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Moisture in Honey: Review of Chemical and Physical Methods

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A critical review is presented of the determination of moisture in honey by chemical (Karl Fischer) and several physical methods, including evaporation, distillation, refractometry, density, and viscosity. Methods are compared for precision and accuracy, and interrelationships are discussed. Wedmore's interpretation of Chataway's specific gravity results is shown to be based on a misconception.

Honey, as extracted from the comb, is an aqueous dispersion of material with a wide range of particle sizes, from inorganic ions, saccharides, and other organic materials in true solution and colloidally dispersed macromolecules of protein and polysaccharide, to spores of yeasts and molds and the largest particles, pollen grains.

Since the sugars are by far the most important constituents, the gross physical attributes of honey are largely determined by the kinds and concentrations of the carbohydrates. These properties are expressed in ranges, rather than by constants, reflecting the variability in composition of honey (1).

Though honey is superficially a sirup and an average of 84% of its solids consist of dextrose and levulose, its properties (viscosity, refractive index, density) differ somewhat from those of an invert sugar solution of the same water content. These characteristics vary in a regular manner with the moisture content (solids content) of honey, but some uncertainty over actual values is caused by a lack of accuracy of methods for determining water content and by the possible effects of differences in ratios of the various sugars and in amounts of the more important minor components. Even so, each of these properties has been used as a means of measuring the moisture content of honey. This is a value of great importance to the honey producer, packer, and merchant, because it bears a direct relation to liability to undesired fermentation.

Direct Determination of Moisture

Because a knowledge of procedures for direct determination of moisture content of honey is important in comparing the results of various investigations on the physical properties, a brief review follows.

Moisture determination may be considered in three categories: evaporation with measurement of weight loss, evaporation with measurement of volume of water removed, and chemical determination. The first is most used; because of the sensitivity of honey sugars to heat, drying at a reduced temperature under reduced pressure is required. Generally an inert drying aid is added to increase bulk and porosity of the mass. Water may be added to the weighed sample to facilitate handling. The great hygroscopicity of dry honey requires the greatest care in manipulation.

As long ago as 1903, Shutt and Charron (2) recognized that even in a vacuum at 70°C, fructose decomposition prevented the attainment of a constant weight; they recommended a temperature of 60–70°C. Bryan (3), however, questioned whether 70°C was sufficient to remove all water, but his reasons were based on a misconception. Fabris (4) reported that 100°C drying *in vacuo* gave results 0.3–0.5% higher than three other procedures, all of which gave similar values: drying at 60°C, a distillation method, or drying in a dry air stream. Auerbach and Borries (5) developed a method in which 1 ml of a 50% solution is mixed with broken clay plate in a drying boat and dried at 60°C in a current of dry air. Röttinger (6) deposited a 0.01 g sample on a roll of dry filter paper and heated the sample at 100°C *in vacuo*. Other procedures for increasing the surface area and preventing surface hardening during drying have been proposed without improving over drying on sand below 70°C *in vacuo* (7–11). The official method of the Association of Official Analytical Chemists (12) uses a 1 g sample which is mixed with sand and dried at less than 70°C under pressure not over 50 mm until the weight is constant within 2 mg (which corresponds to about 0.2% water). Fulmer *et al.* (13) proposed that the sample weight be increased to 5 g, claiming greater accuracy, but their data do not support this claim.

Distillation with turpentine and measurement of recovered water was one of the procedures tested by Fabris (4); for three samples, results agreed with those of 60°C vacuum drying. Abramson (14) found that the Karl Fischer chemical titration for water gave 0.29% more moisture than vacuum drying at 70°C, with lower experimental error ($S = 0.14$ against 0.33). Hadorn (15) confirmed that vacuum drying at 100°C was unsatisfactory, as was Terrier's procedure (10). Further study of this application of the Karl Fischer method might be useful.

