.25	6.85	3.23	.51	.127

[a] Expressed as invert sugar.

[b] See footnote on page 15.

The chemical composition of American apples has been studied so little up to the present time that there is not much material for comparison. In Bulletin No. 71 of the Bureau of Chemistry, issued in 1903, the data then available on the subject were collected, and no special work of this nature has been published since, so far as can be ascertained. The data herein presented comprise, therefore, the greatest number of analyses of varieties that has yet been made in any one season and include a considerable number of varieties commonly grown in the United States. This report necessarily lacks the conclusiveness which attaches to a work covering a series of years, but takes its place merely as a contribution to the solution of the problem under consideration.

In connection with the average composition of the apple must shown by these analyses it is interesting to compare them with the averages obtained in some previous work done on American apples, as given in Table IV.

TABLE IV.—*Average composition of apple musts (compiled).*

Analyst.	Specific gravity.	Solids.	Total sugar.	Reducing sugar.	Cane sugar.	Acid, as sulphuric.	Tannin.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Browne, Pennsylvania Experiment Station, 1899	1.05523	13.36	11.94	7.78	3.76	0.453	.....
Davidson, Virginia Experiment Station, 1901	1.053	12.19	9.58	6.78	2.65	.35	0.022
Davidson, Virginia Experiment Station, 1901 (crab)	1.059	13.98	10.88	7.00	3.68	.42	.060
Burd, U. S. Department of Agriculture, 1901	1.0535	13.39	10.45	6.84	3.48	.37	.....

These averages bear a close relation to the results given in the preceding tables when it is remembered that the figures for summer varieties can not properly be compared with results on winter fruits. The gradual increase in solids and total sugars in passing from summer to fall and winter varieties supports in a way the well-recognized facts as to their quality, but these differences are much less striking than one would expect when the averages are considered. The individual variations, however, of the several varieties of any given season, as compared with each other, are far more important, and what is also more to the point, these variations clearly indicate quality. For example, Summer Pearmain, the high rank of which is conceded, shows 16.05 per cent of total solids and 12.44 per cent of total sugars (Table II), the highest result of any summer or fall variety. The analysis of Jersey Sweet, one of the good varieties of its season, shows a relatively high per cent of total sugar, and in cane sugar surpasses all of the summer and fall varieties, but it has a low acid content. The low sugar content of Red June and Oldenburg is very striking, and the latter is the poorest in cane

sugar of the early varieties. The low acid content of Westfield is in striking contrast with most of the other summer varieties and reveals a real defect in the quality of this fruit.

The fall varieties show decidedly less variation of sugar content than the summer or winter sorts, and yet the average sugar content is about 1 per cent higher than in the early varieties. Fall Pippin and Maiden Blush are striking examples of well-balanced analyses as to reducing and cane sugar and acid content, and thus the standard quality of these fruits is explained. Fanny and Mother sustain their claim to be classed among the best varieties, and here the analysis points to the high content of cane sugar as the probable explanation of their fine quality. The acid content of the fall fruits averages low, as is the case with the summer varieties, but the high percentage shown in Plumb Cider and Smith *Cider* is distinctly correlated with characteristic quality.

The analyses of the winter varieties average about the same as the results quoted from Browne in Table IV. The composition of each of the 19 varieties is fairly uniform in the majority of cases, but a remarkable contrast is shown by the extremes, Via and Roxbury *Russet*. The sugar content of the latter is remarkably high, and the analysis so well balanced between sugars and acid that the splendid quality of the fruit is well explained. The cane-sugar content, 6.14 per cent, is the highest found for the entire series analyzed. The physical characteristics of this fruit and its chemical composition doubtless explain its good keeping qualities, even when grown as far south as Blacksburg, Va. Grimes *Golden*, Smokehouse, and Winesap all give analyses which mean much as to their fine quality and value as parent stocks for future selection. The latter has the highest total sugar content of all of the varieties analyzed, and has a well-balanced sugar and acid content. Belle de Boskoop, a coarse-fleshed apple, which apparently has little to recommend it, compares favorably with these better varieties in analysis and exceeds some of them in its content of cane sugar. This apple is apparently the one striking exception to the relation found to exist between quality and chemical composition, and its objectionable characteristics are physical rather than chemical.

Attention should be called to the two analyses of pippins. For fifteen years the *Albemarle Pippin*,[a] as propagated in Albemarle County, and the Yellow Newtown,[a] as propagated in New York, have been grown at the Virginia station. The differences between the two and the points they have in common have been noted in the Virginia station

[a] The name *Albemarle Pippin* is considered by pomologists to be a synonym of Yellow Newtown, which is the recognized name of the variety. The analytical and other data concerning the two are given separately in the tables in order to show their similarity.

bulletins.[a] The analyses of the apples are so nearly alike that they are worthy of special note. From these analyses it appears probable that the high quality of these apples depends not so much upon actual sugar content as upon the well-balanced percentages of sugars and acid, and the physical peculiarities of the flesh of the fruit.

The variety Moulin à Vent is a French scion grafted on Chenango. In discussing the French varieties in Bulletin No. 71[b] allusion is made to the peculiar qualities and richness in sugar of the French cider apples. Many scions were brought from France and are now growing at the Virginia station, and this one is the first of them to fruit. It bore the characteristic fruit observed in France, but the analysis of the juice shows only 11 per cent of sugar, whereas the French analyses of this variety run as high as 16.57 per cent. The interesting question is thus raised, Will these French varieties fail to produce as rich juice in this country as in France? The tannin content is also lower than shown by the French analyses, but is higher than in any of the American varieties except some of the crabs. Of the crabs Maiden Blush shows a remarkably good analysis, and the practical work done has clearly proved that this variety is one of the most desirable for canning and jelly making.

From the data brought together by these analyses it would seem that an investigation of the composition of apples covering sufficient material and a suitable period of time will reveal facts of the utmost importance to the pomologist and also to those who use this fruit in factory work. It does not appear to have been heretofore recognized what an important part the cane sugar may possibly play in the quality of the apple.

The analysis of the pomace is important principally because it enables us to express clearly the loss which may occur if the pomace is not utilized in such a manner as to recover these substances. At the custom mills in the United States it has been the usual practice to deposit the pomace where possibly a little of it may be eaten by stock, but on the whole it is practically treated as waste. It will doubtless surprise many people to learn what a large amount of sugar is lost in the pomace. This point is brought out in Table V.

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[a] Virginia Agr. Exp. Sta. Buls. Nos. 128 and 130.

[b] U.-S. Dept. of Agr., Bureau of Chemistry: A Study of Cider Making.

TABLE V.—*Sugar and acid content calculated to the whole fruit from Tables I, II, and III (calculated at the Bureau of Chemistry).*

SUMMER VARIETIES.

Variety.	Grams per 100 grams.						Percentage of recovered sugar in pomace.
	Total sugar.	Invert sugar.	Cane sugar.	Acid as sulphuric.	Total sugar recovered in juice.	Total sugar recovered in pomace.	
Benoni	8.87	4.96	3.70	0.31	5.29	3.17	37.47
Chenango	8.97	6.67	2.17	.32	5.58	3.25	36.80
Jersey Sweet	10.70	5.52	4.91	.09	5.29	5.08	48.98
Oldenburg	7.61	5.54	1.97	.70	4.28	3.33	43.76
Red June	7.47	4.48	2.81	.42	3.74	3.50	48.34
Sops of Wine	9.67	5.57	3.88	.28	3.39	6.13	64.39
Summer Pearmain	11.21	7.71	3.30	.25	6.83	3.95	36.64
Summer Rose	8.56	5.61	2.79	.41	4.68	3.45	42.43
Westfield	8.60	5.33	3.09	.08	4.56	3.51	43.49
Williams *Favorite*	9.49	5.52	3.76	.34	2.84	6.26	68.79
Average	9.11	5.69	3.23	.32	4.64	4.16	47.10

AUTUMN VARIETIES.

Baltzby	9.42	6.00	3.24	0.09	5.43	3.79	41.10
Buckingham	8.61	6.58	1.93	.34	5.37	3.24	37.63
Fall Orange	9.77	6.42	3.15	.23	3.16	6.15	66.05
Fall Pippin	9.75	6.49	3.09	.41	5.63	4.06	41.89
Fanny	9.89	6.48	3.21	.36	5.91	3.80	39.13
Maiden Blush	9.50	6.20	3.13	.46	5.09	4.12	44.73
Mother	11.34	7.10	4.02	.21	6.71	4.63	40.83
Moulin à Vent	9.84	6.67	3.00	.18	6.87	2.97	30.18
Plumb Cider	9.96	6.90	2.89	.60	5.84	4.12	41.36
Porter	9.50	6.96	2.40	.38	3.34	5.95	64.04
Smith *Cider*	10.78	7.04	3.55	.50	5.88	4.90	45.45
Tolman *Sweet*	10.45	6.71	3.54	.14	5.43	4.59	45.81
Wealthy	10.47	7.09	3.19	.44	5.82	4.43	43.22
Average	9.94	6.66	3.10	.33	5.42	4.36	44.72

WINTER VARIETIES.

