without first transforming them into indices of refraction, readings in indices of refraction may be obtained at different temperatures without calculation, and readings on either refractometer scale may be readily transformed into readings on the other.

In using this rule the slide is moved until the initial temperature and refraction coincide, then opposite the required temperature is found the corresponding refraction. If this temperature falls outside of the refraction scale it will be necessary to shift the slide, for example:

At 35.5° C. an oil reads 40.1 on the butyro-refractometer. Required, its refraction at 20°. Place the slide so that 35.5 on the slide coincides with 40.1 on the butyro scale, then it will be seen that the right end of the refractometer scale (45.2) exactly coincides with 25° on the slide. Move the slide until 25 coincides with 45.2 on the lower scale, then opposite 20 on the slide read 47.7.

[CONTRIBUTION FROM THE DEPARTMENT OF FOOD AND DRUG INSPECTION OF THE MASSACHUSETTS STATE BOARD OF HEALTH.]

THE DETECTION OF WATERED MILK.

BY ALBERT E. LEACH AND HERMANN C. LYTHGOE.

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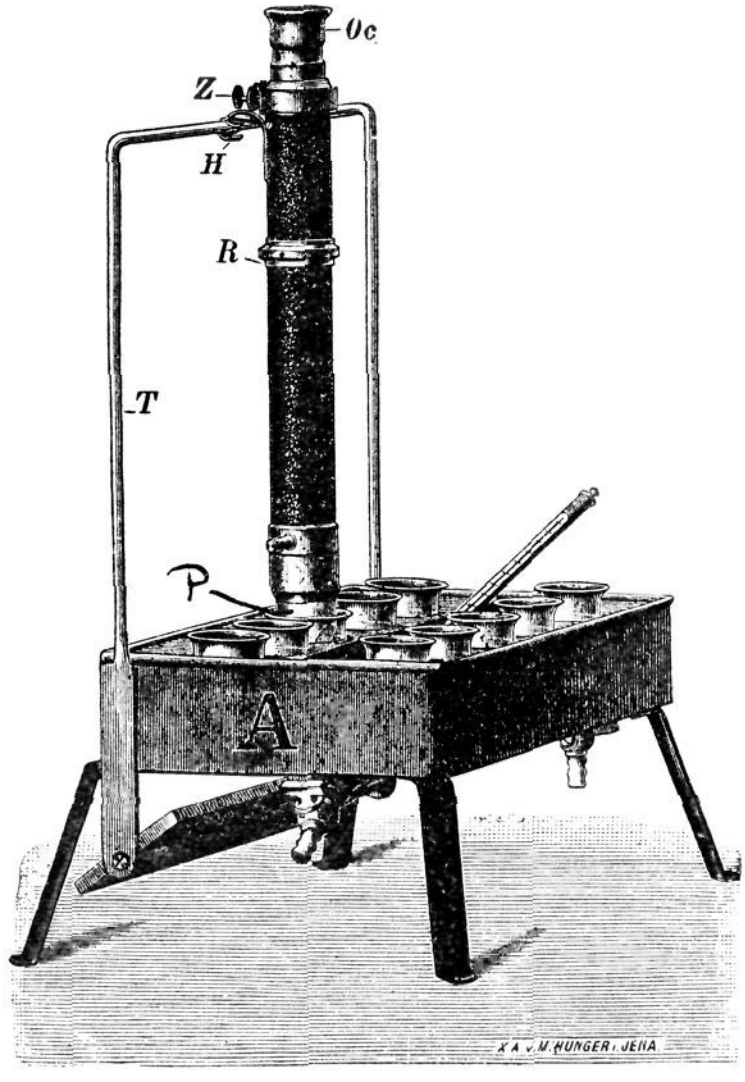
ONE of the most difficult problems with which the analyst is confronted is that of distinguishing between what might be termed honest low-standard milk, or milk below the standard coming from the cow as such, and milk that is fraudulently watered. Judgment on this point has heretofore been based largely on the relative proportion of fat to solids not fat, taken in connection with an abnormally low percentage of total solids. Additional information on this question is furnished by the density of the milk serum when the milk has been curdled under fixed conditions, though this in itself is by no means conclusive.