The direct drying procedure in any of its modifications is at best slow and cumbersome. Indirect methods have been studied, including refractometry at 20 or 40°C, density by pycnometer, specific gravity by spindle, and viscosity. Wedmore (16) wrote an excellent critical review of the moisture determination in honey. He correlated the results of various investigators and proposed equations for the instrumental methods. Unfortunately, before his death he had completed only Part 1 of a projected six-part study of the subject, but it included his general conclusions. The four physical methods listed above will be examined in some detail.

Refractive Index of Honey and Moisture Content

As noted above, the prime interest in this property of honey is to provide a rapid, accurate, and simple measure of moisture content of honey. Early workers (3, 17) noted that the moisture values obtained by converting refractometric readings by means of sucrose tables were 1 to 2% higher than those obtained from vacuum drying. Bryan (3) interpreted this to mean that the latter method might not remove all water. Not until Auerbach and Borries (5) studied the procedure was the necessity of special calibration for honey recognized. They calibrated the refractometer at 40°C against a vacuum drying procedure, using 23 samples, of which, however, only 10 were fresh floral honeys. Auerbach and Borries provide the following relationship between dry substance and refractive index at 40°C:

$$\text{Dry matter } (T) = 78 + 390.7\,(n_{40} - 1.4768)$$

This may be solved for n_{40} to give $n_{40} = 0.002559\,T + 1.2772$ where T must be 78 or more.

In spite of this work Marvin and Wilson (7,18), Schenk (19), Marvin (20), and Snyder (21) used sucrose tables for refractometric determination of moisture in honey. However, Chataway (22) provided the definitive study of the relationship, calibrating the refractometer at 25°C with vacuum oven determinations for 60 honey samples and providing temperature correction factors which have been corroborated (21). Her values agreed quite well with those of Auerbach and Borries when the latter were converted to 25°C. Fulmer *et al.* (13) felt that since the data of Auerbach and Borries and of Chataway (and the vacuum drying methods) gave values lower by 1.7% moisture than those obtained from sugar tables, it was advisable to modify the vacuum drying method to give higher water values. The modification they used was to increase the sample to 5 g honey. Their refractometer calibration equation then was:

$$\text{Per cent moisture} = 400\,(1.5380 - n_{20}).$$

These values are about 1% less moisture than the Schönrock table and 0.7% more moisture than Chataway. After several papers (7, 18, 20) in which honey refractometric values were converted to Brix (per cent sucrose), Marvin (23) finally published a table relating water content and refractive index, without attribution, which agreed with the Chataway data within 0.0001–0.0002 units. Experimental data were not published. Eckert and Allinger (24), in their analytical study of California honeys, determined moisture by drying (AOAC) and also by refractometer. They stated that they used the methods and tables of Marvin; however, the papers they cited contained only the Schönrock sucrose conversion. Study of the

Eckert and Allinger values for moisture by refractometer shows that they actually used either the Chataway table or the 1934 table of Marvin noted above, and certainly not a sucrose table. Their data, then, may not provide an independent confirmation of Chataway's results, as Wedmore thought (16). Torrent (25) did confirm the Chataway table. Wedmore gives the following as the best relationship obtainable from the data of Chataway, Eckert and Allinger, and Torrent:

$$\text{Water content} = [\bar{1}.73190 - \log(n_{20} - 1)]/0.002243$$

Table 1 shows the refractive indices of honey at moisture contents from 13.0 to 22.0%, as calculated by Wedmore (16) with the above relationship. Also shown in the table are corresponding values for 40°C, calculated from the Auerbach and Borries equation (5).

Wedmore did not include the relationship proposed by Auerbach and Borries (5) in his considerations. Values obtained from their equation may be corrected to 20°C by using the Chataway correction of 0.00023/°C. The results of this calculation for water contents over the entire range are shown in Table 2. The excellent agreement with the Wedmore values is seen in the table. It thus appears that the Wedmore table is indeed the best presently available.

