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A STUDY OF AMERICAN BEERS AND ALES.

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CONTENTS.

INTRODUCTION.

The investigation, the results of which are reported in this bulletin, was undertaken for the purpose of securing information in regard to the composition of brewery products made in this country. The main object of this investigation was to find, if possible, a means of distinguishing beers and ales made entirely from malt from those made from malt together with other cereal products, such as rice, corn, and cerealin.

It was concluded, after looking into the literature, that in order to accomplish this purpose it would be necessary to collect a series of samples made from the various raw materials ordinarily used and make a study of the effect of these raw materials upon the composition of the finished product.

The investigation seemed desirable for the reason that practically all of the existing data related to foreign beers, in the preparation of which a type of malt was used entirely different from that ordinarily used in the production of American beers. Furthermore, very few of the existing data relating either to foreign or domestic beers were based upon samples concerning which exact information was available in regard to the raw materials used in the wort.

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METHOD OF UNDERTAKING THE INVESTIGATION.

It was felt that it would be wholly unsatisfactory to make this investigation by means of laboratory brewings on a small scale, as the results thus obtained would not show the true conditions, because it is not possible in the laboratory to duplicate exactly the mashing or fermenting processes actually used in a commercial way. It was decided, therefore, to attempt, with the cooperation of several breweries, to make this study under the exact conditions prevailing in commercial plants. Access was secured to several breweries making different types of products from various kinds of raw materials, under such conditions that it was possible to obtain a complete history of the beer through its various stages to the finished product. One of the writers (Riley) watched the method of manufacture during its whole process and obtained samples of the product at the various stages of manufacture. Thus, it was possible to procure finished samples with practically the same degree of certainty, as regards knowledge of composition and history, as would have been the case had they been prepared in the laboratory.

In three different breweries manufacturing a wide range of products samples of the wort and beer were obtained in this manner, the entire process of manufacture being studied in detail. A record showing the kind and amount of raw materials placed in the mash and in the cooker was made of the samples collected from these three breweries. A record also was kept of the time and temperature of each operation until the mash was ready to run into the kettle. The filtering and sparging [1] of the mash, the time of boiling in the kettle, the amount of hops added and the point at which they were added, and the break [2] of the wort were all noted. After the wort had been pumped from the kettle its course was followed through the hop jack [3] over the coolers to the settling tank. The specific gravity or Balling [4] of the original wort, the temperature at which the product was pitched,[5] the aeration of the wort, the kind and amount of yeast added, as well as the time and maximum temperature of the primary fermentation, also were noted. The course of the beer through the storage vats, chip casks, and filters to the racks was watched, and samples of the wort and of the beer in its various stages of production were collected and examined.

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[1] Washing the grains with hot water to remove the extract or valuable constituents as completely as possible.

[2] Precipitation and uniting, in the form of flakes, of the coagulable albuminoids, leaving the liquid clear.

[3] A filtering tank.

[4] Percentage of solids in the liquor according to the Balling hydrometer.

[5] Pitching is the operation of adding the yeast to the wort.

METHODS OF ANALYSIS.

The methods of analysis used were those given in Bulletin 107, revised (U. S. Dept. Agr., Bur. Chem.), pages 90–94, with the exception that the determination of phosphoric acid was made by the method used in fertilizer analysis (ibid., pp. 2–5), destroying the organic material in the beer by digestion with strong sulphuric acid and nitric acid and determining the phosphoric acid finally by the optional volumetric method (ibid., p. 4). The uranium acetate method given for beers was not used, for the reason that it was found to be exceedingly difficult to obtain accurate results on dark-colored beers.[1]

It was found in the estimation of dextrin by the Sachsse-Allihn method (ibid., p. 91) that there is an error in the method of calculation of the amount of dextrose formed from the amount of maltose in the original beer. Instead of multiplying the amount of maltose in the original beer by the factor 0.9, it should be multiplied by the factor 1.053, as 1 gram of anhydrous maltose yields, on hydrolysis, 1.053 grams of dextrose. The product is the quantity which should be subtracted from the total amount of dextrose found after hydrolysis. The extract in the beer was determined by use of the tables of Schultz and Ostermann (ibid., pp. 209–213). The same methods were used in the analyses of the worts as were used in the examination of the beers.

RESULTS OF ANALYSIS.

Tables I to IV contain the results of the analyses of the worts and finished fermented products obtained at the various breweries where this investigation was conducted, arranged so as to show readily the changes which took place during fermentation and, in a few cases, the changes which took place during storage. The results are all given in terms of grams per 100 cc, so that a direct comparison of the quantities of any particular ingredient in a definite volume of material may be made. The comparison of the grams per 100 cc of an ingredient in the wort, with the grams per 100 cc in the finished fermented product, is based on the assumption that there is no appreciable change in the volume of the wort during fermentation.

In Table I are given the results of the analyses of 7 malt worts and the beers produced from them. Table II contains the results of the analyses of 2 malt-and-rice worts and 2 malt-and-corn worts, and

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[1] Riley, in his report to the Association of Official Agricultural Chemists for the year 1913, stated that the method giving the most uniform results was that of ashing the beer with an excess of standard calcium acetate, and that while the moist combustion method in the hands of those familiar with it gave satisfactory results, the various collaborators working with the method did not get as uniform results as with the method of ashing with calcium acetate. J. Assoc. Off. Agr. Chemists 1 (1915), 138–143.

the beers produced from them. In Table III are given the results of the analyses of 4 porter worts and the finished porters produced from them. The results of the analyses of 9 ale worts and the finished ales are shown in Table IV. In these four tables the extract in the original wort has been calculated by multiplying the alcohol (expressed in terms of grams per 100 cc) by 2, and adding to the product the extract of the beer, porter, or ale (expressed in terms of grams per 100 cc). In the porter and ale worts a percentage of dextrose had been added as brewer's sugar. Since dextrose reduces more copper than does maltose in the determination of the sugars, in order to obtain the true percentage of total sugars it was necessary to calculate the amount of copper reduced by the known amount of dextrose present, and then to calculate the amount of maltose. The results thus obtained are given in Tables III and IV under the heading "Reducing sugars as anhydrous maltose."