Albemarle Pippin	10.32	6.25	3.86	0.42	6.00	3.89	39.33
Arkansas	10.98	7.45	3.24	.51	5.82	5.16	46.99
Baldwin	10.06	5.57	4.25	.48	6.11	3.95	39.26
Belle de Boskoop	11.49	6.48	4.76	.75	6.83	4.23	38.24
Cannon	8.86	4.62	4.02	.28	6.70	2.16	24.37
Gano	10.02	6.20	3.61	.28	4.95	4.86	49.54
Grimes *Golden*	11.28	6.15	4.87	.30	5.65	5.42	48.96
Jonathan	10.99	6.66	4.10	.20	5.31	5.46	50.69
Lankford	10.21	6.81	3.21	.39	6.44	3.77	36.92
Lawver	10.61	7.63	2.83	.40	6.10	4.51	42.51
Limbertwig	10.45	6.90	3.37	.42	5.75	4.70	44.97
Peck	10.40	6.57	3.63	.37	5.77	4.63	44.51
Ralls *Genet*	10.07	7.47	2.46	.33	4.57	3.45	43.01
Roxbury *Russet*	12.23	6.30	5.62	.58	5.86	6.15	51.21
Smokehouse	11.66	7.05	4.37	.48	6.81	4.85	41.59
Via	8.47	7.22	1.18	.12	4.47	3.83	46.14
Winesap	11.60	7.26	4.10	.40	7.78	3.58	31.51
Yellow Bellflower	9.13	6.16	2.80	.41	6.10	3.03	33.18
Yellow Newtown	10.04	6.26	3.57	.45	6.00	3.83	38.96
Average	10.46	6.57	3.67	.39	5.94	4.28	41.67

CRAB APPLES.

English	10.93	7.32	3.41	0.39	6.28	4.65	42.54
Maiden Blush	13.58	9.11	4.24	.32	8.93	4.65	34.24
Queen *Choice*	11.02	6.24	4.54	.41	7.66	3.36	30.49
Red Siberian	11.67	9.83	1.73	.72	6.02	5.65	48.41
Soulard	8.30	5.59	2.55	.63	5.06	2.90	36.43
Transcendent	11.27	6.88	4.16	.70	7.09	4.18	37.09
Whitney	11.02	7.97	2.88	.29	6.05	4.46	42.43
Average	11.11	7.56	3.35	.49	6.72	4.26	38.80

From Table V, giving the sugar and acid content of the whole fruit, it is at once seen that the total sugar for the whole fruit is not on the average so high as the total sugar in the juice (Table II), but is a little higher on the average than the sugar found in the pomace (Table III). Also, the cane sugar of the whole sample is proportionately lower than the cane sugar found in the juice. This would indicate that the juice extracted by grinding and pressing is relatively richer than that which remains in the pomace, and that the cane sugar is also secured proportionately in larger percentage than that in which it actually exists in the original fruit. The actual quantities of sugar recovered in the juice and pomace are given in grams per hundred grams of whole fruit in this table. These two columns do not represent the total sugar, except when there was no loss of sample. This loss was not proportionately distributed between the two columns, the comparison being deemed more reliable as presented than if the loss were so distributed.

The last column in Table V gives the percentage of sugar actually recovered which is left in the pomace. This percentage will become rapidly less as the proportion of the original weight of fruit recovered as juice increases, and therefore the question of improved methods of grinding and pressing is a very important one. It does not appear up to the present time that the American manufacturers have solved the question of recovering, in a practical manner, this comparatively large waste which ordinarily is lost in the pomace. There is, however, a simple but rather expensive method of recovering the valuable constituents of the pomace by exhaustion with warm or cold water, preferably the former. This may be accomplished in tubs or casks or in regular diffusion batteries, such as are used in sugar factories. The weak must or juice thus recovered may be used to dilute richer juice intended for vinegar stock. Pomace can also be used in the silo if mixed with leguminous crops or corn, and its feeding value is thus successfully conserved and utilized.

DRY MATTER AND MINERAL CONSTITUENTS.

For these determinations only a few varieties of standard value were selected. These appear to give a fair range of fruits for the several seasons, except in case of the earliest varieties. It was intended to include Early Ripe and Oldenburg in this list, but these were out of season before the work could be undertaken, and therefore it can not be said to represent the probable variations in composition which will be found in the very early varieties. The complete analysis of a large number of varieties of apples involves so large an amount of work that it was decided not to attempt complete analyses of any of the varieties in the strict sense of this term. The preceding tables cover quite fully those substances of direct importance to quality and com-

mercial value of a large number of varieties. The analyses presented in Table VI include the determination of nitrogen, phosphoric acid, potash, and lime.

The standard list of varieties examined for these constituents was selected with a view to continuing the chemical examination of fruit from these same trees for a series of years, thus establishing the normal content of these important elements. Such determinations, together with the crop statistics from the same trees, will give in time most valuable data for the guidance of cultural practice. There is at present little to be gained by deductions which could be made from the work of this one season.

TABLE VI—*Determination of moisture, solids, ash, and the more important mineral constituents in whole fruits (Blacksburg, Va., 1903).*

Variety.	Grams per 100 grams.						
	Moisture.	Solids.	Nitrogen.	Ash.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).
SUMMER VARIETY.							
Jersey Sweet	82.81	17.19	0.060	0.29	0.056	0.190	0.020
AUTUMN VARIETIES.							
Buckingham	88.85	11.15	0.060	0.20	0.018	0.110	0.008
Maiden Blush	86.96	13.04	.030	.24	.014	.120	.005
Average	87.90	12.09	.045	.22	.016	.115	.0065
WINTER VARIETIES.							
Albemarle Pippin	85.67	14.33	0.060	0.25	0.026	0.140	0.009
Arkansas Black	86.48	13.52	.041	.34	.020	.230	.006
Cannon	83.99	16.01	.082	.26	.026	.150	.009
Gano	86.01	13.99	.059	.23	.022	.120	.012
Grimes *Golden*	84.69	15.31	.060	.25	.028	.143	.010
Peck	86.11	13.89	.042	.20	.018	.120	.007
Winesap	84.70	15.30	.049	.31	.018	.180	.010
Average	85.38	14.62	.056	.26	.023	.155	.009
CRAB APPLES.							
Maiden Blush	81.64	18.36	0.060	0.37	0.022	0.220	0.012
Transcendent	84.03	15.97	.064	.36	.030	.180	.007
Average	82.83	17.16	.062	.365	.026	.200	.0095

II.—THE COMPOSITION OF CIDER AS DETERMINED BY DOMINANT FERMENTATION WITH PURE YEASTS.

By Wm. B. Alwood, R. J. Davidson, and W. A. P. Moncure.

WORK OF 1901-2.

INTRODUCTION.

In the autumn of 1901 a series of experiments upon the manufacture of ciders with pure yeast cultures was begun at the Blacksburg station in cooperation with the Bureau of Chemistry.

The apple must or juice used for this experiment was made with the power mill belonging to the station from ordinary mixed apples, mostly of inferior varieties. Immediately after pressing, the juice was placed in sound, clean, 50-gallon casks, and these were at once bunged to prevent further access of organisms to the juice until it could be sown with yeast. These casks, or 50-gallon barrels, were placed on the second floor of the factory building and were sown with yeast cultures about three hours after grinding the fruit. In these experiments, which were made on a scale comparable with commercial work, the juice or must was not sterilized or pasteurized before sowing with the pure yeast cultures. While the destruction by use of heat of the many microscopic organisms always present in fresh fruit juice is practicable, even on a large scale in factory work, as yet it has not been found to be desirable for commercial ciders. Heating the must causes such changes in the flavor that the most careful cellar work and use of pure ferments has failed to counteract this effect, and thus the fine natural flavors are quite commonly injured by attempts at sterilization.

Control or dominant fermentation is easily secured if one sows a sufficient amount of fresh culture of a strong yeast into the newly made must. The question of the relative activities of the pure ferments in comparison with mixed yeasts and "wild" ferments in sterilized and unsterilized must will be treated in a subsequent paper which will deal more specifically with the ferment organisms. The station is without suitable cellars or fermentation rooms, and therefore this work was done under such varying conditions of temperature that the

best results could not be anticipated; yet the experiment was, all things considered, a success. Several other experiments were undertaken in the autumn of 1901, but only two are reported, because the other tests were made in large casks purchased from an old wine cellar which were in such bad condition that they could not be properly cleansed, and the experiments failed. The two experiments here reported were carried on in the 50-gallon casks above mentioned. Bulletin No. 71, Bureau of Chemistry, treats of the general and theoretical considerations in cider making; hence these phases of the question are not discussed again in this report.

CASK EXPERIMENTS NOS. 2 AND 3.

The plan of the experiment was very simple. The must or juice was taken from the same vat and came from one bulk of fruit; it was divided among several casks, and sown with different yeast races at the same time. Thus the results produced by these yeasts could be compared, as the same must was handled under identical conditions, the only variant being the yeasts.

The experiment was begun on September 24, 1901, on which date casks Nos. 2 and 3 were filled with juice freshly expressed. This juice tested on the hydrometer 1.050, which would indicate a sugar content of 10.15 per cent. A full analysis was not made. At 3 o'clock p. m. of the same day these barrels were sown as follows: No. 2 with a pure culture of about 1 pint of sterilized cider, which had been inoculated with Sauterne yeast, known in the station laboratory as No. 73. Cask No. 3 was inoculated with about 1 pint of a pure culture made from Vallée d'Auge yeast, known as No. 74. Both cultures were sown when in full vigor and grew promptly, dominating the entire fermentation. The Sauterne yeast, No. 73, was isolated from French Sauterne wines, and No. 74 from cider from the famous Vallée d'Auge cider country in Normandy, France. After inoculation both barrels were stoppered with vents which permitted the escape of the gas formed in the barrels and yet prevented the entrance of extraneous organisms from the air.[a]

The casks were sown with this considerable quantity of an active yeast culture in order to secure the prompt growth of a pure yeast in each cask before the ordinary "wild" organisms present in the juice could grow and take possession of the fermentation. A microscopic examination of small samples of liquor removed from the casks, made each day from September 25 to 28, showed an abundant growth of pure yeast with apparently no occurrence of deleterious organisms.