The addition of water to milk perceptibly affects the degree of refraction of the serum to such an extent that this latter constant promises to be a most helpful one in determining whether or not the milk has been watered. For this purpose the immersion refractometer of Zeiss is most useful, although the Abbé refractometer may be employed.

The Zeiss Immersion Refractometer.—The construction of this instrument is such that, as its name implies, it may be directly immersed in a solution, the degree of refraction of which, within limits, may be determined upon an arbitrary scale. The accompanying figure shows this instrument.



P is a glass prism, fixed in the lower end of the tube of the instrument, while at the top of the tube is the ocular *Oc*, and just below this on a level with the vernier screw *Z* is the scale, on which is read the degree of refraction of the liquid in which the prism *P* is immersed. The tube may be held in the hand and directly dipped in the liquid to be tested, this liquid being contained in a vessel with a transparent bottom, through which the light is reflected. The preferable method of use is, however, that shown in the figure.

A is a metal bath with inlet and outlet tubes, arranged whereby water is kept at a constant level. The water is maintained at a constant temperature by means of a controller or refractometer heater. In the bath *A* are immersed a number of beakers, containing the solutions to be tested. *T* is a frame on which is hung the refractometer by means of the hook *H*, at just the right height to permit of the immersion of the prism *P* in the liquid in any of the beakers in the row beneath. Under this row of beakers the bottom of the tank is composed of a strip of ground glass, through which light is reflected by an adjustable, pivoted mirror.

The temperature of the bath is noted by a delicate thermometer immersed therein, capable of reading to tenths of a degree.

Returning to the main refractometer-tube, *R* is a graduated ring or collar, which is connected by a sleeve within the tube with a compound prism near the bottom, the construction being such that by turning the collar *R* one way or the other the chromatic aberration or dispersion of any liquid may be compensated for, and a clear-cut shadow or critical line projected across the scale. By the graduation on the collar *R* the degree of dispersion may be read. Tenths of a degree on the main scale of the instrument may be read with great accuracy by means of the vernier screw *Z*, graduated along its circumference, the screw being turned in each case till the critical line on the scale coincides with the nearest whole number.

If the immersion refractometer is unavailable, and the analyst is provided with the Abbé instrument, indices of refraction as read on the Abbé may be converted into scale readings of the immersion refractometer by the following table:

n_D.	Scale reading.	n_D.	Scale reading.	n_D.	Scale reading.	n_D.	Scale reading.
1.3390	30.0	1.3410	35.3	1.3430	40.6	1.3450	45.9
1.3391	30.3	1.3411	35.6	1.3431	40.8	1.3451	45.2
1.3392	30.6	1.3412	35.8	1.3432	41.1	1.3452	45.5
1.3393	30.8	1.3413	36.1	1.3433	41.4	1.3453	45.7
1.3394	31.1	1.3414	36.3	1.3434	41.6	1.3454	47.0
1.3395	31.3	1.3415	36.6	1.3435	41.9	1.3455	47.3
1.3396	31.6	1.3416	36.9	1.3436	42.2	1.3456	47.5
1.3397	31.9	1.3417	37.1	1.3437	42.4	1.3457	47.8
1.3398	32.1	1.3418	37.4	1.3438	42.7	1.3458	48.0
1.3399	32.4	1.3419	37.7	1.3439	43.0	1.3459	48.3
1.3400	32.7	1.3420	37.9	1.3440	43.2	1.3460	48.6
1.3401	32.9	1.3421	38.2	1.3441	43.5	1.3461	48.9

n_D	Scale reading.	n_D	Scale reading.	n_D	Scale reading.	n_D	Scale reading.
1.3402	33.2	1.3422	38.5	1.3442	43.8	1.3462	49.1
1.3403	33.4	1.3423	38.7	1.3443	44.0	1.3463	49.4
1.3404	33.7	1.3424	39.0	1.3444	44.3	1.3464	49.7
1.3405	34.0	1.3425	39.3	1.3445	44.6	1.3465	49.9
1.3406	34.2	1.3426	39.5	1.3446	44.8	1.3466	50.2
1.3407	34.5	1.3427	39.8	1.3447	45.1	1.3467	50.5
1.3408	34.8	1.3428	40.0	1.3448	45.4	1.3468	50.7
1.3409	35.0	1.3429	40.3	1.3449	45.6	1.3469	51.0