Several subsequent workers compared water determination by refractometer with other procedures, direct and indirect. In general the deviation between water content by two instrumental methods (refractive index, density, viscosity) was considerably less than between the drying procedure and any other, indicating the relative imprecision of the drying procedure (14, 15). In some cases it is possible to infer n_{20} values from published equivalent values (Brix), convert them to moisture values by the Chataway table, and compare these values with those reported in the publication

Table 1. Refractive index of honeys of different water contents[a]

Water Content, %	Refractive Index			Water Content, %	Refractive Index		
	20°C[b]	60°F[c]	40°C		20°C	60°F	40°C
13.0	1.5044	1.5053	1.4998	18.0	1.4915	1.4925	1.4870
13.2	1.5038	1.5048	1.4993	18.2	1.4910	1.4920	1.4865
13.4	1.5033	1.5043	1.4988	18.4	1.4905	1.4915	1.4860
13.6	1.5028	1.5038	1.4983	18.6	1.4900	1.4910	1.4855
13.8	1.5023	1.5033	1.4978	18.8	1.4895	1.4905	1.4850
14.0	1.5018	1.5027	1.4973	19.0	1.4890	1.4900	1.4845
14.2	1.5012	1.5022	1.4968	19.2	1.4885	1.4895	1.4840
14.4	1.5007	1.5017	1.4962	19.4	1.4880	1.4890	1.4835
14.6	1.5002	1.5012	1.4957	19.6	1.4875	1.4885	1.4829
14.8	1.4997	1.5007	1.4952	19.8	1.4870	1.4880	1.4824
15.0	1.4992	1.5002	1.4947	20.0	1.4865	1.4875	1.4819
15.2	1.4987	1.4997	1.4942	20.2	1.4860	1.4870	1.4814
15.4	1.4982	1.4992	1.4937	20.4	1.4855	1.4865	1.4809
15.6	1.4976	1.4986	1.4932	20.6	1.4850	1.4860	1.4804
15.8	1.4971	1.4981	1.4927	20.8	1.4845	1.4855	1.4799
16.0	1.4966	1.4976	1.4922	21.0	1.4840	1.4850	1.4794
16.2	1.4961	1.4971	1.4916	21.2	1.4835	1.4845	1.4788
16.4	1.4956	1.4966	1.4911	21.4	1.4830	1.4840	1.4783
16.6	1.4951	1.4961	1.4906	21.6	1.4825	1.4835	1.4778
16.8	1.4946	1.4956	1.4901	21.8	1.4820	1.4830	1.4773
17.0	1.4940	1.4951	1.4896	22.0	1.4815	1.4825	1.4768
17.2	1.4935	1.4946	1.4891				
17.4	1.4930	1.4940	1.4886				
17.6	1.4925	1.4935	1.4881				
17.8	1.4920	1.4930	1.4876				

[a] The values for 20°C and 60°F are Wedmore's calculations (16). The 40°C values are calculated from the Auerbach and Borries equation (5).

[b] If the refractive index is measured at a temperature above 20°C, add 0.00023/°C above 20°C before using table.

[c] If the refractive index is measured at a temperature above 60°F, add 0.00013/°F above 60°F before using table.

Table 2. Refractive index of honeys of selected water content

Water Content, %	Refractive Index (20°C)		
	Chataway (34)	Wedmore (16)	Auerbach-Borries (5)[a]
13.0	1.5041	1.5044	1.5044
15.0	1.4990	1.4992	1.4993
17.0	1.4940	1.4940	1.4942
19.0	1.4890	1.4890	1.4891
21.0	1.4844	1.4840	1.4840

[a] Calculated by adding temperature correction of 0.0046 to 40°C values in Table 1.

by vacuum drying. Table 3 includes a comparison of the average deviations between the two procedures so calculated. Since refractometric values are relatively more precise, the high average deviations reflect the uncertainty in the determination of moisture by drying. The superiority of Chataway's data is evident in the small value obtained for average deviation from her data.