By the afternoon of September 26 both casks were in full fermenta-

[a] A discussion of this device is given in Bulletin No. 71, Bureau of Chemistry, U. S. Department of Agriculture, pp. 82 to 86.

tion and gas was issuing from the vents. On the morning of September 27, at 9 o'clock, the temperature of the liquor in barrel No. 2 was 56° F., and in barrel No. 3, 57° F., the fermentation proceeding in a rather turbulent manner. On September 28 both casks were fermenting in an orderly manner and the microscopic examination showed the development of a slight growth of the false yeast form known as *Apiculatus*, but the great majority of the organisms were a pure yeast growth. The temperature of the room where these casks were stored varied, perhaps, from 60° to 80° F., as the recorded outdoor temperatures show maximums ranging from 53° to 79° F. and a mean of 51° F.

Daily examinations of the must to determine the organisms present were continued, with the result that the yeast growth was found to be entirely dominant. On October 4 the first fermentation was plainly subsiding; on October 8 both barrels had become practically quiet. The liquor in cask No. 2 was opalescent in color, not bright, had a fairly good head over the top, and no pomace in the juice. The taste was pleasant and fruity, and the cider seemed to be completing the first fermentation in a perfectly sound and promising condition. It was on this date racked off into a well-sulphured, clean barrel, and tightly bunged with the ventilating device before mentioned. On this date a chemical analysis was made of cask No. 2, which gave the following results:

Specific gravity		1.026
Total solids	grams per 100 cc.	6.80
Sugar	do	4.82
Alcohol	do	2.76
Acid as sulphuric	do	.43

The liquor in cask No. 3 was brighter than that in No. 2 and showed practically no head on the liquor. The cider had a slightly unpleasant flavor, differing in taste from No. 2. This barrel also was racked into a clean sulphured barrel, and a chemical analysis was made of the partially fermented cider with the following results:

Specific gravity		1.020
Total solids	grams per 100 cc.	5.72
Sugar	do	4.16
Alcohol	do	3.21
Acid as sulphuric	do	.50

Both casks were left lying side by side on the upper floor of the factory, and after racking repeated observations were made upon the condition of the cider until November 23. A slight difference could be observed during the entire time of the second fermentation in these two casks, yet both remained in a perfectly sound condition, and the microscopic examination after racking off showed the presence of only yeast organisms. There was apparently no growth whatever of the vinegar ferment or other deleterious organisms in these barrels.

On November 23 both barrels were bottled. A mixed collection of wine, apollinaris, and other somewhat nondescript bottles was used. These were all carefully cleansed with hot water and sterilized by rinsing with 35 per cent alcohol before filling. The corks were also sterilized by dipping in alcohol. This precaution was taken to prevent, as far as possible, the growth of such malorganisms as might be present, the casks having been kept under conditions favorable to the growth of malferments, and it was now desired to mature the cider in bottles. On the date of bottling a sample was taken from each cask, which gave the following analyses:

No. 2:		
Specific gravity		1.006
Sugar	grams per 100 cc	1.16
Alcohol	do	4.68
Acid as sulphuric	do	.48
No. 3:		
Specific gravity		1.003
Sugar	grams per 100 cc	.27
Alcohol	do	5.36
Acid as sulphuric	do	.55

After filling the bottles they were carried into a small cellar under the office building, laid down on the side, and left for further ripening of the cider. Both samples continued to ferment in the bottle, and the following notes were made on the changes which occurred:

NOTES.

December 29, 1901.—No. 2 was a clear amber liquor, with a rather yellowish tinge and a decided deposit of yeast cells. No. 3 had a beautiful, clear, bright amber color, with a very slight deposit, which seemed to be coagulated.

January 20, 1902.—The bottles from No. 2 contained a bright, clear amber liquor, with a fine, uncoagulated sediment. The liquor had become gaseous, and showed a transient but decided effervescence when poured into a glass. The flavor was good, with a fine bouquet. The chemical analysis at this time was as follows:

No. 2:		
Specific gravity		1.007
Total solids	grams per 100 cc	2.87
Sugar	do	1.02
Alcohol	do	4.44
Acid as sulphuric	do	.36

Thus it would appear that the alcohol and acid content of the cider declined slightly during this period of ripening in the bottle, and the sugar, as would be expected, also declined, but only to a small extent, while there was a fairly active growth of yeast, indicating that this growth was somewhat at the expense of alcohol and acid.

On the same date (January 20) No. 3 was examined. The liquor

was very bright, but rather paler in color than No. 2. The sediment was coagulated, but light and flocculent. There was no gas and the liquor was perfectly still on pouring. The cider was of good flavor, without roughness, bouquet faint, having the general characteristics of a sour claret wine. The analysis made on this date was as follows:

No. 3:

Specific gravity		1.003
Total solids	grams per 100 cc.	2.33
Sugar	do	.30
Alcohol	do	5.09
Acid as sulphuric	do	.53

January 24 to May 16.—The stock from both tests was rebottled by decanting, so as to clear the liquor of the sediment mentioned. The bottles used were prepared and cleansed as above stated and the corks were also sterilized. After this date observations were made at inter vals until May 16, 1902, when the last notes were made on No. 2. Though it had been rebottled, the liquor was bright and sparkling, slightly gaseous when poured, aroma very good, flavor excellent and free from roughness, and of a bright amber straw color. The analysis of No. 2 made at this time gave the following results:

No. 2:

Specific gravity		1.004
Total solids	grams per 100 cc.	2.60
Sugar	do	.98
Alcohol	do	4.43
Acid as sulphuric	do	.35

There was considérable sediment present in the bottles again, due to after-fermentation. The sugar, acid, and alcohol had remained almost constant, but there had been sufficient fermentation to slightly charge the cider. It was at this time pronounced by several who sampled it to be one of the finest ciders they had ever tasted, and equal to some grades of sparkling wine.

May 22.—No. 3 was given its last examination at this time. Though it had been rebottled as above stated, the liquor had become slightly gaseous, and showed an evanescent but decided effervescence in the glass; the color was a clear pale amber; the aroma very fine, fruity in quality, making altogether an excellent dry cider. While No. 2 had the character of a sparkling wine, this cider differed from it very decidedly, having, after the disappearance of the slight effervescence, more the character of a Graves wine. The chemical analysis of No. 3 made at this time gave the following results:

No. 3:

Specific gravity		1.003
Total solids	grams per 100 cc.	2.24
Sugar	do	.20
Alcohol	do	5.20
Acid as sulphuric	do	.48

The great difference observed in the character of these two ciders is borne out by a comparison of the analyses, and yet they were made from absolutely the same juice and handled alike in every particular, the yeast cultures alone being different. Both ciders were of remarkably good quality, but No. 2 was more to the average American taste, while No. 3 was considered the best by those who prefer a light, dry, sour cider.

WORK OF 1903–4.

No experiments were undertaken in the fall of 1902, because the fruit crop was so small that no stock could be obtained, but in the fall of 1903 a rather extensive series of cask experiments was again instituted, the more successful of which are here reported.

FIRST SERIES OF EXPERIMENTS, CASKS NOS. 6 TO 11.

These six experiments were all begun the same day and conducted as described in the following notes:

September 30, 1903.—The ordinary mixed stock of cider apples was ground in the power mill at the station and six 50-gallon casks were filled with the fresh must of identical character and transferred to a small cellar under the garden tool house, where they were sown with yeasts as specified in the reports on each cask. The casks were carefully cleansed with washing powder, scalded with a steam hose from the boiler, and then thoroughly rinsed with cold water before filling. A chemical analysis of the must fresh from the mill was made with the following results:

Stock must:		
Specific gravity		1.051
Total solids	grams per 100 cc.	13.04
Sugar (total)	do	10.08
Sugar (reducing)	do	7.31
Sucrose	do	2.63
Acid as sulphuric	do	.49
Tannin	do	.05

CASK EXPERIMENT NO. 6.

Cask No. 6 was sown on September 30, as soon as placed in the cellar, with one pint of must which had been sterilized and sown with yeast No. 8 on September 25, and was in full fermentation when used. The cask was plugged with a cotton plug, and later the ventilating tube was used as in the experiments of 1901. Yeast No. 8 was isolated from a very good Normandy cider obtained at the factory of the Union Agricole at St. Ouen-de-Thouberville, France.[a]

[a] This yeast was isolated by Mr. Alwood while working at Geisenheim, Germany.

NOTES.

Cellar conditions.—The general cellar conditions here noted will not be repeated for the other numbers of this series, as the casks stood side by side and were handled exactly alike.

October 1.—Fermentation under way and foam forming on liquor; temperature of must in barrel 66° F.; temperature of room 64° F.

October 2.—Fermenting slowly; temperature of room 62° F.

October 3.—Fermenting more slowly than the day before; temperature of room 60° F.

October 4.—Fermenting more vigorously; temperature of room 62.5° F.

October 5.—Temperature of room 62° F.

October 6.—Temperature of room 61° F.

October 7.—Temperature of room 62.5° F.

October 8.—Temperature of room 59° F.

October 9.—Temperature of room 55° F.