Method of Procedure.—The method of curdling milk, employed in this laboratory, is that of Woodman[1]—as follows:

To 100 cc. of milk, at a temperature of about 20° C., are added 2 cc. of 25 per cent. acetic acid (sp. gr. 1.0350) in a beaker, and the beaker, covered with a watch-glass, is heated in a water-bath for twenty minutes at a temperature of 70° C. After this the beaker is placed in ice-water for ten minutes, and the solution filtered. The refractometer is placed directly in the clear filtrate. Table I shows analyses of milk selected from a wide range of samples regularly collected and examined in the routine of inspection.

TABLE I.—CONSTANTS OF MILK AND MILK SERUM. LABORATORY SAMPLES.

Determinations on milk.						On milk serum.	
Total solids. Per cent.	Water. Per cent.	Fat. Per cent.	Solids, not fat. Per cent.	Ash. Per cent.	Spec. grav. at 15° C.	Spec. grav. at 15° C.	Immersion refractometer reading at 20° C.
16.45	83.55	8.20	8.25	...	1.0255	1.0274	40.95
15.90	84.10	7.00	8.90	0.69	1.0277	1.0285	42.00
14.37	85.63	5.50	8.88	0.58	1.0282	1.0280	42.40
14.17	85.83	4.85	9.32	0.62	1.0313	1.0281	44.20
14.04	85.96	4.95	9.09	0.60	1.0303	1.0274	42.70
13.80	86.20	5.00	8.80	0.65	1.0302	1.0289	42.75
13.59	86.41	4.30	9.29	0.64	1.0321	1.0285	44.50
13.39	86.61	4.40	8.99	0.50	1.0324	1.0285	43.70
13.28	86.72	4.40	8.88	0.60	1.0299	1.0289	42.65
13.12	86.88	4.00	9.12	0.59	1.0317	1.0280	43.75
13.00	87.00	4.30	8.70	0.56	1.0310	1.0266	42.60
12.90	87.10	3.85	9.05	0.61	1.0318	1.0289	43.40
12.80	87.20	4.30	8.50	0.46	1.0304	1.0277	42.70
12.70	87.30	3.80	8.90	0.53	1.0314	1.0280	43.10
12.63	87.37	3.50	9.13	0.65	1.0323	1.0277	43.65
12.62	87.38	4.10	8.52	0.52	1.0298	1.0272	42.40

[1] This Journal, **21**, 503 (1899).

Determinations on milk.						On milk serum.	
Total solids. Per cent.	Water. Per cent.	Fat. Per cent.	Solids, not fat. Per cent.	Ash. Per cent.	Spec. grav. at 15° C.	Spec. grav. at 15° C.	Immersion refractometer reading at 20° C.
12.57	87.43	3.70	8.87	0.68	1.0317	1.0278	43.45
12.47	87.53	3.60	8.87	0.65	1.0303	1.0282	43.15
12.36	87.64	3.20	9.16	0.55	1.0327	1.0282	43.25
12.30	87.70	3.20	9.10	0.62	1.0327	1.0283	44.00
12.16	87.84	4.35	7.81	0.49	1.0275	1.0265	41.10
12.00	88.00	3.40	8.60	0.62	1.0275	1.0280	41.75
11.86	88.14	3.60	8.26	0.49	1.0306	1.0266	42.40
11.67	88.33	3.95	7.77	0.48	1.0265	1.0240	39.30
11.60	88.40	2.75	8.85	0.65	1.0320	1.0282	43.55
11.50	88.50	3.45	8.05	0.51	1.0290	1.0269	41.40
11.40	88.60	3.10	8.30	0.60	1.0297	1.0278	42.00
11.25	88.75	2.80	8.45	0.58	1.0282	1.0274	40.90
11.07	88.93	3.00	8.07	0.62	1.0290	1.0270	40.75
10.69	89.31	2.95	7.74	...	1.0288	1.0262	39.85
10.25	89.75	3.20	6.95	0.55	1.0230	1.0223	36.40
8.34	91.66	2.20	6.14	0.38	1.0224	1.0207	34.70

Table II shows analyses of a whole milk submitted to varying degrees of watering up to 50 per cent. of added water.