Zalewski (26) compared pycnometry (20% solution) with refractive index at 40 and 20°C. For the last, the AOAC *Official Methods of Analysis* (which contains Chataway's table) is cited, but since Zalewski's solids values by 20°C reading averaged 2.1% lower than by the other two methods, it seems possible that the

Table 3. Average deviation between moisture determination in honey by direct drying and refractometry

Investigator	No. Samples	$\bar{d}$
Bryan, 1908 (3)[a]	22	0.47
Auerbach and Borries, 1924 (5)	10[b]	0.51
Auerbach and Borries, 1924 (5)	17[c]	0.47
Chataway, 1932 (22)	60	0.12
Marvin and Wilson, 1931 (7)	21[d]	0.76
Fulmer *et al.*, 1934 (13)	25	0.20
Eckert and Allinger, 1939 (24)	99[e]	0.28
Torrent, 1949 (25)	30	0.12
Sacchi, 1955 (27)	72	0.30[f]

[a] Dry substance converted to refractive index at 28°C by Geerling's table as given, converted to moisture by Chataway table, compared with vacuum drying values.

[b] Fresh floral honeys only.

[c] All floral honey samples.

[d] First 21 samples in publication: refractive index obtained from Schönrock table, converted to moisture by Chataway table, compared with vacuum drying values.

[e] Levorotatory samples only.

[f] After correction of errors in her Table 2 (*see* text).

sucrose table therein was used. No specific citation was given. Abramson (14) lists S (between duplicates) for 50 samples by 70°C vacuum drying as 0.33; for refractive index with Chataway conversion (50 samples) as 0.06; and for Karl Fischer titration (148 samples) as 0.14.

Sacchi (27) has published a rather extensive study of moisture determination by refractometry for Umbrian (Italian) honey. Unfortunately, she chose the Fulmer *et al.* conversion table (13). She did find a better fit with her drying data if the equation of Fulmer *et al.* is modified by subtracting 0.32. Examination of her Table 2 shows 13 errors which, when corrected, revise the equation given by Sacchi to

$$\text{Per cent water} = 400\,(1.5380 - n_{20}) - 0.35.$$

This reduces the 0.7 difference between the higher values of the Fulmer *et al.* conversion table (13) and the Chataway values to half that amount.

It is impossible to separate the discussion of refractive index of honey and of water content. The limiting factor in improving the accuracy of the Wedmore-derived relation is the independent direct method for moisture determination. Since the Karl Fischer method may have a lower error than oven drying (14) and since a higher correlation coefficient was found (0.894) between Karl Fischer and refractive index than between drying and refractometer (0.856), calibration of the refractive index method against moisture by Karl Fischer titration should be considered. Abramson could not determine from his data which procedure should be the reference.

From a practical viewpoint it is debatable whether further accuracy in moisture determination by refractometer would be significant with honey composition varying as it does. The calibrations given in Table 1 are presently more accurate than necessary for the hand refractometers that are in considerable use by honey producers and packers. Pearce and Jegard (28) have calibrated such a refractometer against the AOAC drying procedure and report a standard error of ±0.4% for the calibration. A standard error of ±0.5% was found for drying and ±0.4% for the refractometer. Thus the hand refractometer is much more convenient than the AOAC vacuum oven method but not appreciably more accurate.

Density, Specific Gravity, and Moisture Content

Density of a solution is its mass per unit volume. This is often expressed for honey as pounds per gallon (U. S. or Imperial). The specific gravity is the ratio of the mass of a given volume of a solution at a stated temperature to that of the same volume of water at a stated temperature. Since water has a density of 1.0000 g/ml at 4°C, specific gravity at any temperature referred to water at 4°C is equal to the density at that temperature. The specific gravity is determined by direct weighing of a known volume of a liquid; it may also be determined by a calibrated hydrometer floating partially immersed in the liquid, and in other ways. There are numerous arbitrary calibrations of hydrometers for various purposes; some of those encountered in sugar analyses are Brix, Balling, Twaddel, and Baumé. In general, the use of hydrometers is potentially much easier and less expensive than pycnometry, but the nature of honey introduces such difficulty and uncertainty to the former that the two procedures are comparable.