October 10.—Liquor in cask ochreous-yellow and turbid; indications of rapid sedimentation and subsidence of first fermentation; ordinary fermenting cider taste; no marked difference between the several experiments. Specific gravity of No. 6, 1.012. Microscopical examination shows yeast to be small, ovoid, apparently pure; no head on liquor; room temperature 30° F.; temperature of liquor in cask 57° F.; fermenting quietly. A decided cold spell ran the temperature of the room down sharply at this time.

October 20.—Fermenting slowly; slight foam resting on liquor. Temperature of the must 52° F.; liquor very cloudy and tastes of tannin; no aftertaste; cellar temperature 52° F. The first head has fallen and the after fermentation set in.

October 25.—Liquor of an opalescent amber color, clearer than at any previous date, and condition good; cellar temperature 48° F.; temperature of must 49° F.

October 27.—Sent to laboratory for partial analysis. Specific gravity, 1.004; alcohol, 4.76 grams, and sugar, 0.46 gram per 100 cc.

October 28.—Racked into a thoroughly clean, sulphured barrel; siphoned the liquor off to within 3 inches of the bottom of the barrel; temperature of the cellar 48° F. It will be seen by reference to the discussion of fermentation in Bulletin No. 71[a] that practically the German method of fermentation was pursued in this instance instead of the French method of racking after the subsidence of the first or tumultuous fermentation, which was followed in 1901 with casks Nos. 2 and 3. By the German method the sugar is practically exhausted before the first racking. It is a simple method, but can not, in the estimation of the authors, produce a cider which is equal in fine character to that secured by the French method.

[a] U. S. Dept. of Agr., Bureau of Chemistry, A Study of Cider and Cider Making, p. 102.

November 6.—Temperature of room 38° F.

November 9.—Temperature of room 46° F.

November 19.—Liquor pale straw color, fairly clear, but not bright; aroma mild and fruity; flavor mild. Specific gravity, 1.002.

December 22.—Bottled 75 quarts and removed to the cellar under the office building. The bottles in all experiments were laid flat. Liquor fairly clear, but not absolutely bright; flavor very good; aroma mild. The remainder of the liquor was left in the cask, properly bunged.

January 5, 1904.—Specific gravity of cider in cask, 1.002; temperature of cellar for some days has been below 35° F.

January 11.—Chemical analysis of cider in cask gave the following results:

Specific gravity		1.003
Solids	grams per 100 cc.	1.97
Sugar	do	.38
Alcohol	do	5.35
Acid	do	.49

January 25.—The cider remaining in the cask was drawn off without agitating and filtered through a gravity filter with a 10-foot fall. Liquor in fine condition; a little clouded in the barrel in comparison with the filtered cider, which is very bright, leaving nothing to be desired. It was found necessary to use one cloth and one paper disk to produce the desired result in the filter. The stock was bottled immediately from the filter in apollinaris bottles, then placed in the small cellar under the office building.

January 25.—The cider bottled on December 22 and placed in the cellar now shows a dirty, flocculent sediment. It is not, therefore, a first-class cider in appearance, but on sampling the liquor is found to be of a clear, amber color, not exactly bright; the aroma rich and fruity, and the flavor excellent—a fine dry cider.

April 19.—First bottling: Liquor fairly clear; straw color; heavy dark sediment; strongly gaseous; bubbles persistent; aroma good; flavor mild and desirable.

Second bottling: Liquor clear; fairly bright, pale straw color; streak of yeast on lower side of bottle, but not sufficient to interfere with marketing; slightly gaseous; good bead; fruity aroma; flavor good, but slightly rough.

May 9.—Second bottling: Color light amber; a little cloudy; slightly gaseous; odor pleasant; dry, sound; flavor a little acid. The filtered stock was not further noted as the samples were lost.

May 25.—First bottling: Liquor dull, lacks brightness in the bottle; a considerable quantity of coagulated sediment present; decidedly gaseous; pours fairly bright, sparkling; bouquet fairly strong and

very fruity; of a clouded straw color; flavor fairly smooth, sound, and slightly acid; medium as to quality. Chemical analysis as follows:

Specific gravity		0.999
Solids	grams per 100 cc	1.79
Total sugar	do	trace.
Alcohol	do	5.66
Acid	do	.33
Tannin	do	.049

This cider, made on the German system of inclusive fermentation, proved to be a fine, sound, apple wine, but its character when thus reduced to complete dryness (all sugar consumed by fermentation) is not generally pleasing to the American taste. After using it some time, however, it is well liked, and as long as the gas generated after bottling is not permitted to escape the cider will remain sound.

Cask Experiment No. 7.

The chemical analysis of the original must and also the notes on the cellar temperature throughout the experiment, as given under cask experiment No. 6, are true for the entire series, and are not repeated. This 50-gallon barrel was sown on September 30, 1903, with yeast No. 37, which culture had been prepared in the same quantity and manner as for cask No. 6. The barrel was at once plugged with cotton wool, and later fitted with the vent before mentioned. Yeast No. 37 was isolated by Mr. Alwood from the same source as No. 8. It is an especially strong yeast, and can be trusted to carry fermentation to completion promptly.

NOTES.

October 1.—Heavy foam already formed; gas in barrel extinguishes a taper promptly; the must shows temperature of 66° F.

October 2.—In rapid fermentation.

October 3.—Fermenting more slowly.

October 10.—Note as to condition same as for test No. 6; specific gravity, 1.019. Microscopic examination shows an abundance of small ovoid yeast cells; fermentation progressing quietly; no head on barrel; temperature of must, 57° F., the same as No. 6.

October 20.—Liquor very cloudy; flavor pleasant; no bitter taste; specific gravity, 1.007.

October 27.—A partial analysis showed a specific gravity of 1.006; total sugar, 0.96, and alcohol, 4.61 grams per 100 cc of cider.

October 28.—This cask was racked as in case of No. 6.

November 19.—Liquor pale straw color; fairly clear, but not bright. Aroma good; flavor very good; specific gravity, 1.004.

January 23, 1904.—Specific gravity, 1.005.

January 25.—A complete analysis gave the following results:

Specific gravity		1.004
Solids	grams per 100 cc	2.48
Sugar	do	.64
Alcohol	do	5.28
Acid	do	.43
Tannin	do	.041

January 28.—Bottled 75 quarts. The cider was filtered through a gravity filter, as in the case of cask No. 6, which left it fairly bright and clear. The remainder of the cider was left in the cask and bunged tightly. The color at this time was pale amber; aroma fruity; flavor good, that of a sound dry cider.

April 19.—The cider in the bottles was rather dull, with a strong yeast deposit, cloudy when shaken; decidedly gaseous; pours with good bead; fine bouquet; flavor slightly rough, but equal to No. 6.

This barrel was also handled on the German plan of cellar work, and the results indicate that while this plan produces a fine, sound, dry cider, it does not bring out those special qualities to be expected from the use of selected yeasts.

Cask Experiment No. 8.

The general notes are the same as for cask experiment No. 6. Cask No. 8 was sown on September 30, 1903, with 1 pint of yeast culture No. 66, prepared as for No. 6. Yeast No. 66 was isolated from a specially fine Pippin cider ten years old, procured from Huntington, Long Island, New York.

NOTES.

October 1.—Already in active fermentation; heavy foam resting on liquor, but air in barrel will still support flame; temperature of must, 66° F.

October 2.—Fermenting rapidly.

October 3.—Fermenting more slowly.

October 10.—Note as to condition same as for test No. 6, except that taste is a trifle inferior; specific gravity, 1.019. Microscopic examination shows yeast numerous, large, and round. No head on liquor; temperature of the must, 57° F.

October 20.—Note as to condition same as test No. 6; specific gravity, 1.008.

October 27.—A partial analysis gave a specific gravity of 1.005; alcohol 5.24 and sugar 1.28 grams per 100 cc of cider.

October 28.—Racked as in case of test No. 6.

November 19.—Liquor pale straw amber, fairly clear, but not bright; aroma very good; flavor very good; specific gravity, 1.004.

January 23, 1904.—Specific gravity, 1.002.

January 25.—Analysis gave the following results:

Specific gravity		1.003
Solids	grams per 100 cc	2.64
Sugar	do	.90
Alcohol	do	6.00
Acid	do	.39
Tannin	do	.034

January 28.—Bottled 75 quarts under same conditions as for test No. 7. Liquor slightly clearer than No. 7, not bright, pale amber; aroma rich and fruity; flavor very good—a fine dry cider.

April 19.—Liquor bright and beautiful; slight yeast deposit; not flocculent; bouquet good; flavor mild; a good, sour, still wine. This is the most promising American yeast isolated.

Cask Experiment No. 9.

General notes the same as on cask experiment No. 6. Cask No. 9 was sown with 1 pint of yeast culture No. 73, prepared as previously described. The barrel was plugged with cotton wool at once, and later closed with the ventilation apparatus. The origin of yeast No. 73 has been given under test No. 2.

NOTES.

October 1.—Fermentation well under way; heavy foam resting on must; no air in the barrel; temperature of the must, 66° F.

October 2.—Fermentation progressing rapidly.

October 3.—Fermenting more slowly. Microscopic examination shows yeast to be abundant and a few *Apiculatus* cells present.

October 10.—Condition same as in test No. 6; specific gravity, 1.012. Microscopic examination shows yeast to be abundant, large, and round. No head on liquor; temperature of must, 58° F.

October 20.—Liquor very cloudy; slight taste of tannin; aroma very good; specific gravity, 1.0025.