TABLE II.—CONSTANTS OF MILK AND MILK SERUM. A WHOLE MILK SYSTEMATICALLY WATERED.

	Determinations on milk.						On milk serum.	
Water added. Per cent.	Total solids. Per cent.	Water. Per cent.	Fat. Per cent.	Solids, not fat. Per cent.	Ash. Per cent.	Spec. grav. at 15° C.	Spec. grav. at 15° C.	Immersion refractometer reading at 20° C.
0	12.65	87.35	4.00	8.65	0.65	1.0315	1.0287	42.40
10	11.33	88.67	3.50	7.83	0.60	1.0278	1.0260	39.75
20	10.10	89.90	3.10	7.00	0.53	1.0252	1.0230	36.90
30	8.95	91.05	2.80	6.15	0.48	1.0211	1.0200	34.10
40	7.67	92.33	2.40	5.27	0.40	1.0192	1.0167	31.10
50	6.43	93.57	2.00	4.43	0.38	1.0154	1.0140	28.45

Table III shows a centrifugally skimmed milk, systematically watered up to 50 per cent. of added water as in Table II. It will be observed that both the specific gravity and immersion refractometer readings of the serum in Table II agree very closely with those of the skimmed milk in Table III, having a corresponding amount of water.

TABLE III.—CONSTANTS OF MILK AND MILK SERUM. A SKIMMED MILK SYSTEMATICALLY WATERED.

	Determinations on milk.						On milk serum.	
Water added. Per cent.	Total solids. Per cent.	Water. Per cent.	Fat. Per cent.	Solids, not fat. Per cent.	Ash. Per cent.	Spec. grav. at 15° C.	Spec. grav. at 15° C.	Immersion refractometer reading at 20° C.
0	9.05	90.95	0.03	9.02	0.64	1.0350	1.0296	42.85
10	8.14	91.85	0.03	8.11	0.60	1.0317	1.0260	39.60
20	7.27	92.73	0.02	7.25	0.56	1.0278	1.0230	36.85
30	6.41	93.59	0.02	6.39	0.48	1.0247	1.0200	34.00
40	5.50	94.50	0.01	5.49	0.44	1.0209	1.0170	31.20
50	4.61	95.39	0.01	4.60	0.39	1.0172	1.0140	28.50

A comparison of the immersion refractometer readings of the sera of milk of varied quality shows at once that the refraction of the serum is a general index to watering. A reading below 40°, with the above conditions carefully observed, seems to indicate added water.

Table IV shows results of analyses of milk of known purity, taken from an exceptionally well-fed herd of Holstein cows,[1] milked in the presence of one of the inspectors. The daily rations of each cow consisted of 6 quarts of shorts, 2 quarts of cottonseed meal and 2 quarts of corn-meal with hay.

As showing what similar conditions prevail between fancy-bred stock, as shown above, and the more common Holsteins, kept under ordinary farm conditions, Table V gives data of the milk of a herd of the latter variety, this milk being taken in the presence of one of the writers. The daily rations in this case consisted of 3 quarts of meal, 2 quarts of mixed feed, 2 quarts of gluten, with green fodder.

In no case has there yet been found a refractometer reading of less than 39 at 20° C. for the serum of pure milk. With our present knowledge, 39 would seem to be a reasonable minimum figure, below which a sample could be declared fraudulently watered when the conditions of the test are carried out precisely as above described.

The following table is convenient for calculation of the reading to 20° C. when it is difficult to keep the water-bath at exactly 20°:

[1] This is a prize herd, carefully bred for exhibition purposes. In spite of this, the very low average quality of the milk should be noted.

TABLE IV.—MILK OF KNOWN PURITY FROM FANCY HOLSTHIN COWS.