Direct Weighing Methods—Pycnometry.—Tables relating specific gravity and dry substance of sucrose solutions have long been available and have been much used in honey analysis. Fiehe and Stegmüller (29), in comparing vacuum drying with density by pycnometer, noted differences in dry matter up to 1.5% with solutions of apparently equal density. They gave the equation

$$T = (D_4^{15} - 0.99913)/0.000771$$

to relate dry matter with density. Auerbach and Borries (5) determined D_4^{20} for 20% (w/v) honey solutions, using a 50 ml pycnometer, and also dry matter by direct drying on the same samples. For 10 fresh floral honeys, the following relationship was obtained by the method of least squares:

$$T = (D_4^{20} - 0.99823)/0.00076763$$

which they simplified to $T = 1302.7 \times (D_4^{20} - 0.99823)$ with the density value being that of a solution of 20.000 g honey in 100 ml. In comparing values for water content for 17 samples calculated from this relation with that found by direct drying, the average deviation was 0.42% water. For comparison, a similar value for their refractometric procedure (drying vs. refractive index) was 0.47.

Snyder (21) compared density (in pounds per gallon) for 18 honey samples as determined: (*a*) by direct weighing of ¼ or ½ pint, (*b*) by a pycnometer, using undiluted honey and converting the resultant D_{20} to weight per gallon from a sucrose table, and (*c*) by refractometer converted to Brix and thence to weight per gallon by sucrose tables. The average values for the 18 samples by these procedures were 11.867, 11.867, and 11.859 lb/gal., respectively. The average difference between (*a*) and (*b*) was 0.011, between (*b*) and (*c*) 0.009, and between (*a*) and (*c*) 0.012. These differences are equivalent to 0.19, 0.16, and 0.21% water in the sucrose tables used. No relationship between moisture content of the honeys and density was determined or reported in this study.

Marvin (20) described two procedures for determining density of honey: weighing of a standard pint or gill measure and conversion of refractive index by sucrose tables to weight per gallon, both as described by Snyder (21). Average values for 37 floral honeys were 11.838 and 11.845 lb/gal., respectively; the average difference was 0.015 (equivalent to 0.26% moisture). Again, no independent determination of moisture content was made. This small difference is in contrast with the difference in moisture content between the sugar and honey calibrations of the refractometer in terms of solids (or water) content. Apparently, honey and sucrose solutions of equivalent density have refractive indices differing only slightly, the average difference between the two being about 0.0006 in refractive index. By contrast, sucrose solutions and honeys of equivalent moisture differ by about 0.0040 in refractive index, or about 1.6% moisture. When Marvin (23) published a revised table relating refractive index, weight per gallon, and water content, the refractive index–weight per gallon values were not changed, though the water values in the revised table corresponded to the Chataway equivalents.

Hadorn (15) found an average difference between the Auerbach and Borries refractive index calculation and pycnometric determination of dry matter of 0.17% solids. The averages of the 10 honeys were only 0.01% apart.

Hydrometry.—Use of hydrometers for specific gravity determination in honey followed by many years the development of these instruments for technical and research measurements in the sugar industry. Pique (30) described a hydrometer for honey musts which had three graduations: specific gravity, weight of honey per hectoliter, and per cent alcohol which should result from proper fermentation. Some use of hydrometers in honey processing was noted by Chataway (22). In considering the use of the hydrometer for undiluted honey, she noted that two such instruments were then in use in Canada, and examined both. One, designed for small honey samples, showed very poor reproducibility (over 2% moisture) and the other (larger) was somewhat better. Later (31) she designed a large, sensitive Baumé hydrometer for honey and tested 38 honey samples for which moisture was also determined by refractive index. In this work, earlier erratic results were eliminated by placing a layer of water on the honey surface after the hydrometer was in place. Readings were made at about 120°F and corrected to 68°F (20°C) and also for the presence of the water layer. Average moisture for the 38 samples by refractometer was 17.42%, and by a calibration curve constructed from the hydrometer values, 17.43%. The average deviation between values by the two methods was 0.15% moisture.