October 27.—Partial analysis showed a specific gravity of 1.003; alcohol 4.96 grams and sugar 0.31 gram per 100 cc of cider.

October 28.—Racked as in case of No. 6.

November 19.—Liquor slightly lighter in color than previous numbers; slight cloud, not exactly bright; aroma the best of all the tests and flavor very good; specific gravity, 1.001.

December 22.—Filled 75 quart bottles. Liquor clear, but not bright; flavor excellent; aroma fruity. The remaining cider was left in the barrel tightly bunged.

January 5, 1904.—Specific gravity, 0.999.

January 11.—Analysis of cider remaining in cask gave the following data:

Specific gravity		1.001
Solids	grams per 100 cc.	1.76
Sugar	do	.31
Alcohol	do	5.60
Acid	do	.38

January 25.—Bottled the remaining cider in cask. It was filtered through the gravity filter, as in the case of No. 6. The filtered liquor was absolutely clear and bright and of light straw color; aroma good; flavor very good, no aftertaste.

April 19.—First bottling: Liquor bright; pale straw color; heavy, dark deposit; strongly gaseous when opened; good bead on glass; bouquet good; flavor rough and strong, scarcely desirable.

Second bottling (filtered). Liquor same color as above; slight yeast deposit of light color; slightly gaseous when opened; mild effervescence in glass; bouquet good; flavor milder; not desirable.

May 25.—Second bottling (filtered): Cider in fine condition; apparently bright in bottle; a very flocculent but slight amount of yeast; almost still when opened; very slight amount of gas when poured; bouquet very mild, agreeable; color almost bright, pale amber; flavor very mild—a pleasant, slightly acid, entirely dry, good cider. Analysis of the second bottling at this date gave the following data:

Specific gravity		0.999
Solids	grams per 100 cc.	1.69
Total sugar	do	Trace.
Alcohol	do	6.36
Acid	do	.37
Tannin	do	.029

May 25.—First bottling: Far less bright in bottle than filtered sample, with more sediment, not all resting on the bottom; a slight granular flocculent precipitate throughout the entire liquor; slightly gaseous when opened, more so than in filtered sample, though not marked; pours off fairly bright, a pale straw color, decidedly lighter than filtered sample; bouquet faint and pleasant; flavor mild, equal to or a trifle better than filtered sample; decidedly a good cider. No analysis made.

June 20.—Samples of this cider, second bottling, filtered, were sent to Dr. H. W. Wiley, Chief of the Bureau of Chemistry, U. S. Department of Agriculture, and sampled and analyzed with two others, to be described later. He reports on July 18, 1904, that No. 9 "was pronounced by a party of three experts to have the finest flavor." This sample analyzed: Sugar, 0.068; alcohol, 6.31; acid, as sulphuric, 0.274

(as volatile acid, acetic, 0.037). While this experiment was carried out on the German model, this yeast (No. 73) has again, as in the tests of 1901 conducted on the French plan, given the best product.

CASK EXPERIMENT NO. 10.

General notes the same as on cask experiment No. 6. Cask No. 10 was sown on September 30, 1903, with 1 pint of culture of yeast No. 74, prepared as previously noted. The origin of yeast No. 74 is given under test No. 3.

NOTES.

October 1.—Fermentation started; heavy foam resting on must, but air still in barrel; temperature of must, 66° F.

October 2.—Fermentation progressing rapidly.

October 3.—Fermenting more slowly.

October 10.—Condition same as in test No. 6; specific gravity, 1.013. Microscopic examination shows yeast abundant, cells large and round, fermenting quietly.

October 20.—Liquor very cloudy; tastes of tannin, though very promising; specific gravity, 1.003.

October 27.—Partial analysis showed a specific gravity of 1.003; alcohol 5.48 grams and sugar 0.41 gram per 100 cc of cider.

October 28.—Racked as in case of test No. 6.

November 19.—Liquor a pale straw amber color; fairly clear, but not bright; aroma very good; flavor good; specific gravity, 1.001.

December 23.—Bottled 75 quarts unfiltered. Liquor clear, but not bright; aroma very good; flavor not quite so good as test No. 9. Remainder of cider left in barrel tightly closed.

January 5, 1904.—Specific gravity, 1.001.

January 13.—Analysis at this date of cider left in the cask gave the following results:

Specific gravity		1.001
Solids	grams per 100 cc	1.91
Sugar	do	.41
Alcohol	do	5.80
Acid	do	.44

January 26.—Bottled remainder of the cider, filtering as in case of No. 6; condition same as No. 9, except that No. 10 had a sour wine taste.

April 19.—First bottling: Liquor bright, pale straw color; heavy, dark deposit; strongly gaseous, good bead; bouquet good; flavor rather rough; not desirable.

Second bottling (filtered). Liquor the same; light sediment; not gaseous; bouquet same as above; flavor milder.

May 25.—Second bottling: In the bottle resembles No. 9; liquor bright and clear; slight gaseousness when opened, pours very bright;

bouquet not strong, but pleasant; flavor not very smooth, but good, clear; a fine acid; generally desirable; color, a pale amber shading to straw color. Analysis of this sample on this date gave the following results:

Specific gravity		0.998
Total solids	grams per 100 cc	1.73
Total sugar	do	Trace.
Alcohol	do	6.20
Acid	do	.37
Tannin	do	.046

May 25.—First bottling (unfiltered): In bottle, bright like filtered goods; shows a slight amount of flocculent granules resting in the liquor; practically like filtered product as to gaseousness; color an opalescent, pale amber, shading to straw color. Bouquet weak and a mild, pleasant flavor; apparently the same as the filtered sample. A sample of the second bottling of this cider was sent to Doctor Wiley, who says, "No. 10 has a good flavor, but not quite so good as No. 9." The analysis made at the Bureau of Chemistry, Department of Agriculture, is as follows:

	Grams per 100 cc.
Sugar	0.082
Alcohol	6.12
Acid, as sulphuric	.223
Acid volatile, as acetic	.037

CASK EXPERIMENT NO. 11.

The general notes are the same as those on cask experiment No. 6. Cask No. 11 was sown with 1 pint of culture of yeast No. 97 on September 30, 1903, the bung plugged with cotton, and later fitted with the ventilation apparatus. Yeast No. 97 was isolated at Blacksburg from a small preparation of must of Soulard crab. It has the peculiar characteristic of growing in test-tube cultures in colonies or coagulated masses, thus showing at all times a bright liquor.

October 1.—Fermenting actively; heavy foam on must; air already driven out of cask; temperature of must, 66° F.

October 2.—Fermentation progressing rapidly.

October 3.—Fermenting more slowly.

October 10.—Condition same as in test No. 6; specific gravity, 1.012. Microscopic examination shows yeast to be abundant; cells large, round.

October 20.—Same as test No. 6 as to quality; specific gravity, 1.002.

October 27.—Partial analysis showed a specific gravity of 1.002; alcohol 5.06 grams and sugar 0.28 gram per 100 cc of cider.

October 28.—Racked as in case of test No. 6.

November 19.—Liquor pale straw amber, fairly clear, but not bright; aroma fair; flavor fair; specific gravity, 1.002.

December 23.—Filled 75 quart bottles. Liquor clear, but not bright; aroma poor; flavor dry and insipid. Remainder of cider left in barrel bunged as usual.

January 5, 1904.—Specific gravity, 1.002.

January 13.—Analysis of stock in barrel gave the following results:

Specific gravity		1.002
Solids	grams per 100 cc.	1.83
Sugar	do	.25
Alcohol	do	5.03
Acid	do	.46

January 26.—Bottled remainder of cider, filtering as in case of No. 6. Liquor clear, bright amber; aroma a little unpleasant; flavor poor, dry, and insipid; not good.

April 19.—First bottling: Liquor very bright indeed; sediment abundant, flocculent, rather light in color; very gaseous, pours with good bead; bouquet mild; flavor pleasant. This sample has greatly improved.

Second bottling (filtered): Sediment abundant; bright color same as in first bottling; gaseous; bouquet mild and good; flavor milder than at the first bottling; desirable; decided improvement since bottling.

May 9.—Second bottling: Color a light amber; odor pleasant; nearly dry, flavor slightly milder than No. 6.

May 25.—First bottling (unfiltered): Not bright in bottle; slight yeast present; liquor opalescent; flavor slightly acid, but not unpleasant, dry; quality medium.

May 25.—Second bottling (filtered): In bottle its general appearance is opalescent, not bright and limpid; a heavy, dark sediment in bottom; strongly gaseous, pours fairly bright, with beautiful sparkling foam; bouquet pleasant, stronger than unfiltered sample; flavor a trifle rough, lacks clearness; sound and dry, quality medium. Analysis of filtered sample on this date gave the following results:

Specific gravity		0.999
Solids	grams per 100 cc.	1.76
Total sugar	do	Trace.
Alcohol	do	5.19
Acid	do	.34
Tannin	do	.051

SECOND SERIES OF EXPERIMENTS, CASKS NOS. 12 TO 15.

A second set of casks were filled and sown with yeast cultures on October 7, 1903, as a partial duplication of the first series, Nos. 6 to 11. In this series some other yeasts were introduced and the must used

had a slightly different composition. It was intended to bottle this set with a larger sugar content and thus vary the detail somewhat. Four casks were sown, viz, Nos. 12 to 15 with yeasts as specified under each number. On October 7, 1903, cull apples of a common stock were ground and a sample of the must sent to the chemist for analysis, which gave the following results:

Specific gravity		1.053
Solids	grams per 100 cc	13.66
Total sugar	do	11.66
Reducing sugar	do	7.87
Sucrose	do	2.97
Acid	do	.44
Tannin	do	.059

All the casks were cleansed and handled the same as Nos. 6 to 11, and were placed beside these former numbers; hence the general notes and cellar temperatures given for No. 6 after October 7 apply to this series of experiments also.