		Determinations on *milk*.								On milk serum.		
Age of cow. Years.	Time since calving. Months.	Specific gravity at 15° C.	Water. Per cent.	Total solids. Per cent.	Fat. Per cent.	Solids not fat. Per ct.	Ash. Per cent.	Milk-sugar. Per ct.	Proteids. Per cent.	Specific gravity at 15° C.	Immersion refractometer reading at 20° C.	n_D 20°.
2	2	1.0317	87.26	12.74	3.70	9.04	0.60	4.80	3.64	1.0297	44.4	1.344408
3	4	1.0303	87.37	12.63	4.00	8.36	0.66	4.55	3.42	1.0290	42.8	1.343804
6	12	1.0296	87.68	12.32	3.90	8.42	0.63	4.20	3.59	1.0286	42.3	1.343614
3	4	1.0307	87.77	12.23	3.80	8.43	0.50	4.20	3.73	1.0289	42.9	1.343842
6	12	1.0296	87.84	13.16	3.45	8.71	0.60	4.10	4.01	1.0297	43.5	1.344070
2	2	1.0312	87.88	12.12	3.40	8.72	0.74	4.75	3.23	1.0329	44.5	1.344445
7	12	1.0301	88.11	11.89	3.40	8.49	0.70	4.35	3.44	.....	43.7	1.344146
12	5	1.0301	88.24	11.76	3.40	8.36	0.54	4.80	3.02	.....	42.9	1.343842
2	2	1.0289	88.33	11.67	3.55	8.12	0.60	4.50	3.02	1.0297	43.2	1.343956
5	4	1.0300	88.37	11.63	3.30	8.33	0.58	4.75	3.00	1.0289	43.6	1.344108
4	6	1.0297	88.41	11.59	3.20	8.39	0.62	4.40	3.31	1.0290	42.9	1.343842
5	½	1.0304	88.43	11.57	3.30	8.27	0.62	4.70	2.95	1.0318	43.0	1.343880
3	4	1.0311	88.51	11.49	3.25	8.24	0.62	4.35	3.27	1.0293	44.1	1.344297
6	1	1.0291	88.52	11.48	3.35	8.13	0.67	4.70	2.76	1.0290	42.8	1.343804
2	2	1.0296	88.53	11.47	3.45	8.02	0.55	4.60	2.87	1.0288	43.1	1.343918
2	2	1.0298	88.70	11.30	3.30	8.00	0.64	4.70	2.66	1.0277	42.1	1.343538
5	7	1.0283	88.82	11.18	3.20	7.98	0.60	3.95	3.43	1.0260	40.5	1.342940
2	2	1.0292	88.84	11.16	3.00	8.16	0.61	4.30	3.25	1.0285	41.6	1.343352
2	2	1.0292	88.93	11.07	2.95	8.12	0.55	4.60	3.02	.....	42.1	1.343538
2	2	1.0290	89.26	10.74	2.95	7.79	0.74	4.25	2.80	1.0280	40.6	1.342978
4	5	1.0262	89.29	10.71	3.25	7.46	0.55	4.00	2.91	1.0279	40.0	1.342750
2	1½	1.0293	89.41	10.59	2.55	8.04	0.52	4.30	3.22	1.0290	41.8	1.343426
	Highest,	1.0371	89.41	12.74	4.00	9.04	0.74	4.80	4.01	1.0329	44.4	1.344408
	Lowest,	1.0262	87.26	10.59	2.55	7.46	0.50	3.95	2 76	1.0260	40.0	1.342750
	Average,	1.0297	88.39	11.61	3.34	8.27	0.61	4.45	3.21	1.0291	42.7	1.343766

TABLE V.—MILK OF KNOWN PURITY FROM COMMON HOLSTEIN COWS.