TABLE I.—*Analyses of all-malt worts and of the beers made from them.*

Sample No.	Product.	Date of taking sample.	Specific gravity at 15.6° C./15.6° C.	Alcohol.	Extract.	Extract in original wort (calculated).	Degree of fermentation.	Total acids as lactic.	Volatile acids as acetic.	Reducing sugar as anhydrous maltose.	Dextrin.	Protein (N×6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Color (Lovibond) in ¼-inch cell.
				Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*		*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Degrees, brewer's scale.*
		1911.														
22013-D	Wort....	July 5	1.0518	....	13.75	....	....	0.198	0.001	9.79	....	0.862	0.231	0.098	....	13.0
22017-D	Beer....	July 12	1.0125	3.85	5.16	12.86	59.88	.216	.001	1.34	2.33	.611	.209	.080	0.67	12.0
22014-D	Wort....	July 6	1.0517	....	13.71	....	....	.198	.001	9.79	....	.876	.228	.095	....	13.0
22018-D	Beer....	July 13	1.0124	3.91	5.16	12.98	60.25	.225	.002	1.36	2.06	.614	.201	.078	.93	13.0
....	Wort....	July 7	1.0517	....	13.71	....	....	.207	.001	10.04	....	.852	.252	.099	....	13.0
22019-D	Beer....	July 14	1.0135	3.83	5.44	13.10	58.47	.234	.002	1.55	....	.610	.215	.082	....	9.0
22015-D	Wort....	July 8	1.0517	....	13.70	....	....	.198	.001	9.86	....	.841	.240	.097	....	13.0
22020-D	Beer....	July 15	1.0130	3.72	5.22	12.66	58.77	.236	.002	1.59	2.23	.639	.206	.081	.55	11.0
22016-D	Wort....	July 10	1.0515	....	13.68	....	....	.225	.001	9.84	....	.845	.245	.097	....	13.0
22021-D	Beer....	July 17	1.0147	3.66	5.66	12.98	56.39	.221	.001	1.85	2.18	.635	.208	.082	.78	10.0
		1912.														
16289-C	Wort....	Feb. 29	1.0455	....	12.05	....	....	.216	.001	7.40	....	.917	.232	.095	....	4.0
16289-C	Beer....	Mar. 7	1.0171	3.02	6.01	12.11	49.88	.230	.003	1.35	2.73	.757	.246	.082	.83	3.0
20714-D	Do....	Apr. 18	1.0167	3.12	5.90	12.14	51.40	.243	.012	1.47	2.68	.732	.229	.090	.79	3.0
16299-C	Wort....	Mar. 1	1.0454	....	12.02	....	....	.180	.001	7.41	....	.874	.238	.101	....	2.0
16299-C	Beer....	Mar. 18	1.0180	2.87	6.16	11.94	48.07	.234	.012	1.40	2.82	.737	.240	.090	.96	2.0

TABLE II.—*Analyses of malt-and-rice and malt-and-corn worts and of the beers made from them.*

Sample No.	Raw materials.	Product.	Date of taking sample.	Specific gravity at 15.6° C./15.6° C.	Alcohol.	Ex-tract.	Extract in original wort (calculated).	Degree of fermentation.	Total acids as lactic.	Volatile acids as acetic.	Reducing sugars as anhydrous maltose.	Dex-trin.	Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Color (Lovibond) in ¼-inch cell.
					Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*		*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Degrees, brewer's scale.*
22026-D	80 per cent malt and 20 per cent rice.	Wort	July 24, 1911	1.0459	....	12.15	....	....	0.124	0.001	8.64	....	0.714	0.193	0.069	....	2.0
22032-D	Do	Beer	July 31, 1911	1.0121	3.31	4.80	11.42	57.97	.275	.003	1.18	2.47	.519	.150	.055	0.48	2.0
22036-D	Do	Wort	Aug. 9, 1911	1.0464	....	12.30	....	....	.126	.001	8.70	....	.624	.204	.072	....	2.0
22042-D	Do	Beer	Aug. 16, 1911	1.0139	3.18	5.23	11.59	54.87	.243	.003	1.57	2.41	.400	.156	.057	.69	2.0
16269-C	60 per cent malt and 40 per cent corn.	Wort	Dec. 5, 1911	1.0489	....	12.95	....	....	.144	.003	9.05	....	.461	.229	.066	....	....
16271-C	Do	Beer	Dec. 12, 1911	1.0149	3.45	5.68	12.58	54.85	.171	.013	1.63	2.49	.308	.213	.056	1.04	....
16287-C	Do	do	Mar. 12, 1912	1.0159	3.33	5.76	12.42	53.62	.180	.014	1.87	2.36	.327	.208	.056	.99	....
16270-C	Do	Wort	Dec. 6, 1911	1.0496	....	13.14	....	....	.144	.003	9.32	....	.498	.216	.067	....	....
16272-C	Do	Beer	Dec. 13, 1911	1.0152	3.41	5.61	12.43	54.87	.171	.013	1.59	2.58	.314	.203	.050	.93	....
16286-C	Do	do	Mar. 12, 1912	1.0157	3.29	5.68	12.26	53.67	.175	.014	1.88	2.58	.314	.222	.058	.69	....

TABLE III.—*Analyses of porter worts made from malt, cerealin, and brewer's sugar, and of the porters made from these worts.*

Sample No.	Product.	Date of taking sample.	Specific gravity at 15.6° C./15.6° C.	Alcohol.	Extract.	Extract in original wort (calculated).	Degree of fermentation.	Total acids as lactic.	Volatile acids as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.	Protein (N×6.25)	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Color (Lovibond) in ¼-inch cell.
		1911.		*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*		*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Degrees, brewer's scale.*
22023-D	Wort	July 20	1.0572	....	15.25	....	....	0.270	0.002	8.67	....	0.696	0.227	0.069	....	58.0
22028-D	Porter	July 26	1.0151	4.30	6.02	14.62	58.82	.324	.003	1.07	3.34	.482	.208	.052	0.92	59.0
22046-D	....do	Aug. 21	1.0135	4.48	5.70	14.66	61.12	.380	.002	1.07	3.19	.482	.182	.051	.78	60.0
22038-D	Wort	Aug. 11	1.0625	....	16.66	....	....	.234	.002	9.74	....	.685	.232	.072	....	65.0
22044-D	Porter	Aug. 18	1.0165	4.75	6.60	16.10	59.01	.342	.002	1.42	3.48	.477	.196	.053	1.02	60.0
22045-D	Wort	Aug. 18	1.0623	....	16.62	....	....	.234	.002	9.68	....	.667	.224	.069	....	55.0
29501-B	Porter	Aug. 25	1.0170	4.72	6.72	16.16	58.42	.288	.002	1.41	3.62	.482	.201	.058	1.01	55.0
22025-D	Wort	July 21	1.0633	....	16.87	....	....	.234	.004	10.25	....	.721	.214	.073	....	70.0
22031-D	Porter	July 28	1.0178	4.70	6.96	16.36	57.46	.378	.002	1.40	3.68	.476	.194	.055	1.21	60.0
22049-D	....do	Aug. 24	1.0162	4.82	6.54	16.18	59.58	.306	.003	1.44	3.44	.479	.189	.053	.99	60.0