Cask Experiment No. 12.

Cask No. 12 was sown October 7, 1903, with 1 pint of pure culture of yeast No. 8. The origin of this yeast has been previously given under cask No. 6.

NOTES.

October 9.—Fermenting with vigor.

October 10.—Fermenting more rapidly.

October 20.—Fermentation slowing down; no head on liquor; temperature of the must, 53° F.; cellar temperature, 52° F.; a decidedly characteristic taste, very good, clearer than any of the first lot; specific gravity, 1.019.

October 25.—Cellar temperature, 48° F.; temperature of must, 49° F.; condition of cider, very good; opalescent amber, brightest in color of any number in the test.

October 27.—Partial analysis gave a specific gravity of 1.012; alcohol 3.77 and sugar 2.40 grams per 100 cc of cider.

October 28.—Racked as in case of test No. 6.

November 19.—Cider very dark amber; clear, but not bright; aroma very good; flavor excellent; specific gravity, 1.010.

January 23, 1904.—Specific gravity, 1.011.

January 26.—Analysis of this date gave the following figures:

Specific gravity		1.011
Solids	grams per 100 cc	3.84
Sugar	do	2.11
Alcohol	do	4.23
Acid	do	.54
Tannin	do	.034

This liquor was filtered through the gravity filter and 100 quarts were bottled. It was of a clear, bright, amber color; aroma very good; flavor excellent. This sample was lost and no further notes could be made. The sugar content of 2.11 gave it a character much more agreeable to the taste of most Americans than that of dry ciders.

CASK EXPERIMENT NO. 13.

This barrel was filled and sowed October 7, 1903, with yeast No. 66, in the manner previously described. The origin of this yeast is given under No. 8.

NOTES.

October 9.—Fermenting very rapidly.

October 10.—Fermenting rapidly.

October 20.—Condition same as in test No. 12, except that liquor is not quite so clear; specific gravity, 1.018; character that of ordinary fermenting cider.

October 25.—Temperature of must, 49° F.; liquor cloudy; specific gravity, 1.012.

October 27.—Partial analysis of tnis date gave a specific gravity of 1.010; alcohol 4.29 and sugar 1.72 grams per 100 cc of cider.

November 2.—Racked into a fresh barrel, previously well sulphured and rinsed with hot water.

November 19.—Cider a very dark amber; clear, but not bright; aroma good; flavor very good.

January 23, 1904.—Specific gravity, 1.006.

January 26.—Analysis on this date gave the following results:

Specific gravity		1.007
Solids	grams per 100 cc	3.06
Sugar	do	1.08
Alcohol	do	4.54
Acid	do	.42
Tannin	do	.042

January 27.—Filtered and bottled 25 quarts in apollinaris bottles and 50 quarts in common bottles. The cider is pale amber; clear, but not bright; aroma good; flavor good; a slight tannin taste; no aftertaste.

April 19.—Cider very bright, pale straw color, best in this series; slight flocculent yeast, very gaseous, foamed over when cork was drawn; bouquet best of all in test; flavor excellent; cider not yet mature.

May 9.—Color light amber, perfectly clear and bright; odor very pleasant, dry, aromatic; peculiar aromatic flavor very marked as compared with others.

May 25.—Bright, beautiful amber color; decidedly gaseous; pours with beautiful bead, clear, pale amber; decidedly fruity bouquet; flavor slightly acid. Analysis on this date resulted as follows:

Specific gravity		1.001
Solids	grams per 100 cc	1.83
Total sugar	do	.35
Alcohol	do	5.16
Acid	do	.35
Tannin	do	.042

This yeast produced in this case a fine grade of effervescing cider, equal to the best French mousseux ciders. While the general character of this cider is the same as that from yeast No. 73, cask 15, there is still a decided difference, which can not be readily defined in words. This difference would appear to be due to the character of the yeast used.

CASK EXPERIMENT NO. 14.

Cask No. 14 is omitted from this report because the results are not of sufficient interest to warrant presentation. It was sown with yeast No. 71, a form isolated from wine lees secured by Mr. Alwood from Alsace, Germany. This yeast is a peculiar form, always growing in coagulated masses and leaving a very clear, bright liquor in the fermentation flasks, but in barrel tests it has in no case shown any valuable characteristics.

CASK EXPERIMENT NO. 15.

General notes the same as for test No. 12. Cask No. 15 was filled and sown on October 7, 1903, with 1 pint of culture of yeast No. 73. The origin of this yeast has been previously given under No. 2.

NOTES.

October 9.—Fermenting slowly.

October 10.—Fermenting more rapidly.

October 20.—Fermenting moderately; temperature of must, 53.5° F. Character that of ordinary fermenting cider; specific gravity, 1.024.

October 25.—Temperature of must, 49.5° F.; cider, cloudy; flavor good; specific gravity, 1.014.

October 27.—Partial analysis on this date shows a specific gravity of 1.013; alcohol 3.85 and sugar 2.42 grams per 100 cc of cider.

November 2.—Racked as in case of test No. 13.

November 19.—Liquor dark amber, cloudy; aroma very good; flavor very good; specific gravity, 1.008.

January 23, 1904.—Specific gravity, 1.005.

January 27.—Analysis as follows:

Specific gravity		1.004
Solids	grams per 100 cc.	2.36
Sugar	do	.78
Alcohol	do	4.80
Acid	do	.34
Tannin	do	.039

January 29.—The cider was filtered through a gravity filter and 100 quarts put up in apollinaris bottles. It is clear, not quite bright; aroma excellent; slight flavor of tannin; no aftertaste; very good quality.

April 19.—Liquor very clear, color pale; yeast sediment light, flocculent; fairly gaseous when uncorked; good foam when poured; beautiful in glass; bouquet excellent; a promising cider.

May 9.—A fine, deep amber color; almost perfectly bright; odor very pleasant, very fragrant; bouquet of the best—fine, dry, and mild; fine flavor.

May 25.—Decidedly gaseous, sparkling; bright, clear amber, lighter than usual with this yeast; bouquet strong, pleasant, fruity; flavor mild, pleasant, agreeable; quality good; entire absence of rank, harsh taste; no after taste. Analysis on this date as follows:

Specific gravity		1.001
Solids	grams per 100 cc.	1.98
Total sugar	do	.35
Alcohol	do	5.37
Acid	do	.39
Tannin	do	.046

A sample sent to Washington in June was sampled by three experts and described as follows: "No. 15 is a sparkling cider, which property to a certain extent interferes with the delicacy of the determination, but it is pronounced also to be of excellent flavor." The analysis made in the Bureau of Chemistry gave a sugar content of 0.142; alcohol, 4.95; acid, as sulphuric, 0.216; and volatile acid (acetic), 0.059—as expressed in grams per 100 cc.

SPECIFIC GRAVITY AND CONTROL OF FERMENTATION.

The question of proper control of fermentation is one of very great importance, and the operator should be able to gauge at all times the rapidity with which the sugar is being consumed. This can be determined with more or less accuracy by the hydrometer readings, which indicate the specific gravity or density of the must or ferment-

ing liquor. However, these readings can not be implicitly relied upon because of the variable quantity of nonfermentable solids. No one has yet been able to devise a method by which gravity determinations can be made to indicate composition with chemical accuracy, but the table published on page 89 of Bulletin 71, Bureau of Chemistry, seems to come within such reasonable bounds of accuracy that it may be used as a guide in the fermentation room.

With a view to illustrating the use of this cellar table all the hydrometer readings taken during fermentation of the ciders made at this station, the chemical analyses made at the several stages of fermentation, and the approximate percentages of sugar and alcohol determined theoretically, have been arranged in parallel columns in Table VII. In those instances where only a hydrometer reading is given there is of course no comparison, but where alcohol and sugar determinations were made the comparison is direct and interesting. In a considerable number of instances the calculated or approximate percentages are close indeed to those actually determined by analysis, but in several instances they are wide apart. The peculiarities of yeast races has to do with this matter, as we have definitely proved that certain yeasts are able to produce a higher percentage of alcohol in identical musts than others. Also, when the theoretical table was compiled it was assumed that the nonsugar solids always exceeded 2 per cent in normal must and ciders, but this does not appear to be always true, as shown by the analyses of the special ciders made with pure yeasts at this station.

TABLE VII.—*A comparison of gravity determinations and analyses made at various stages of fermentation, with the percentages of sugar and alcohol calculated from gravity readings alone.*[a]

WORK OF 1901–2.

Date.	Sample.	Specific gravity.	Grams per 100 cc as determined by analysis.				Approximate percentages as calculated.	
			Total solids.	Sugar-free solids.	Total sugar.	Alcohol.	Total sugar.	Alcohol.
September 24	Original must	1.050					10.15	0.00
October 4	Test No. 2	1.026	6.80	1.98	4.82	2.76	5.35	2.40
November 23	do	1.006			1.16	4.68	1.35	4.40
January 20	do	1.007	2.87	1.85	1.02	4.44	1.55	4.30
May 16	do	1.004	2.60	1.62	.98	4.43	.95	4.60
October 4	Test No. 3	1.020	5.72	1.56	4.16	3.21	4.15	3.00
November 23	do	1.003			.27	5.36	.75	4.70
January 20	do	1.003	2.33	2.03	.30	5.09	.75	4.70
May 22	do	1.003	2.24	2.04	.20	5.20	.75	4.70

[a] For table of hydrometer readings, see page 89, Bul. No. 71, Bur. of Chem., U. S. Dept. of Agr.