Marvin (20) described the use of a hydrometer for determining the weight per gallon of honey. This density measure was used because recently issued U.S. Department of Agriculture grades had specified a minimum weight of 11.75 lb/gal. at 68°F. Two procedures were described: use of a Brix hydrometer in warm full-density honey and the Brix dilution method in which a Brix hydrometer was used in a 1:1 dilution and the reading was doubled. Conversion to weight per gallon from Brix was made from standard sugar tables. Results from this latter method were compared with those from direct weighing and averaged (for 37 honeys) 11.915 lb/gal. against 11.838 lb/gal. by weighing. The difference is equivalent to 1.35% moisture. This value is close to the −1.3 correction which must be applied to Brix values of molasses when determined by the double dilution procedure; the factor is needed in that case to correct for the excess volume contraction of molasses over sucrose when diluted (32, p. 29). Marvin noted the higher values but ascribed no cause.

Some of the physical shortcomings of hydrometry in a heavy viscous liquid such as honey may be overcome by enclosing the sample in the float and suspending it in water. White (33) has made a preliminary evaluation of this type of hydrometer, the Eichhorn type, for moisture determination in honey. He concluded that the accuracy of his model was as good as the hand refractometer, or better.

Wedmore (16), while admiring Chataway's work on refractive index of honeys, felt that her work on specific gravity of honey "though not yet superseded, is not in the same class." He discussed two calibration charts (per cent water vs. degrees Baumé) of Chataway: one in the original 1933 publication (31) and one published later (34). When converted to the same temperature basis they differ somewhat, particularly in the lower moisture ranges. Wedmore thought that this was the result of using insufficient numbers of samples of lower moisture content (below 15.5%) and using a straight-line relationship for the later conversion table instead of a curve, which was shown in the 1933 paper and is also seen with other sugar solutions.

In Wedmore's Table 6, column 6 is entitled "Author's new determination" and lists specific gravity values at 20/20°C. Careful reading of the paper leads one to believe that this refers not to independent experimental work, but to his fitting of a new line to the original Chataway data which he obtained from her Figure 2, from which Wedmore "reproduced the original experimental results by the use of a reading microscope" (16). The specific gravity values in Wedmore's Table 6, column 6, differ from the 1935 Chataway table, and Wedmore noted that the specific gravity figures in the 1935 Chataway table not only suffered from the use of the linear relationship, "but also from some error made during conversion to S. G.; it seems impossible now to trace this to its source, by its magnitude or otherwise. . . . her published S. G. figures tend to give too low a water content, the differences in S. G. representing a difference in water content of about 0.2 per cent." The source of this difference now appears clear. In a letter written in 1937 to a U.S. Department of Agriculture official, which has recently come to hand, Dr. Chataway commented on a Baumé-Brix conversion table in a 1933 Department honey grading circular, pointing out that it did not agree with her table because two different Baumé scales were involved.[1] The U.S. scale was the U.S. Bureau of Standards Bates and Bearce modification (32, page 81) established in 1918 and relating Baumé to specific gravity at 20/20°C. Dr. Chataway used the older "American Standard" Baumé which related to specific gravity at 60/60°F. Since the differences between specific gravity values at 20/20°C calculated from Baumé are about 0.0012–0.0016 in specific gravity in the proper direction, it is evident that Wedmore assumed Chataway was using the modern Baumé (20/20°C) when in fact she used 60/60°F, so that her lower values resulted from her proper correction of the specific gravity 60/60°F values obtained from the Baumé equation[2] to specific gravity 20/20°C values, which Wedmore did not do. An example will perhaps clarify this explanation. Wedmore notes that her values (in degrees Baumé) in the middle of the range are practically identical with his newly calculated figures. Her Table 2 (31) gives for 17.4% moisture a Baumé value at 68°F of 42.89. Converting by her value of 0.024/°F, we obtain 43.08 Baumé at 60°F (her 1935 tables gives 43.09). Since the Baumé scale Chataway used was the older American scale, the specific gravity at 20/20°C is obtained as