TABLE IV.—*Analyses of ale worts and of the ales made from them.*

Sample No.	Raw materials.	Product.	Date of taking sample.	Specific gravity at 15.6° C./15.6° C.	Alcohol.	Extract.	Extract in original wort (calculated).	Degree of fermentation.	Total acids as lactic.	Volatile acids as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.	Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined	Color (Lovibond) in $\frac{1}{4}$-inch cell.
					Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*		*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Grams per 100 cc.*	*Degrees, brewer's scale.*
22024-D	Malt, cerealin, and brewer's sugar.	Wort	1911. July 21	1.0608	....	16.24	....	....	0.153	0.001	10.00	....	0.788	0.230	0.059	....	4.0
22030-D	....do	Ale	July 27	1.0139	4.82	5.93	15.57	61.91	.225	.003	1.16	3.23	.425	.194	.039	0.92	5.0
22047-D	....do	Ale after storage.	Aug. 22	1.0124	4.97	5.62	15.56	63.88	.270	.003	1.43	2.69	.441	.180	.038	.88	5.0
22034-D	....do	Wort	Aug. 7	1.0610	....	16.30	....	....	.153	.003	10.24	....	.771	.214	.060	....	5.0
22039-D	....do	Ale	Aug. 14	1.0123	5.11	5.67	15.89	64.32	.225	.003	1.26	2.85	.471	.186	.043	.90	5.0
29504-B	....do	Ale after storage.	Oct. 6	1.0106	5.26	5.28	15.80	66.58	.225	.003	1.10	2.60	.462	.189	.041	.93	5.0
22037-D	....do	Wort	Aug. 10	1.0611	....	16.32	....	....	.149	.002	10.60	....	.763	.209	.057	....	4.0
22043-D	....do	Ale	Aug. 17	1.0124	4.93	5.62	15.48	63.69	.216	.003	1.40	2.82	.441	.172	.043	.79	4.0
22022-D	Malt and cerealin	Wort	July 19	1.0642	....	17.10	....	....	.180	.002	10.19	....	.776	.212	.072	....	3.0
22027-D	....do	Ale	July 26	1.0133	5.17	5.95	16.29	63.47	.207	.004	1.25	3.28	.500	.192	.055	.73	3.0
22035-D	....do	Wort	Aug. 8	1.0668	....	17.80	....	....	.189	.002	10.99	....	.776	.212	.072	....	3.0
22040-D	....do	Ale	Aug. 15	1.0145	5.34	6.30	16.98	62.90	.293	.004	1.42	3.31	.541	.192	.051	.84	4.0
16267-C	....do	Ale after storage.	Nov. 15	1.0134	5.52	6.11	17.15	64.37	.234	.004	1.65	2.76	.506	.213	.053	.98	3.0
29506-B	....do	Wort	Oct. 10	1.0760	....	20.23	....	....	.198	.001	11.19	6.81	.959	.294	.077	.98	3.0
29512-B	....do	Ale	Oct. 17	1.0253	5.43	9.19	20.05	54.16	.369	.008	2.69	4.39	.671	.273	.058	1.17	3.0
13922-D	....do	Ale after storage.	1912. Jan. 3	1.0208	5.80	8.18	19.78	58.64	.360	.008	2.54	3.42	.622	.275	.057	1.32	4.0
29507-B	....do	Wort	1911. Oct. 11	1.0767	....	20.40	....	....	.198	.001	12.14	5.59	.965	.282	.078	1.42	3.0
29514-B	....do	Ale	Oct. 18	1.0228	5.67	8.52	19.86	57.10	.360	.005	2.51	4.08	.664	.256	.057	1.01	2.0
29513-B	....do	Wort	Oct. 18	1.0781	....	20.75	....	....	.198	.002	11.73	5.95	.936	.300	.075	1.83	2.0
29519-B	....do	Ale	Oct. 24	1.0244	5.53	9.00	20.06	55.13	.281	.006	2.62	4.31	.671	.255	.057	1.14	2.0
13923-D	....do	Ale after storage.	1912. Jan. 2	1.0210	5.67	8.18	19.52	58.09	.360	.013	2.54	3.61	.603	.282	.064	1.15	4.0
22050-D	....do	Wort	1911. Aug. 23	1.0793	....	21.05	....	....	.270	.003	11.41	6.34	.864	.326	.091	2.11	75.0
29503-B	....do	Stout	Aug. 30	1.0242	5.69	9.02	20.40	55.78	.558	.003	2.03	4.54	.735	.286	.071	1.42	69.0

A study of these tables shows very clearly that during fermentation marked changes are brought about other than the mere conversion of sugar into alcohol. While it is well known that these changes take place it seems worth while to consider them here, because no similar study relating to American brewery products has been published. Further since we have the exact analysis of the wort and of the beer which was made from it, we have a special opportunity to examine quantitatively some of these changes, such as the production of alcohol, the fermentation of dextrin, the development of acids, and the losses of protein, ash, and phosphoric acid during fermentation.

In order to study the question of the yield of alcohol, to test the present factor used for the calculation of the solids in the original wort, and to show the approximate amount of dextrin, calculations were made, the results of which are presented in Table V.

TABLE V.—*Changes taking place in the conversion of worts into beers and ales.*

Product.	Loss in solids.	Loss in sugar.	Alcohol.	Loss in solids divided by alcohol.	Difference between loss in solids and loss in sugar.
	Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*		*Grams per 100 cc.*
Beer (all-malt)	8.59	8.45	3.85	2.23	0.14
Do	8.55	8.43	3.91	2.18	.12
Do	8.27	8.49	3.83	2.13	.22
Do	8.48	8.27	3.72	2.27	.21
Do	8.02	7.99	3.66	2.19	.03
Beer (60 per cent malt and 40 per cent corn)	7.27	7.42	3.45	2.10	.15
Do	7.53	7.73	3.33	2.00	.20
Beer (80 per cent malt and 20 per cent rice)	7.35	7.46	3.31	2.22	.11
Do	7.07	7.13	3.18	2.22	.06
Beer (all-malt)	6.04	6.05	3.02	2.00	.01
Do	5.86	6.01	2.87	2.04	.15
Average for beers				2.14	.04
Porter (small)	9.23	7.60	4.30	2.14	1.63
Porter (large)	9.91	8.32	4.70	2.10	1.59
Do	10.06	8.27	4.75	2.11	1.79
Do	9.90	7.82	4.72	2.09	2.08
Ale	10.31	8.84	4.82	2.13	1.47
Do	10.63	8.98	5.11	2.08	1.65
Do	10.70	9.20	4.93	2.17	1.50
Do	11.15	8.94	5.16	2.15	2.21
Do	11.50	9.57	5.34	2.15	1.93
Do	11.62	9.06	5.35	2.17	2.56
Pale ale	11.04	9.50	5.43	2.03	1.54
Do	11.88	9.63	5.67	2.09	2.25
Do	11.75	9.11	5.53	2.12	2.64
Brown stout	12.03	9.38	5.69	2.11	2.65
Average for ales				2.12	1.96
Average for beers and ales				2.13	

In Table V have been collected results (calculated from Tables I–IV) which show the loss in solids between the wort and the finished fermented product, the loss in sugar, the yield of alcohol, the loss in solids divided by the alcohol, and the difference between the loss in solids and the loss in sugar. By dividing alcohol into loss in solids there was secured a factor which makes possible the estimation of the solids in the original wort, provided that alcohol and extract are known. This factor also shows the yield of alcohol for a given amount of solids disappearing during fermentation. It has been found in the case of the beers that this factor averages 2.14, while in the case of the ales it averages 2.12, making an average for all of the products of 2.13. This clearly shows that in the yield of alcohol for a given amount of fermentable solids there is no appreciable difference between top fermentation products, such as ales, and bottom fermentation products, such as beers.

A marked difference in loss in solids is shown, however, when we compare the beers with the ales. In the case of the beers we find there is practically no difference between the loss in solids and the loss in sugar, while in the case of the porters and ales there is a very appreciable difference. The difference between the loss in solids and the loss in sugar is only 0.04 per cent for all of the beers; while in the case of the porters and ales the difference varies from 1.47 per cent to 2.65 per cent, with an average of 1.96 per cent. These figures clearly show that in the case of the porters and ales there has been some material other than sugar fermented. Unfortunately, the determination of dextrin was not made in all of the worts, so that the actual decrease in dextrin can be shown only in a few cases. But in those cases where we have the actual results the difference between loss in solids and the loss in sugar compares very closely with the actual amount of dextrin disappearing during fermentation.

DEVELOPMENT OF ACIDS DURING FERMENTATION.

A comparison of the amounts of volatile and fixed acids in the worts and in the finished beers shows that normally there is no appreciable development of volatile acid during fermentation and only a slight increase in the fixed acid. This increase in fixed acid averages in the case of the beers 0.049 per cent, while in the case of the ales the increase averages 0.103 per cent.