TABLE VII.—*A comparison of gravity determinations and analyses made at various stages of fermentation, etc.*—Continued.

FIRST SERIES OF EXPERIMENTS, 1903–4.

Date.	Sample.	Specific gravity.	Grams per 100 cc as determined by analysis.				Approximate percentages as calculated.	
			Total solids.	Sugar-free solids.	Total sugar.	Alcohol.	Total sugar.	Alcohol.
September 30	Original must	1.051	13.04	2.96	10.08	0.00	10.38	0.00
October 10	Test No. 6	1.012					2.58	3.90
October 27	do	1.004			.46	4.76	.98	4.70
November 19	do	1.002					.58	4.90
January 5	do	1.002					.58	4.90
January 11	do	1.003	1.97	1.55	.38	5.35	.78	4.80
May 25	do	.999	1.79	1.75	Trace.	5.66	.00	5.19
October 10	Test No. 7	1.019					3.98	3.20
October 27	do	1.006			.96	4.61	1.38	4.50
November 19	do	1.004					.98	4.70
January 23	do	1.005					1.19	4.60
January 25	do	1.004	2.48	1.84	.64	5.28	.98	4.70
October 10	Test No. 8	1.019					3.98	3.20
October 27	do	1.005			1.28	5.24	1.18	4.60
November 19	do	1.004					.98	4.70
January 23	do	1.002					.58	4.90
January 25	do	1.003	2.64	1.74	.90	6.00	.78	4.80
October 10	Test No. 9	1.012					2.58	3.90
October 27	do	1.003			.31	4.96	.78	4.80
November 19	do	1.001					.38	5.00
January 5	do	.999					.00	5.13
January 11	do	1.001	1.76	1.45	.31	5.60	.38	5.00
May 25	do	.999	1.69	1.69	Trace.	6.36	.00	5.13
October 10	Test No. 10	1.013					2.78	3.80
October 20	do	1.003					.78	4.80
October 27	do	1.003			.41	5.48	.78	4.80
November 19	do	1.001					.38	5.00
January 5	do	1.001					.38	5.00
January 13	do	1.001	1.91	1.50	.41	5.80	.38	5.00
May 25	do	.998	1.73	1.73	Trace.	6.20	.00	5.19
October 10	Test No. 11	1.012					2.58	3.90
October 20	do	1.002					.58	4.10
October 27	do	1.002			.28	5.06	.58	4.90
November 19	do	1.002					.58	4.90
January 5	do	1.002					.58	4.90
January 13	do	1.002	1.83	1.58	.25	5.03	.58	4.90
May 25	do	.999	1.76	1.76	Trace.	5.19	.00	5.19

SECOND SERIES OF EXPERIMENTS, 1903–4.

October 7	Original must	1.053	13.66	2.00	11.66	0.00	10.84	0.00
October 20	Test No. 12	1.019					4.04	3.40
October 27	do	1.012			2.40	3.77	2.64	4.10
November 19	do	1.010					2.24	4.30
January 23	do	1.011					2.44	4.20
January 26	do	1.011	3.84	1.73	2.11	4.23	2.44	4.20
October 20	Test No. 13	1.018					3.84	3.50
October 25	do	1.012					2.64	4.10
October 27	do	1.010			1.72	4.29	2.24	4.30
January 23	do	1.006					1.44	4.70
January 26	do	1.007	3.06	1.98	1.08	4.54	1.64	4.60
May 25	do	1.001	1.83	1.48	.35	5.16	.44	5.20
October 20	Test No. 15	1.024					5.04	2.90
October 25	do	1.014					3.04	3.90
October 27	do	1.013			2.42	3.85	2.84	4.00
November 19	do	1.008					1.84	4.50
January 23	do	1.005					1.24	4.80
January 27	do	1.004	2.36	1.58	.78	4.80	1.04	4.90
May 25	do	1.001	1.98	1.63	.35	5.37	.44	5.20

COMPARISON OF ANALYTICAL DATA.

The final analyses of the finished ciders made in our experiments are brought together in Table VIII. An inspection of these data shows the remarkably uniform character of the ciders in regard to specific gravity, acid, and sugar-free solids. The three samples of must from which these various ciders were made were so nearly alike that no deduction can be made on this point; yet in alcohol content there is a striking variation throughout, and even in samples from the same must where the sugar is practically exhausted, as in tests Nos. 9 and 11, there is a whole per cent difference in alcohol content. This affects greatly the character of the beverage, and in other characteristics, as effervescence, aroma, and flavor, these ciders were very different. The indications are that there is here a fruitful field for further investigation.

The sugar content in all these ciders was low, and in several practically exhausted. No sucrose whatever was present, and in fact there never is any sucrose remaining in a properly fermented cider, as this form of sugar is promptly inverted during the first fermentation. Table VIII contrasts strangely with Tables IX and X, in which are presented the analyses of miscellaneous ciders collected for study and comparison.

TABLE VIII.—*Final analyses of the finished ciders made with pure yeast cultures at the Virginia station, 1901–4.*

Sample No.	Test No.	Yeast No.	Specific gravity.	Grams per 100 cc.					Remarks.
				Alcohol.	Acid as sulphuric.	Total sugar.	Total solids.	Sugar-free solids.	
137	2	73	1.004	4.43	0.35	0.98	2.60	1.62	Made from the same must, sp. gr. 1.050.
138	3	74	1.003	5.20	.48	.20	2.24	2.04	
304	6	8	.999	5.66	.33	Trace.	1.79	1.79	
305	7	37	1.004	5.28	.43	.64	2.48	1.84	
306	8	66	1.003	6.00	.39	.90	2.64	1.74	Made from the same must, sp. gr. 1.051.
307	9	73	.999	6.36	.37	Trace.	1.69	1.69	
308	10	74	.998	6.20	.37	Trace.	1.73	1.73	
309	11	97	1.003	5.37	.34	Trace.	1.76	1.76	
310	12	8	1.011	4.23	.54	2.11	3.84	1.73	
311	13	66	1.001	5.16	.35	.35	1.83	1.48	
312	14	71	1.005	4.76	.32	.75	2.39	1.64	Made from the same must, sp. gr. 1.053.
313	15	73	1.001	5.37	.39	.35	1.98	1.63	
314	16	97	1.000	5.00	.35	Trace.	1.59	1.59	
315	21	37	1.003	4.66	.41	.38	2.17	1.79	
316	18	74	1.001	5.09	.40	.27	1.93	1.66	
330	17	Wild.	1.005	5.48	.38	1.41	2.73	1.32	
Average			1.002	5.26	.39	.52	2.21	1.69	

Tables IX and X present the results of analyses of American-made ciders collected for comparison during this investigation, and analyzed at the Bureau of Chemistry and at the chemical laboratory of the Virginia Agricultural Experiment Station. Among these samples there are some of fine quality, as determined both by analysis and sampling. Those given in Table IX are among the best, but others of the comparatively dry ciders are commendable.

The important point in these tables is the great variation in composition of the beverages sold as cider. How shall we determine what a cider is until we have some definite idea as to how this beverage shall be fermented and handled so as to preserve its valuable properties? The fluctuations in sugar content from nothing to 13.56 per cent, and in alcohol content from nothing to 6.87 per cent, give the full range of variation from fresh apple juice to a completed cider. Between these extremes various compositions are sold as ciders. The samples showing such high sugar content are ordinarily treated with preservatives or sterilized by heat, as it is difficult to bottle and hold a liquid containing much above 1.5 or 2 per cent of sugar.

TABLE IX.—*Analyses of commercial samples of American-made ciders (Bureau of Chemistry, U. S. Department of Agriculture, 1901).*

Sample No.	Name or brand.	Specific gravity.	Grams per 100 cc.					
			Alcohol.	Total acids.	Volatile acids.	Reducing sugar.	Total solids.	Ash.
49	Sparkling draft cider, extra dry.	1.0053	4.66	0.2979	0.0890	1.15	3.39	0.2830
50	Sparkling draft cider	1.0101	4.42	.3508	.1340	2.11	4.67	.2880
51	Plain fermented cider	.9987	6.22	.3626	.0860	.00	2.86	.2920
52	Crab-apple cider	1.0178	4.37	.2372	.0490	3.34	6.70	.2770
53a	Paulding Pippin cider, 1900	1.0289	1.71	.4567	.0250	5.99	8.23	.2410
53	Same, 1899	1.0292	3.12	.....	.0220	5.17	9.03	.2830

TABLE X.—*Analyses of commercial samples of American-made ciders (Virginia Agricultural Experiment Station, 1901–4).*