$$\text{S. G. } 60/60°\text{F} = 145/(145 - 43.08) = 1.42268.$$

Using Wedmore's conversion factors to convert 60/60°F to 20/20°C, we have specific gravity 20/20°C = (1.42268 × 1.00081) − 0.0027 = 1.42113 which rounds to 1.4211. The corresponding value in the 1935 Chataway table is 1.4212. If we assume (as apparently Wedmore did) that the "new" Baumé scale was used, we get

$$\begin{aligned}\text{S. G. } 20/20°\text{C} &= 145 - (145 - 43.08)\\ &= 1.42268\end{aligned}$$

which rounds to 1.4227. The value given by Wedmore in his Table 6, column 6, is 1.4226 for his "new" determination.

We must therefore conclude that Wedmore's new curve was obtained from Chataway's experimental Baumé values but was erroneously converted to specific gravity. We cannot then accept his Table 5, "Proposed figures for the specific gravity of honeys of different water contents," because the values he labels specific gravity 20/20°C are in fact specific gravity 60/60°F and must be converted as indicated above to obtain the 20/20°C table.

Table 4 shows the Wedmore revision of Chataway's data as correctly converted to specific gravity. Departure from the 1935 Chataway table is primarily at the lower-moisture end and the two tables are coincident between 17.2 and 19.2% moisture.

The specification "modulus 145" used by Chataway (34) is not sufficient to identify the Baumé scale she used. True, other scales use different moduli but the Bates-Bearce scale differed from the older American standard only in the use of S. G. 20/20°C rather than S. G. 60/60°F, and uses the same modulus. The newer scale appears to be in general use in the United States (32, page 82; 35, page 249). Chataway anticipated confusion, for in the letter noted above she remarked that the Bates-Bearce scale "is still recognized, apparently, as it appears in the fourth, 1936, edition of the American Official Agricultural Handbook[3] . . . but it can hardly be con-

[1] The pertinent paragraph follows: "You ask for comment on Circular 24 of the U.S. Department of Agriculture. The most serious discrepancy between the figures given in this circular and the figures in my tables, lies in the relationship between degrees Beaumé and degrees Brix. I think you will find that the trouble goes back to the U.S. Bureau of Standards Circular No. 44, entitled 'Polarimetry.' In the second, 1918, edition of this circular, Table 31 gives a relation between the degrees Brix, the specific gravity, and the degrees Beaumé of sugar solutions. Although the relationships are based on modulus 145, the specific gravities used are those at 20°/20°C instead of, as in the American Standard Beaumé scale, those at 60°/60°F. (cf. page 160)."

[2] Degrees Baumé = 145 − 145/S.G. 60/60; Bureau of Standards Baumé = 145 − 145/S.G. 20/20.

[3] This table appears in the *Official Methods of Analysis*, 10th ed. (12). It gives "true specific gravity," corresponding to weights *in vacuo*, calculated directly from the formula. Table 3 in Browne and Zerban (32) also gives the Bates-Bearce scale but is calculated to give "apparent specific gravity" at 20/20°C which corresponds to weighing in air.