DECREASE IN PROTEIN, ASH, AND PHOSPHORIC ACID.

A general study of the preceding tables will show that there is an appreciable loss of protein, ash, and phosphoric acid during the fermentation. Table VI has been prepared to show the average loss during fermentation of the various classes of worts with respect to their protein, ash, and phosphoric acid contents.

TABLE VI.—*Average loss during fermentation.*

Kind of wort.	Protein.	Ash.	Phosphoric acid.
	Grams per 100 cc.	*Grams per 100 cc.*	*Grams per 100 cc.*
Beer worts (all-malt)	0.209	0.017	0.015
Beer worts (malt and rice)	.210	.045	.014
Beer worts (malt and corn)	.168	.014	.013
Porter worts	.213	.031	.017
Ale worts	.275	.029	.019

The results given in Table VI show a great similarity in the changes in all of the products, as there is about the same amount of loss of protein, ash, and phosphoric acid in the beer, ale, and porter worts. There does not appear to be any appreciable loss, however, of either protein or phosphoric acid during the storage or aging period as is shown by the few samples which we have analyzed after storage. This is practically in agreement with the experiment of Bertschinger,[1] whose results show only a very slight increase in alcohol and loss of sugar during the storage period.

EFFECT OF RAW MATERIALS USED UPON COMPOSITION OF THE FINISHED BREW.

In order to show the effects on the finished beers or ales of the use of corn, rice, cerealin, and brewer's sugar as substitutes for malt in the worts, Table VII has been prepared, giving the results of analyses of a number of brews made in different breweries and from varying kinds and amounts of raw materials.

[1] Z. angew. Chem. (1890), p. 670.

TABLE VII.—*Analyses of beers and ales from various breweries.*

Sample No.	Raw materials.	Product.	Alcohol.	Extract (Schultz and Ostermann).	Extract in original wort (calculated).	Degree of fermentation.	Total acid as lactic.	Volatile acid as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.	Protein (N × 6.25).	Ash.	Phosphoric acid (as P_2O_5.)	Undetermined.	Polarimeter.	Color (Lovibond) in ¼-inch cell.	Calculated to basis of wort with 15 per cent solids. Protein (N × 6.25).	Calculated to basis of wort with 15 per cent solids. Ash.	Calculated to basis of wort with 15 per cent solids. Phosphoric acid (as P_2O_5.)
	Brewery No. 1.		*P. ct. by wght.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Degs. V.*	*Degs.*[1]	*P. ct.*	*P. ct.*	*P. ct.*
14004–H	Malt	Beer	3.07	5.55	11.69	52.54	0.223	0.013	1.59	2.64	0.615	0.207	0.072	0.49	+58.0	5	0.789	0.266	0.092
14005–H	65 per cent malt and 35 per cent cerealin.	do	2.42	6.19	11.03	43.88	.142	.013	1.81	3.15	.355	.141	.042	.73	+50.8	3	.483	.192	.057
14006–H	60 per cent malt and 40 per cent corn.	do	2.16	5.28	9.60	45.00	.178	.007	1.52	2.96	.260	.124	.039	.42	+44.0	4	.407	.194	.061
	Brewery No. 2.																		
22017–D	Malt	Beer	3.83	5.06	12.72	60.22	.214	.001	1.32	2.30	.603	.206	.079	.63	....	12	.712	.243	.093
22018–D	do	do	3.90	5.06	12.86	60.65	.223	.002	1.34	2.03	.606	.199	.077	.88	....	13	.701	.230	.090
22020–D	do	do	3.69	5.12	12.50	59.04	.234	.002	1.57	2.20	.630	.203	.080	.52	....	11	.756	.244	.096
22021–D	do	do	3.63	5.54	12.80	56.72	.219	.001	1.82	2.15	.626	.205	.081	.74	....	10	.734	.240	.095
22042–D	80 per cent malt and 20 per cent rice.	do	3.16	5.13	11.45	55.20	.241	.003	1.55	2.48	.395	.154	.056	.55	+37.2	2	.517	.202	.073
	Brewery No. 3.																		
29517–B	80 per cent malt and 20 per cent cerealin.	Ale	6.33	6.77	19.43	65.15	.357	.005	1.42	3.26	.622	.279	.066	.75	+40.4	....	.480	.215	.051
22027–D	78 per cent malt and 22 per cent cerealin.	do	5.14	5.82	16.10	63.85	.205	.004	1.23	3.27	.488	.189	.054	.64	+41.2	3	.455	.176	.050
22040–D	do	do	5.31	6.17	16.79	63.25	.291	.004	1.40	3.29	.533	.189	.050	.76	+38.6	4	.476	.169	.045
22048–D	do	do	5.33	6.15	16.81	63.42	.232	.002	1.51	3.29	.563	.203	.045	.58	+40.4	4	.502	.181	.040
29512–B	75 per cent malt and 25 per cent cerealin.	do	5.32	8.88	19.52	54.51	.366	.008	2.62	4.28	.650	.266	.057	1.06	+65.2	3	.499	.204	.044
29514–B	do	do	5.43	8.25	19.11	56.83	.357	.005	2.45	3.99	.650	.250	.056	.91	+59.8	2	.509	.196	.044
29519–B	do	do	5.43	8.70	19.56	55.52	.278	.006	2.56	4.21	.655	.249	.056	1.02	+64.0	2	.502	.191	.043
22030–D	65 per cent malt, 28 per cent cerealin, and 7 per cent brewer's sugar.	do	4.79	5.80	15.38	62.29	.223	.003	1.14	3.20	.419	.190	.038	.85	+40.0	5	.409	.185	.037
22039–D	do	do	5.10	5.55	15.75	64.64	.223	.003	1.24	2.84	.465	.184	.042	.37	+37.6	5	.443	.175	.040
22043–D	do	do	4.91	5.50	15.32	63.27	.214	.003	1.38	2.81	.436	.170	.042	.70	+38.0	4	.427	.166	.041

[1] Brewer's scale.

In the results given under brewery No. 1, a beer made entirely from malt is compared with a beer made from 65 per cent of malt and 35 per cent of cerealin, and with a beer made from 60 per cent of malt and 40 per cent of corn, in all of which the same quality of malt was used.

In the case of brewery No. 2, a beer made entirely from malt and a beer made from 80 per cent of malt and 20 per cent of rice are given, in both of which the same quality of malt was used.

Under brewery No. 3 are given determinations for ales prepared from 80 per cent of malt and 20 per cent of cerealin; 78 per cent of malt and 22 per cent of cerealin; 75 per cent of malt and 25 per cent of cerealin; and 65 per cent of malt, 28 per cent of cerealin, and 7 per cent of brewer's sugar. The same quality of malt was used in all of these brews, but the brews were of different strengths.

Table VII is given practically in two parts, the first part showing the actual results obtained by the analysis of the finished beer or ale and the second part showing protein, ash, and phosphoric acid calculated to the basis of a uniform wort containing 15 per cent of solids.