Sample No.	Name.	Specific gravity.	Grams per 100 cc.								Preservatives.
			Alcohol.	Total acid as sulphuric.	Volatile acid.	Total sugar.	Reducing sugar.	Sucrose.	Total solids.	Sugar-free solids.	
139	Refined cider	1.025	2.69	0.57	0.038	4.54	4.54	0.00	7.27	2.73	Not tested.
140	Dry still cider	1.000	6.35	.28	.060	.08	.08	.00	2.45	2.37	Benzoic acid and saccharin.
141	.....do	1.000	6.27	.29	.076	.08	.08	.00	2.49	2.41	Do.
142	.....do	1.000	6.87	.31	.080	.00	.00	.00	2.17	2.17	Do.
143	Country cider	1.065	.35	.66	.021	13.52	12.73	.75	16.86	3.30	Benzoic acid.
144	Labeled champagne cider.	1.052	.00	.37	.....	9.16	8.50	.62	12.63	3.47	Not tested.
145	Gilson's cider	1.040	.95	.42	.....	8.86	7.29	1.49	9.84	.98	Do.
146	Paulding's pippin, 1901.	1.046	.87	.48	.....	9.02	8.12	.86	11.55	2.53	No preservatives.
317	"Extra Dry"	1.013	4.56	.57	.....	2.14	2.14	.00	4.41	2.27	Do.
318	Standard dry refined.	1.027	2.81	.43	.....	5.12	5.12	.00	7.29	2.17	Do.
331	Mott's sauterne	1.012	4.40	.52	.....	1.40	1.40	.00	4.05	2.65	Do.
332	Dry cider	1.004	4.36	.34	.....	.26	.26	.00	2.58	2.32	Salicylic acid.
333	Cider, 1903	1.010	4.07	.53	.....	.38	.38	.00	4.20	3.82	Do.
340	Cider B	1.026	2.45	.50	.....	5.93	5.93	.00	8.11	2.18	No preservatives.
341	C. C	1.005	4.71	.28	.....	1.19	1.19	.00	3.04	1.85	Do.
342	R. 1	1.032	3.40	.45	.....	7.36	6.97	.37	9.85	2.49	Do.
343	Golden russet	1.033	3.62	.63	.....	7.20	6.42	.74	9.89	2.69	Do.
344	Duffy's unfermented cider.	1.056	.09	.59	.....	11.37	11.08	.24	15.27	3.90	Do.

NOTES ON SAMPLES OF CIDERS FROM TABLES VIII, IX, AND X.

Sample 137.—A cider made with a pure yeast culture isolated at the Virginia Agricultural Experiment Station and known as Sauterne or No. 73. The cider was, when finished, a dry, effervescing or sparkling cider. It is discussed under test No. 2, 1901. The same yeast was used in tests Nos. 9 and 15, 1903.

Sample 138.—A cider made with a pure yeast culture isolated at the Virginia Agricultural Experiment Station and known as Vallée d'Auge or No. 74. This was a very dry cider. It is discussed under test No. 3, 1901. The same yeast was used in test No. 10, 1903.

Sample 304.—A cider made with a pure yeast culture isolated by Mr. Alwood at the Royal Pomological School, Geisenheim, Germany, and known as St. Ouen-de-Thouberville or No. 8. It is discussed under test No. 6. The same yeast was also used in test No. 12.

Sample 305.—A cider made with a pure yeast culture isolated as the above and known as yeast No. 37. It is discussed under test No. 7.

Sample 306.—A cider made with a pure yeast culture isolated at the Virginia Agricultural Experiment Station and known as yeast No. 66. It is discussed under test No. 8. The same yeast was used in test No. 13.

Sample 307.—A cider made with the same yeast, No. 73, as was used in sample 137. It is discussed under test No. 9. The same yeast was used in tests Nos. 2 and 15.

Sample 308.—Made with the same yeast, No. 74, as that used in sample 138. It is discussed under test No. 3. The same yeast was used in test No. 10.

Sample 309.—A cider made with a pure yeast culture isolated at the Virginia Agricultural Experiment Station from Soulard Crab and known as yeast No. 97. This cider is discussed under test No. 11.

Sample 310.—Made with the same yeast, No. 8, as was used in sample 304. Discussed under test No. 12.

Sample 311.—Made with yeast No. 66, the same as that used in sample 306. It is discussed under test No. 13.

Sample 312.—This cider was made with yeast No. 71, isolated at the Virginia Agricultural Experiment Station from wine lees brought from Alsace, Germany, by Mr. Alwood. The result of the fermentation was not such as to warrant special discussion. It is mentioned under test No. 14.

Sample 313.—This cider was made with yeast No. 73, used in samples 137 and 307. It is discussed under test No. 15.

Sample 314.—This cider was made with yeast No. 97, used also in sample 309. It is not given special discussion, because the results do not warrant particular mention.

Samples 315, 316, and 330.—Not discussed for like reasons.

Sample 49.—A comparatively dry cider, made in a large factory with ordinary or wild yeast fermentation; slightly gaseous from flask fermentation.

Sample 50.—A cider from the same source, not fermented so dry, and charged by natural yeast fermentation.

Sample 51.—A cider from the same source, fermented perfectly dry, uncharged.

Sample 52.—A special brand of cider made from selected crab apples and only partially fermented before bottling; heavily charged by natural fermentation.

Sample 53a.—A special cider made from selected pippins in 1900, only partially fermented, and bottled while sweet; heavily charged by natural fermentation.

Sample 53.—The same brand of cider from the same factory, made in 1899. It shows greater alcoholic strength and was more heavily charged by natural fermentation.

(The last three samples were bottled in heavy champagne bottles and foamed over on drawing the cork. All were extra fine ciders.)

Sample 139.—A refined cider made in Vermont. The stock was one year old and only partially fermented.

Sample 140.—A dry, still cider from New York. This was a cider made from must sown with a pure yeast furnished by the Virginia station.

Sample 141.—A cider like sample 140, made in a like manner and by the same parties.

Sample 142.—From the same cellars as samples 140 and 141; a similar cider made with natural yeasts.

Sample 143.—A country-made cider, or so called. The analysis showed that it was not a cider, as only slight fermentation had taken place. The liquor was very turbid and muddy looking, and was heavily treated with benzoic acid to prevent fermentation. This sample was quite unfit for use, though it was not worse than many ciders commonly sold.

Sample 144.—Labeled "Champagne cider." This was also a country cider of somewhat better character so far as the appearance of the juice was concerned, but quite unfermented. From the examination it appeared that the apple juice had been filtered, heated so as to destroy the organisms present, and bottled. Such a preparation is not a cider.

Sample 145.—A country cider shipped in small kegs to the city for hotel use. The analysis shows that this cider also was only slightly fermented, and the liquor was in a muddy, uninviting condition. Like No. 243 it was scarcely fit for use.

Sample 146.—This was a sample of bottled cider in fine condition in so far as the condition of the juice was concerned, but it had been bottled almost without fermentation, and unless sterilized or stored in a very cold place the bottles would surely have burst in time. It is not possible to carry in bottles 9 per cent of total sugar without sterilizing, placing in cold storage, or using preservatives.

Sample 317.—Labeled "Extra dry refined cider." Chemical analysis shows that it contained over 2 per cent of sugar, so that it certainly could not be called a dry cider, and unless sterilized or processed even this quantity of sugar is liable to burst any but the best bottles.

Sample 318.—Labeled "Standard dry refined cider." This sample shows by analysis over 5 per cent of sugar; hence it is in no sense a dry cider, and could not well be held in ordinary bottles without sterilization or the use of preservatives.

Sample 331.—This cider was made by the same persons who furnished the two previous samples, from Sauterne yeast obtained from the Virginia station. It has very much the character of the cider made from Sauterne yeast at the station, and far excelled samples 317 and 318. The analysis shows 1.40 per cent of sugar, a desirable amount for ordinary use.

Sample 332.—Labeled "Dry cider," and the analysis shows that practically all the sugar had been consumed.

Sample 333.—A cider resembling sample 332, and made by the same person.

Sample 340.—An ordinary refined cider made by a large manufacturer. This cider was fermented partially, then refined by filtering through paper pulp. While this produced a fine, clear liquid, it did not remove all the yeasts, and this cider when bottled became very gaseous. Though put up in champagne bottles, there was danger of bursting them if kept long in a warm room. The percentage of sugar was entirely too high for bottled goods. The character of the cider was fair; it was deficient in flavor and bouquet.

Sample 341.—Made from ordinary apples by the same manufacturers as sample 340 and fermented to 0° on the Black cider spindle, then refined with wine finings and bottled. Though it showed the same per cent of sugar as the previous sample, this cider was perfectly still when opened. It had a bright and fine color, but in bouquet and flavor left much to be desired; in fact, it was scarcely palatable.

Sample 342.—A cider made by the same manufacturers as samples 340 and 341, from a fine grade of apples, partially fermented, refined through paper pulp, and bottled. The chemical analysis showed 7 per cent of sugar in this sample, and yet it was perfectly still when opened and no fermentation could be detected. The flavor of this cider was very objectionable, almost unpalatable. How it was preserved with-

out further fermentation in bottles is not understood, as the ordinary preservatives could not be detected.

Sample 343.—A so-called champagne cider made from fine apples and fermented down to 14° on the Black cider spindle; then clarified, bottled, and charged artificially with gas. This was a very beautiful bright cider, sparkling like champagne when opened, and made a fine appearance in the glass. It was not of very good quality, but was greatly improved by the presence of the gas. This cider showed over 7 per cent of sugar, yet after uncorking it stood for a month in the laboratory without showing the slightest fermentation. Notwithstanding this, none of the ordinary preservatives could be detected in it. Sown with a fresh yeast culture it fermented slowly.

Sample 344.—A beautiful, clarified sample of apple juice, unfermented. This juice had been refined in a most skillful manner, bottled, and charged artificially with gas. Apparently no fermentation had taken place in it and the juice was fresh as when put up. When exposed it fermented readily, indicating the absence of chemical preservatives.

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