Age of cow. Years.	Time since calving. Months.	Determinations on milk. Specific gravity at 15° C.	Water. Per cent.	Total solids. Per cent.	Fat. Per cent.	Solids not fat. Per ct.	Ash. Per cent.	Milk-sugar. Per ct.	Proteids. Per cent.	On milk serum. Specific gravity at 15° C.	Immersion refractometer reading at 20° C.	n_D 20°.
6	1	1.0290	87.24	12.76	4.50	8.26	0.52	4.90	2.84	1.0253	42.9	1.343842
5	2	1.0297	87.32	12.68	4.10	8.58	0.45	4.90	3.23	1.0295	43.1	1.343918
3	9	1.0305	87.87	12.13	3.55	8.58	0.55	4.35	3.68	1.0287	41.5	1.343315
8	3	1.0302	87.89	12.11	3.65	8.46	0.50	4.90	3.06	1.0291	42.0	1.343500
5	3	1.0296	88.07	11.93	3.45	8.48	0.60	4.30	3.58	1.0271	41.4	1.343278
7	1½	1.0307	88.24	11.76	3.60	8.16	0.50	4.80	2.86	1.0291	42.1	1.343538
2	3	1.0295	88.32	11.68	3.30	8.38	0.49	4.65	3.24	1.0285	41.8	1.343426
6	4	1.0300	88.60	11.40	3.05	8.35	0.60	4.55	3.20	1.0287	40.9	1.343092
5	8	1.0285	88.83	11.17	3.25	7.92	0.53	4.10	3.29	1.0286	39.7	1.342636
6	9	1.0290	88.90	11.10	3.30	7.80	0.65	3.95	3.25	1.0266	39.9	1.342712
7	7	1.0286	89.44	10.56	2.70	7.86	0.63	3.75	3.48	1.0296	39.0	1.342370
2	2	1.0286	89.55	10.45	2.60	7.45	0.59	4.25	3.01	1.0267	40.0	1.342750
	Highest,	1.0307	89.55	12.76	4.50	8.58	0.60	4.90	3.68	1.0296	43.1	1.343918
	Lowest,	1.0282	87.24	10.45	2.60	7.80	0.45	3.75	2.84	1.0253	39.0	1.342370
	Average,	1.0295	88.35	11.65	3.45	8.22	0.54	4.45	3.23	1.0281	41.6	1.34352

TABLE VI.—READINGS OF MILK SERUM ON THE IMMERSION REFRACTOMETER REDUCED TO 20°.

Temp.	Scale readings.									
	36.	37.	38.	39.	40.	41.	42.	43.	44.	45.
15°	34.75	35.75	36.75	37.75	38.75	39.75	40.70	41.70	42.65	43.65
16	35.05	36.05	37.05	38.05	39.05	40.05	41.00	41.95	42.90	43.85
17	35.25	36.25	37.25	38.25	39.25	40.25	41.20	42.20	43.15	44.10
18	35.50	36.50	37.50	38.50	39.50	40.50	41.45	42.45	43.40	44.40
19	35.75	36.75	37.75	38.75	39.75	40.75	41.75	42.75	43.70	44.70
20	36.00	37.00	38.00	39.00	40.00	41.00	42.00	43.00	44.00	45.00
21	36.25	37.25	38.25	39.30	40.30	41.30	42.30	43.30	44.30	45.30
22	36.50	37.50	38.50	39.55	40.60	41.60	42.60	43 60	44.60	45.60
23	36.80	37.80	38.80	39.85	40.90	41.90	42.90	43.90	44.90	45.90
24	37.10	38.10	39.10	40.15	41.20	42.20	43.20	44.20	45.20	46.20
25	37.40	38.40	39.40	40.45	41.50	42.50	43.50	44.50	45.40	46.50

Example.—If at 25° the milk serum reads 42.3, the correct reading at 20° is 43.5 + 0.3 = 43.8.

[CONTRIBUTION FROM THE DEPARTMENT OF FOOD AND DRUG INSPECTION OF THE MASSACHUSETTS STATE BOARD OF HEALTH.]

COMPOSITION AND ADULTERATION OF GROUND MUSTARD.

BY ALBERT E. LEACH.

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MUSTARD has long taken the lead as the most extensively adulterated of all the spices, especially in localities where no system of food inspection prevails. The custom of deliberately mixing cereal flour or starch with ground mustard was practiced for many years, and, in fact, continued long after the serious adulteration of other spices had been held in check by the increased enforcement of pure food laws.

Coloring with turmeric was also a time-honored custom, and, in fact, still prevails, except in localities where the public have been educated to view with suspicion the deep yellow color of the product. Of late the employment of other colors than turmeric, such, for example, as various of the oil-soluble coal-tar dyes, has arisen to claim the attention of the analyst.