Taking into consideration the actual results obtained upon the beers and ales, it will be seen in the case of brewery No. 1 that the three beers vary in composition to a considerable degree. Especially is this variation marked in regard to the protein, ash, and phosphoric acid contents, which exhibit a marked decrease approximately in direct proportion to the amount of cerealin or corn substituted for malt. The same condition is apparent in the case of the products made in brewery No. 2, the beer made from 80 per cent of malt and 20 per cent of rice showing a material reduction in protein, ash, and phosphoric acid. In brewery No. 3, however, a somewhat different condition is noted. Unfortunately, there is no all-malt product of this brewery to compare with the brews made from a portion of cerealin or from cerealin and brewer's sugar. It will be noted, however, that when the actual results obtained on the finished products of this brewery are compared with those of the all-malt brews of breweries Nos. 1 and 2, they do not clearly show a reduction of protein and ash as might be expected. For example, in the case of one of the samples of the ale made with 25 per cent of cerealin and 75 per cent of malt (sample No. 29512–B), the percentage of protein is 0.65 and of the ash 0.266. The percentages of protein and ash for the three samples of this ale represented by Nos. 29512–B, 29514–B, and 29519–B are higher than were found in any of the all-malt products of the first two breweries under consideration. This, however, can be readily explained when it is considered that in the case of brewery No. 2 in the all-malt beers (sample No. 22017–D) only 58 pounds of malt were used in the preparation of a barrel of beer containing 31 gallons; while in the case of sample No. 29512–B there were used, in preparing a barrel of similar capacity, 68 pounds of malt and 23 pounds of cerealin. That is, in the second product there is, in the same volume of liquid, the extractive material from 68 pounds of malt and 23 pounds of cerealin, while in the first product there is present the extractive material from only 58 pounds of malt. Since the analysis is made upon the finished liquid it is evident that the percentage composition of any particular ingredient should be very much larger in the second product because of the very much larger amount of material used in its preparation. It is apparent, therefore, that no direct comparison can be made between the percentage composition of these different brews in order to determine the effects of the raw materials upon their composition.

The most satisfactory way to have tested this question of the effect of raw materials on the finished product would have been to make a series of worts with exactly the same percentage of solids, some of pure malt and others of mixtures of pure malt and corn, rice, and cerealin; then a direct comparison between the results would have shown the effects of these various materials. This method was impracticable because it was necessary to take the brews as actually made under varying commercial conditions. The object sought can be accomplished, however, by calculating the results of these analyses either to the basis of dry material in the original wort or by calculating them to the basis of a wort with constant water content. It was decided to calculate all of the results to the basis of a wort containing 15 per cent of solids, as this would give a uniform basis for comparison and would be approximately an average wort. The method employed in calculating the various beers and ales to this uniform basis was as follows:

The percentage of solids in the original wort was calculated by multiplying the percentage by weight of alcohol by 2 and adding the percentage by weight of extract. The result for an ordinary beer would be about 12 per cent, while in the case of a very heavy ale it might be as high as 18 or 20 per cent. The actual percentages of protein, ash, and phosphoric acid found by analysis were then calculated to the basis of a uniform wort containing 15 per cent of solids. This was the method used for preparing the second part of this table. A study of this portion of the table shows the actual effects of the various substitutes used for malt on the composition of the fermented product. For instance, the first of the all-malt beers from brewery No. 2 (22017–D) showed in the analysis of the original product a protein percentage of 0.603, an ash percentage of 0.206, and a phosphoric acid percentage of 0.079. When calculated to the basis of a wort containing 15 per cent of solids instead of 12.72 per cent (the actual percentage of solids in the wort from which it was made), it gave the following percentages: Protein, 0.712; ash, 0.243; and phosphoric acid, 0.093. In the case of brewery No. 3, sample No. 29512–B, where the original analysis of the product showed 0.650 per cent of protein, 0.266 of ash, and 0.057 of phosphoric acid, it will be found that when this product is calculated to the basis of a wort of 15 per cent of solids instead of a wort of 19.52 (the actual percentage of solids in the wort in this case) the percentage of ash is 0.204, of protein 0.499, and of phosphoric acid 0.044. A comparison of these results shows that in the protein, ash, and phosphoric acid there has been a material reduction below the figures found upon the all-malt beer, due to the presence of the 25 per cent of cerealin. A study of these results, calculated to the basis of 15 per cent of solids in the wort, shows very clearly that the general effect of the substitution of cerealin, brewer's sugar, rice, and corn is to reduce the content of ash, protein, and phosphoric acid.

It is evident from the results here given that the most important things to be considered in judging the nature of the raw materials used in the preparation of a beer are the quantities of protein, phosphoric acid, and ash; as the other constituents present in the finished beer are more or less variable, the quantities present depending upon the methods of mashing and fermentation.

Table VIII contains a summary of results giving the ash, protein, and phosphoric acid in all of the finished products of known composition which were examined, calculated to the basis of a uniform wort of 15 per cent of solids.

TABLE VIII.—*Summary of the results of analyses (showing ash, protein, and phosphoric acid determinations) in all finished products of known composition, calculated to the basis of a uniform wort containing 15 per cent of solids.*

Raw materials.	Products.	Ash.	Protein (N×6.25).	Phosphoric acid (as P_2O_5).
Malt	Beers; 21 samples:	*Per cent.*	*Per cent.*	*Per cent.*
	Maximum	0.336	1.079	0.143
	Minimum	.230	.701	.087
	Average	.275	.870	.109
80 per cent malt and 20 per cent rice	Beer	.202	.517	.073
66 per cent malt and 34 per cent rice	do	.198	.555	.084
62 per cent malt and 38 per cent rice	do	.205	.488	.061
55 per cent malt and 45 per cent rice	do	.148	.380	.077
50 per cent malt and 50 per cent rice	do	.167	.351	.056
	Maximum	.205	.555	.084
70 per cent malt and 30 per cent corn	Beer	.199	.343	.057
Do	do	.188	.367	.065
68 per cent malt and 32 per cent corn	do	.150	.461	.057
Do	do	.181	.466	.062
Do	do	.164	.459	.056
60 per cent malt and 40 per cent corn	do	.215	.563	.074
Do	do	.188	.593	.076
Do	do	.223	.597	.074
45 per cent malt and 55 per cent corn	do	.145	.347	.057
	Maximum	.223	.597	.076
65 per cent malt and 35 per cent cerealin	Beer	.192	.483	.057
80 per cent malt and 20 per cent cerealin	Ale	.215	.480	.051
78 per cent malt and 22 per cent cerealin	do	.176	.455	.050
Do	do	.169	.476	.045
Do	do	.181	.502	.040
75 per cent malt and 25 per cent cerealin	do	.204	.499	.044
Do	do	.196	.509	.044
Do	do	.191	.502	.043
65 per cent malt, 7 per cent brewer's sugar, and 28 per cent cerealin	do	.185	.409	.037
Do	do	.175	.443	.040
Do	do	.166	.427	.041
	Maximum	.213	.509	.051

A study of the results given in Table VIII shows that in the case of American beers the all-malt beers are higher in ash, protein, and phosphoric acid than are any of the beers made from a mixed mash of malt and other cereals. The difference is sufficiently marked to make it possible to draw a rather sharp line between the all-malt beers and the beers made from the present commercial mixtures. Take, for instance, the beers made from mixtures of malt and rice in which the proportion of rice varies from 20 to 50 per cent. It will be seen that in none of these samples is the ash, phosphoric acid, or protein so high as the minimum found in the all-malt beers. The same will be seen in the case of the malt-and-corn beers. In none of the malt-and-corn beers is the ash, protein, or phosphoric acid so high as the minimum found in the all-malt beers, and the same is true of the mixtures of malt and cerealin and of malt, brewer's sugar, and cerealin. This shows clearly that the commercial beers made in this country from malt and malt substitutes can be distinguished readily from all-malt beers.