Table 4. True specific gravity of honeys of different water content[a]

Water Content, %	Specific Gravity 20/20°C	60/60°F	Water Content, %	Specific Gravity 20/20°C	60/60°F
13.0	1.4457	1.4472	17.0	1.4237	1.4252
13.2	1.4446	1.4461	17.2	1.4224	1.4239
13.4	1.4435	1.4450	17.4	1.4211	1.4226
13.6	1.4425	1.4440	17.6	1.4198	1.4213
13.8	1.4414	1.4429	17.8	1.4185	1.4200
14.0	1.4404	1.4419	18.0	1.4171	1.4187
14.2	1.4393	1.4408	18.2	1.4157	1.4173
14.4	1.4382	1.4397	18.4	1.4143	1.4159
14.6	1.4372	1.4387	18.6	1.4129	1.4145
14.8	1.4361	1.4376	18.8	1.4115	1.4131
15.0	1.4350	1.4365	19.0	1.4101	1.4117
15.2	1.4339	1.4354	19.2	1.4087	1.4103
15.4	1.4328	1.4343	19.4	1.4072	1.4088
15.6	1.4317	1.4332	19.6	1.4057	1.4073
15.8	1.4306	1.4321	19.8	1.4042	1.4058
16.0	1.4295	1.4310	20.0	1.4027	1.4043
16.2	1.4284	1.4299	20.2	1.4012	1.4028
16.4	1.4272	1.4287	20.4	1.3996	1.4012
16.6	1.4260	1.4275	20.6	1.3981	1.3997
16.8	1.4249	1.4264	20.8	1.3366	1.3982
			21.0	1.3950	1.3966

[a] Wedmore's (16) revision of Chataway's (31) data as corrected (*see* text). By definition, values for specific gravity 20/20 calculated from Baumé are "true" specific gravity, i.e., they correspond to weight *in vacuo*. To obtain "apparent" specific gravity, i.e., corresponding to weight in air with brass weights, the correction to be added to the true value varies from 0.00047 at 21% moisture to 0.00055 at 13% moisture. An average correction of +0.0005 is satisfactory.

sidered correct. In effect it establishes a second American Baumé scale with no convenient title to distinguish it from the one more generally recognized."

The relatively large differences in density among honeys require that particular care be taken to mix thoroughly in blending of honeys. Layering of different honeys in a tank can be quite pronounced; in fact, Fix and Palmer-Jones (36) state that the top layer of honey in settling tanks is the most dilute not because of absorption of moisture from air, but rather because of density difference. Heating and mixing is recommended to avoid such layering.

Viscosity and Moisture Determination of Honeys

Fellenberg (37) attempted to use viscosity as a means to detect the addition of glucose sirup to honey. Considerable variation among honeys reduced the value of the procedure for this purpose. In the study of the effect of moisture content on various physical attributes of honey already discussed, Chataway (22) included viscosity measurement. Using a falling-ball viscometer, she reported a nearly straight-line relationship between log of viscosity and log of moisture content. Using this curve, moisture contents for the 60 honeys were calculated and compared with those obtained by the AOAC vacuum drying procedure. Average difference for all samples was 0.20% moisture; elimination of five buckwheat samples which did not fit the curve reduces the average difference to 0.14% moisture. Chataway noted that a difference of 0.1% in moisture gives viscosity differences of 4–6%. The viscosity value is highly temperature-sensitive. Chataway constructed a correction chart by which times at any temperature (to 0.1°) between 15.0 and 30.0°C could be corrected to 25.0°C before conversion to moisture values.

Oppen and Schuette (38) found a very poor degree of correlation between refractive index and moisture content of honey by the AOAC drying method (no data given) and hence investigated the use of viscosity for this purpose. They criticized Chataway's apparatus as permitting errors up to 8% because of wall effects caused by the use of a too narrow tube. Using an apparatus with a more favorable ratio of ball diameter to tube diameter, they determined viscosities of 30 samples at 40°C, and 15 samples at four other temperatures. An equation relating viscosity, moisture, and temperature was developed and a graph was presented for obtaining moisture content from time of fall of the ball in their apparatus. The average difference between moisture values from the chart and by the AOAC method found by Oppen and Schuette is 0.20%. Since they claimed their procedure is more accurate than Chataway's, her lower average deviation may be due to better technique for AOAC moisture determination.

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