When the average composition of the 21 all-malt beers examined is taken into consideration it will be seen that there is a very sharp line of demarcation between the all-malt and the malt, rice, and corn products. From the figures which were obtained upon American beers it would seem that protein as a rule is more sharply reduced by the addition of malt substitutes than is the ash or the phosphoric acid, although where corn or cerealin is used there is a very marked reduction in the amount of phosphoric acid. It would appear, therefore, from the results of this investigation that in the consideration of American beers it will be comparatively easy to draw a line between beers made solely from malt and those made from mixtures of malt with rice, corn, and other substitutes.

This conclusion is not entirely in agreement with the results which have been obtained by others upon foreign beers, in the preparation of which low protein barleys have been used. Joseph Race[1] has reported some interesting results of an investigation carried on for the same purpose as that for which this particular investigation was undertaken; that is, to distinguish between all-malt beers and those made from substitutes. His results do not show as sharp a reduction of the protein, but he found in his all-malt beers a very much lower percentage of total protein than was found in the malt beers of this country. He did observe, however, a material reduction of the phosphoric acid due to the use of substitutes. Unfortunately, he made his determination of phosphoric acid in the ash, and while he reports a marked difference between the phosphoric acid content of the malt beers and those made from substitutes, his total figures for phosphoric acid are much lower than those reported in this

[1] J. Soc. Chem. Ind., 27 (1908), 544–547.

bulletin. For this reason the figures for total phosphoric acid given by him are not at all comparable with those determined by the moist combustion method, by the uranium acetate method, or by the method of ashing with calcium acetate.[1]

The same fact observed by Race, namely, that foreign beers are of low protein content, is shown very clearly in the published literature on European beers in general. König[2] gives the following results of analyses made by himself and H. Weigmann of two all-malt beers, calculated to the basis of a wort containing 15 per cent of solids:

Beer and percentage of wort.	Protein.	Ash.	Phosphoric acid.
	Per cent.	*Per cent.*	*Per cent.*
Pure malt beer:			
12 per cent wort	0.548	0.259	0.098
14 per cent wort	.457	.214	.076

From these results of König it will be seen that the protein content of these beers is considerably less than that of the beers examined by the writers. As the phosphoric acid and ash results, however, are practically the same as in American beers, it might be expected that the use of substitutes in place of the low-protein malt would not show so sharp a reduction of the protein as was found by the authors, although one would expect a reduction in phosphoric acid and ash similar to that found in American beers. This is confirmed by the results obtained by Race.

Robert Wahl[3] made parallel brewings of a high-protein barley and a low-protein barley, and from these obtained two beers which, when calculated to a uniform wort with 15 per cent of solids, showed a total protein in the beer made from the low-protein malt of 0.734 per cent, and in the beer made from the high-protein malt 1.041 per cent. This clearly indicates that where a beer is made from high-protein barley, as is the case with practically all of the beers made in this country,[4] the reduction in protein by the use of substitutes will be a valuable index to the true nature of the product. This, when taken in connection with the reduction of phosphoric acid brought about by the use of substitutes, gives two factors of value in judging American beers, to determine whether or not substitutes have been used; while in the case of beers made from low-protein barley there is practically only one factor, namely, the reduction of phosphoric acid.

[1] Riley, in his report to the Association of Official Agricultural Chemists for the year 1913, showed that a large proportion of the phosphoric acid was ordinarily lost when the beer was directly ashed (J. Assoc. Off. Agr. Chemists, 1 (1915), 138–143). For this reason, in comparing the amount of phosphoric acid given in the literature on beers, it is very essential to know the method used for determining the phosphoric acid.

[2] König, F. J., Chemie der Menschlichen Nahrungs- und Genussmittel, 4th ed., v. 1, p. 1154. Berlin, 1903.

[3] Am. Brewers' Rev., 18 (1904), 339.

[3] Wahl, Robert. *In* Am. Brewers' Rev., 29 (1915), 316–317.

After this rather extensive study had been made at the three breweries, the investigation was extended to include breweries in various sections of the country where different types of raw materials were used. A special effort was made to obtain authentic samples of practically all of the malt beers made in this country and also a large series of malt-and-rice and malt-and-corn beers. In Table IX have been tabulated the results obtained on all-malt beers. All of these results show practically the same condition noted in the other samples of malt beer; that is, a comparatively high protein and phosphoric acid content as compared with beers made in part from rice or corn. These malt beers show figures considerably higher in protein than those given in the literature for all-malt beers made from the low-protein malt of Europe.

TABLE IX.—*Analyses of all-malt American beers.*

Sample No.	Alcohol.	Extract (Schultz and Ostermann).	Extract in original wort (calculated).	Degree of fermentation.	Total acid as lactic.	Volatile acid as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.	Protein (N×6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Polarimeter.	Color (Lovibond) in ¼ inch cell.	Calculated to basis of wort with 15 per cent of solids. Protein (N×6.25).	Ash.	Phosphoric acid (as P_2O_5).
	Per cent by weight.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Degrees V.*	*Degrees.*[1]	*Per cent.*	*Per cent.*	*Per cent.*
22017-D...	3.83	5.06	12.72	60.22	0.214	0.001	1.32	2.30	0.603	0.206	0.079	0.63	....	12	0.712	0.243	0.093
22018-D...	3.90	5.06	12.86	60.65	.223	.002	1.34	2.03	.606	.199	.077	.88	....	13	.701	.230	.090
22020-D...	3.69	5.12	12.50	59.04	.234	.002	1.57	2.20	.630	.203	.080	.52	....	11	.756	.244	.096
22021-D...	3.63	5.54	12.80	56.72	.219	.001	1.82	2.15	.626	.205	.081	.74	....	10	.734	.240	.095
16289-C....	3.00	5.88	11.88	50.50	.228	.003	1.33	2.68	.752	.242	.081	.88	+36.8	....	.950	.306	.102
16299-C....	2.84	6.02	11.70	48.55	.232	.012	1.38	2.77	.724	.237	.088	.91	+40.0	....	.932	.304	.113
20714-D...	3.07	5.80	11.94	51.42	.241	.012	1.45	2.64	.721	.225	.089	.76	+36.4	3	.906	.283	.112
20715-D...	2.95	5.77	11.67	50.56	.228	.009	1.43	2.67	.725	.213	.088	.73	+36.0	4	.932	.274	.113
23571-E....	3.68	4.44	11.80	62.45	.232	.010	1.06	1.67	.653	.229	.096	.83	+21.6	....	.830	.291	.122
23585-E....	3.60	5.04	12.24	58.82	.277	.005	1.36	1.81	.811	.257	.102	.80	+23.2	6	.994	.315	.124
23528-E....	3.28	6.36	12.92	50.80	.384	.016	1.62	2.74	.905	.239	.123	.86	+37.2	13	1.051	.277	.143
23533-E....	3.41	5.48	12.30	55.45	.232	.008	1.48	2.44	.612	.200	.086	.75	+33.6	3	.747	.244	.105
23537-E....	3.80	7.26	14.86	51.35	.250	.012	2.51	2.95	.802	.228	.098	.77	+44.0	14	.809	.230	.099
23588-E....	3.16	6.11	12.43	50.84	.250	.008	1.93	2.41	.797	.208	.086	.76	+37.2	4	.952	.251	.104
23538-E....	3.13	6.61	12.77	48.24	.250	.009	2.13	2.82	.612	.225	.087	.82	+43.6	9	.719	.264	.102
23589-E....	3.35	6.21	12.91	51.90	.178	.017	1.78	2.87	.627	.204	.075	.73	+40.0	7	.729	.237	.087
23539-E....	3.22	6.63	13.27	48.53	.312	.017	2.18	2.58	.778	.248	.097	.84	+38.8	22	.879	.280	.109
23540-E....	3.93	6.77	14.63	53.73	.348	.007	2.64	1.87	1.010	.324	.129	.93	+34.0	18	1.035	.332	.132
23590-E....	3.48	5.45	12.41	56.09	.375	.010	2.21	1.48	.892	.264	.109	.60	+25.6	7	1.079	.319	.132
23541-E....	3.12	5.06	11.30	55.22	.259	.004	1.69	1.27	.777	.253	.087	1.07	+20.0	4	1.031	.336	.115
14004-H...	3.07	5.55	11.69	52.54	.223	.013	1.59	2.64	.615	.207	.072	.49	....	5	.789	.266	.092

[1] Brewer's scale.

In Tables X and XI are given the results for beers made from malt and rice and from malt and corn. A study of these tables shows the same condition as was noted in the other tables giving malt-and-rice and malt-and-corn beers; that is, the beers have a lower protein and phosphoric acid content than those made entirely from malt.

TABLE X.—*Analyses of malt-and-rice American beers.*

Sample No.	Raw materials.	Alcohol.	Extract (Schultz and Ostermann).	Extract in original wort (calculated).	Degree of fermentation.	Total acid as lactic.	Volatile acid as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.
		Per ct. by weight.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22042-D	80 per cent malt and 20 per cent rice	3.16	5.13	11.45	55.20	0.241	0.003	1.55	2.41
23527-E	66 per cent malt and 34 per cent rice	3.32	5.50	12.14	54.70	.196	.008	1.46	2.74
23581-E	62 per cent malt and 38 per cent rice	2.86	6.16	11.88	48.16	.173	.014	1.77	3.15
23587-E	55 per cent malt and 45 per cent rice	3.56	4.96	12.08	58.94	.151	.007	1.24	2.53
23586-E	50 per cent malt and 50 per cent rice	3.44	5.67	12.55	54.82	.160	.008	1.44	3.08

Sample No.	Raw materials.	Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Polarimeter.	Color (Lovibond) in ¼-inch cell.	Calculated to basis of wort with 15 per cent of solids.		
								Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Degrees V.*	*Degrees.*[1]	*Per ct.*	*Per ct.*	*Per ct.*
22042-D	80 per cent malt and 20 per cent rice	0.395	0.154	0.056	0.62	+37.2	2	0.517	0.202	0.073
23527-E	66 per cent malt and 34 per cent rice	.449	.160	.068	.69	+40.0	2	.555	.198	.084
23581-E	62 per cent malt and 38 per cent rice	.386	.162	.048	.69	+48.6	......	.488	.205	.061
23587-E	55 per cent malt and 45 per cent rice	.306	.119	.062	.76	+37.0	2	.380	.148	.077
23586-E	50 per cent malt and 50 per cent rice	.294	.140	.047	.72	+46.4	2	.351	.167	.056

[1] Brewer's scale.

TABLE XI.—*Analyses of malt-and-corn American beers.*

Sample No.	Raw materials.	Alcohol.	Extract (Schultz and Ostermann).	Extract in original wort (calculated).	Degree of fermentation.	Total acid as lactic.	Volatile acid as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.
		Per ct. by weight.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
3534–E	70 per cent malt and 30 per cent corn	2.75	5.53	11.03	50.32	0.125	0.005	1.27	3.13
23535–E	.....do	3.03	4.85	10.91	55.55	.224	.011	1.15	2.76
23518–E	68 per cent malt and 32 per cent corn	3.37	5.96	12.70	53.07	.116	.006	1.63	3.07
23561–E	.....do	3.26	6.14	12.66	51.50	.134	.016	1.54	3.07
23572–E	.....do	3.37	6.07	12.81	52.62	.143	.020	1.56	3.29
23584–E	60 per cent malt and 40 per cent corn	3.09	4.90	11.08	55.78	.178	.020	1.35	2.43
23523–E	.....do	3.16	6.07	12.39	51.01	.214	.009	1.60	3.36
23660–E	.....do	3.26	6.07	12.59	51.79	.205	.009	1.55	3.06
16286–C	.....do	3.19	5.60	11.98	53.34	.173	.014	1.85	2.61
16287–C	.....do	3.23	5.67	12.13	53.26	.178	.014	1.84	2.41
23524–E	45 per cent malt and 55 per cent corn	3.43	5.75	12.61	54.40	.169	.007	1.44	3.19

Sample No.	Raw materials.	Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Polarimeter.	Color (Lovibond) in ½-inch cell.	Calculated to basis of wort with 15 per cent of solids.		
								Protein (N× 6.25).	Ash.	Phosphoric acid (as P_2O_5).
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Degrees V.*	*Degrees.*[1]	*Per ct.*	*Per ct.*	*Per ct.*
23534–E	70 per cent malt and 30 per cent corn	0.252	0.146	0.042	0.73	+42.6	2	0.343	0.199	0.057
23535–E	.....do	.267	.137	.047	.53	+37.2	2	.367	.188	.065
23518–E	68 per cent malt and 32 per cent corn	.390	.127	.048	.74	+49.6	3	.461	.150	.057
23561–E	.....do	.393	.153	.052	.98	+48.0	....	.466	.181	.062
23572–E	.....do	.392	.140	.048	.69	+47.0	....	.459	.164	.056
23584–E	60 per cent malt and 40 per cent corn	.416	.159	.055	.54	+34.6	....	.563	.215	.074
23523–E	.....do	.490	.155	.064	.46	+45.0	5	.593	.138	.076
23660–E	.....do	.501	.187	.062	.77	+44.4	5	.597	.223	.074
16286–C	.....do	.311	.219	.057	.61	+41.0	....	.389	.274	.071
16287–C	.....do	.322	.205	.055	.89	+41.0	....	.398	.254	.068
23524–E	45 per cent malt and 55 per cent corn	.292	.122	.048	.71	+45.6	2	.347	.145	.057

[1] Brewer's scale.

In Table XII have been brought together the results of the examination of a large number of commercial beers of American production, which were represented to be made from malt and hops. This representation subsequently proved to be false, although exact information as to the amount or kind of substitute used is not available. These results are of value, however, in showing the general composition of American beers made from the ordinary commercial mixtures and clearly indicate that by taking into consideration the ash, protein, and phosphoric acid content it is practicable to distinguish commercial beers made in this country from malt and malt substitutes from beers made from malt alone.

TABLE XII.—*Analyses of American beers incorrectly represented to be all-malt.*

Sample No.	Alcohol.	Extract (Schultz and Ostermann).	Extract in original wort (calculated).	Degree of fermentation.	Total acid as lactic.	Volatile acid as acetic.	Reducing sugars as anhydrous maltose.	Dextrin.	Protein (N × 6.25).	Ash.	Phosphoric acid (as P_2O_5).	Undetermined.	Polarimeter.	Color (Lovibond) in ¼-inch cell.	Calculated to basis of wort with 15 per cent of solids.		
															Protein (N × 6.25).	Ash.	Phosphoric acid (as P_2O_5).
	Per cent by weight.	*Per cent.*	*Per cent.*		*Per ct.*	*Per cent.*	*Per cent.*	*Per ct.*	*Per cent.*	*Per ct.*	*Per cent.*	*Per cent.*	*Degrees V.*	*Degrees.*[1]	*Per cent.*	*Per ct.*	*Per cent.*
2417-E	3.67	4.66	12.00	61.33	0.154	0.013	1.59	1.97	0.341	0.120	0.053	0.64	+31.0	1	0.426	0.150	0.066
36612-E	3.10	7.55	13.75	45.09	.232	.017	2.33	3.93	.274	.149	.043	.87	+54.4	35	.299	.163	.047
1146-E	4.23	7.35	15.81	53.51	.241	.029	2.21	3.39	.472	.202	.074	1.08	+50.0	32	.448	.192	.070
3014-E	3.26	6.74	13.26	49.17	.167	.014	2.74	2.56	.406	.147	.060	.89	+49.6	3	.459	.166	.068
2538-E	2.86	6.69	12.41	46.09	.214	.017	3.22	2.12	.390	.181	.050	.78	+43.2	54	.472	.219	.060
1734-E	3.55	6.55	13.65	52.02	.250	.028	1.87	3.58	.303	.145	.048	.65	+53.0	3	.333	.159	.053
1154-E	3.55	5.62	12.72	55.82	.187	.014	1.88	2.52	.352	.158	.043	.71	+41.0	3	.415	.186	.051
1006-E	3.58	4.74	11.90	60.17	.138	.017	1.42	1.99	.420	.158	.057	.75	+31.2	12	.529	.199	.072
195-E	3.56	4.21	11.33	62.84	.127	.008	2.72	.77	.254	.127	.044	.34	+22.6	3	.336	.168	.058
5022-E	2.95	5.60	11.50	51.30	.133	.022	2.30	2.20	.233	.121	.036	.75	+41.0	3	.304	.158	.047
1005-E	2.69	5.33	10.71	50.24	.102	.010	1.77	2.34	.354	.132	.048	.74	+39.6	3	.496	.185	.067
194-E	3.18	4.00	10.36	61.39	.062	.017	1.37	1.58	.296	.110	.045	.64	+27.0	5	.423	.159	.065
185-E	3.44	3.92	10.80	63.70	.141	.011	2.06	.97	.250	.116	.041	.52	+23.2	3	.347	.161	.057
5314-E	3.78	5.65	13.21	57.15	.151	.010	1.46	2.84	.416	.177	.059	.76	+40.8	3	.472	.201	.067
4451-E	3.23	6.52	12.98	49.77	.228	.009	2.80	2.44	.519	.153	.054	.61	....	78	.599	.177	.062
5696-E	4.19	6.44	14.82	56.55	.268	.012	2.15	3.06	.309	.197	.082	.72	+44.0	18	.313	.199	.083
3359-E	4.96	7.43	17.35	57.18	.321	.019	1.76	3.74	.509	.294	.074	1.13	+48.4	44	.440	.254	.064
3358-E	3.23	5.53	11.99	53.83	.121	.009	1.88	2.51	.314	.175	.045	.65	+41.0	3	.392	.219	.056
481-E	3.87	5.20	12.94	59.82	.147	.014	1.32	2.47	.319	.163	.054	.93	+36.6	2	.370	.189	.063
687-E	3.24	4.71	11.19	57.91	.080	.009	1.63	2.20	.284	.124	.048	.47	+35.6	2	.382	.167	.065
193-E	3.66	5.75	13.07	56.01	.148	.017	1.78	2.67	.346	.153	.048	.80	+42.8	3	.397	.176	.055
5023-E	3.16	5.30	11.62	54.39	.128	.005	1.95	2.13	.214	.126	.033	.88	+40.0	2	.276	.163	.043
5318-E	3.57	5.20	12.34	57.86	.220	.003	1.50	2.59	.320	.147	.045	.64	+41.8	3	.389	.179	.055
6715-E	3.75	7.98	15.48	48.45	.174	.006	2.55	3.60	.430	.186	.058	1.21	+61.6	14	.417	.180	.056
6716-E	3.66	7.73	15.05	48.64	.187	.009	2.37	3.84	.384	.164	.055	.97	+61.6	14	.383	.164	.055
2388-E	2.95	5.35	11.25	52.45	.080	.012	1.61	2.32	.337	.135	.042	.91	+40.4	2	.449	.180	.056
2352-E	3.20	4.69	11.09	57.71	.147	.011	1.99	1.76	.326	.146	.037	.46	+32.2	3	.441	.198	.050
2770-E	3.66	5.99	13.31	55.00	.169	.019	1.82	2.56	.276	.194	.050	1.14	+45.2	6	.311	.219	.056
8705-E	2.91	5.62	11.44	50.96	.147	.017	1.86	2.58	.366	.150	.041	.66	+41.0	....	.480	.197	.053
8706-F	3.48	4.93	11.89	58.54	.214	.022	1.83	1.83	.470	.160	.062	.64	+30.4	....	.593	.202	.078
8704-E	2.76	4.98	10.50	52.57	.160	.010	1.62	2.26	.390	.150	.054	.56	+36.4	....	.557	.214	.077
7839-E	3.51	5.38	12.40	56.61	.142	.012	1.57	2.77	.290	.116	.031	.63	+41.2	....	.351	.140	.038
5707-E	3.35	5.82	12.52	53.51	.160	.011	2.01	2.65	.352	.147	.048	.66	+43.0	....	.422	.176	.058
8171-F	3.50	5.99	12.99	53.85	.169	.013	1.92	2.67	.271	.178	.054	.95	+45.2	....	.313	.205	.062
397-E	3.73	6.71	14.17	52.65	.169	.007	1.56	3.96	.324	.151	.051	.72	+55.2	2	.343	.160	.054

[1] Brewer's scale.

The data reported in Tables X, XI, and XII give the results of analyses of commercial American beers obtained from various breweries in different parts of the United States as these beers are found on the market at the present time; hence, they are of general value for the purpose of showing the composition of American beers. These data also are of considerable interest when we compare them with data relating to American beers published by the department in 1887.[1] A comparison of these two sets of figures shows that beers made at the present time have a much lower percentage of alcohol and are made from a wort containing a much lower percentage of solids than beers made a generation ago. The average of 28 samples examined and reported in 1887 in the publication cited[1] showed an average alcohol content of 4.63 per cent by weight and solids in the original wort of 14.79 per cent, while the average of 72 beers representing the products now on the market showed an average of 3.52 per cent by weight of alcohol and solids in the original wort of 12.50 per cent. This is a reduction of 1.11 per cent by weight of alcohol and 2.23 per cent of solids in the original wort.

CONCLUSIONS.

The all-malt beers made in this country contain higher percentages of protein than the all-malt beers made in Europe, owing to the use in this country of a barley high in protein.

The use of rice, corn or corn products, and brewer's sugar as substitutes for malt reduces the content of protein, ash, and phosphoric acid in the finished beer.

This difference, as regards the protein, ash, and phosphoric acid, is a sufficient basis for distinguishing the all-malt beers made in this country from those containing the commercial mixtures of rice, corn, cerealin, and brewer's sugar.

It is necessary to calculate analytical results to the basis of a common wort in order to interpret them properly.

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[1] U. S. Dept. Agr., Div. Chem., Bul. 13, 1887, pt. 3, p. 282.

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