

## COMPOSITION OF AMERICAN HONEYS

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Each year about 250 million pounds of honey are harvested by the beekeepers of the United States. This honey is produced by more than five million colonies of honeybees, owned by beekeepers whose operations range from the single hive of the hobbyist to that of the full-time commercial apiarist who may control many thousands of colonies. Hundreds of plants are known to be attractive to bees as nectar sources. Many of these, either cultivated or in the wild state, occur in local concentrations large enough to be valuable as sources of surplus honey. Since honey is produced in each of the 50 States of this country, the possibilities for variation in its composition and properties are enormous. Added to the variety of nectar-secreting plants are the effects of beekeeping and farming practices, local climatic and environmental conditions, and soils, any or all of which might affect the composition of honey. It is apparent that honey is potentially an extremely variable commodity. This variability retards the extensive use of honey in many parts of the food industry. The trend appears to be toward standardization of ingredients and toward increasing use of materials of known composition. Honey, a most valuable carbohydrate that carries unique flavoring properties, is a relatively complex material whose composition, either in general or specifically, has been only imperfectly known and reported. Although hundreds of honey types and blends are known only 25 or 30 are of commercial significance. These are the bulk honeys of trade; the ones that are available from year to year and that provide most of the commercial beekeeper's income. Little or no information has been available on the variations in composition to be expected among these honeys.

Profound changes have taken place in agricultural practices in this country over the past few decades. These have been reflected in changes in the types of honey produced and also in the increased dependence of American agriculture on the honeybee for pollination of many crops. The last analytical survey of the composition of American honey was that of Browne, published in 1908 (Browne, 1908). Honey samples studied were probably of the 1902 or 1903 crops. The procedures then used for carbohydrate analysis of honey have been employed ever since with only minor improvements (Eckert and Allinger, 1939; Milum, 1948). Recently, innovations have been made (White, 1959; White and Maher, 1954), and the resulting analyses are far less empirical than previous ones (Boer, 1934). Differences in results for carbohydrates between old and new methods are sufficiently large that it is necessary to re-examine the carbohydrate composition of honey by the newer procedures.

A fuller knowledge of the composition of honey and its variation with floral source, age, production area, and crop year is essential to maintaining or improving its competitive position in the market and in the food industry. It is the objective of this book to provide such information.

Only partial attainment of this objective is within our grasp. Physical limitations have confined our efforts to do as complete an analysis as possible of 504 samples of honey and honeydew, representing two crop years. These samples originated in 47 States and represent 83 single floral types, 93 blends of known composition, and four honeydew types. Certainty regarding floral type(s) of the samples is not absolute by any means; further comment on this appears elsewhere in this book. Samples of the more common and important types of honey yield some information on variation due to area of production.

## REVIEW OF PREVIOUS WORK

Relatively little attention has been given to the composition of American honey in recent years. About 500 commercial "honey" samples were analyzed late in the 19th century during Wiley's crusade for the Pure Food Laws (Wiley, 1892). At that time much of the honey on the market was adulterated with other carbohydrate materials. The analytical methods developed during that time were later used by Browne (1908) and his report has remained the standard reference in this field. He analyzed 100 samples of honey (and honeydew) from 42 floral types representing 21 plant families. In addition to dextrose, levulose, sucrose, and dextrin, the amount of ash, free acidity, and the presence of tannin were also determined. In 1908, Van Dine and Thompson reported the analysis of 54 samples of Hawaiian honey and honeydew. Using a new procedure for dextrose determination in honey, Lothrop and Holmes (1931) published values for dextrose and levulose for 33 United States honey samples of 30 floral types. Three years later, Lynn et al. (1934) analyzed 25 samples of Illinois honey representing eight floral types and blends. All these analyses were largely empirical, though the analytical methods used by Lynn et al. and by Lothrop and Holmes resulted in more realistic values than those reported earlier. Eckert and Allinger (1939) later published analysis of 112 samples of California honey and honeydew. These represented 47 floral types and blends. The carbohydrate methods they used were essentially those of Browne, which have appeared in the Official Methods of the Association of Official Agricultural Chemists (1955) since 1916. Ellegood and Fisher (1940) analyzed four samples of fireweed honey by these methods in 1940. A critical study of methods of sugar analysis applicable to honey was made by White et al. (1952). None of five methods generally in use or proposed for honey analysis, including the Official Methods, gave results reflecting the true composition of the sample. Later White and Maher (1954a) developed an entirely new procedure for carbohydrate analysis of honey, which they applied to 19 domestic honey samples (White and Maher, 1954b). Using this method they found a new category of honey sugars, the reducing disaccharides; the method also provided more accurate values for dextrose, levulose, and higher sugars than did older methods. This method has been used in analyzing the samples in this report. It has been subjected to collaborative testing (White 1957, 1959) and accepted as first action by the Association of Official Agricultural Chemists (Osborn et al. 1959). It has also been used in Canada (Austin, 1958), Chile (Bravar, 1958), and South Africa (Anderson, 1958).

## HONEY SAMPLES

### Procurement

Samples of honey for the crop years 1956 and 1957 were solicited personally and by mail from beekeepers and producer organizations. Special emphasis was placed on obtaining samples of known source and history. Where local conditions and practices produced complex blends, these were identified as such and are characterized by location, area of production, and time of harvest. Instructions were given on proper sampling and as much detail as possible was requested regarding area of production, floral type or blend information, and type of processing. While unheated samples were preferred, samples of known heating history were accepted. During the two-year period, 516 samples of honey and honeydew were obtained, of which 12 were not analyzed for various reasons. The locations from which samples were obtained are shown on the map (Figure 1).

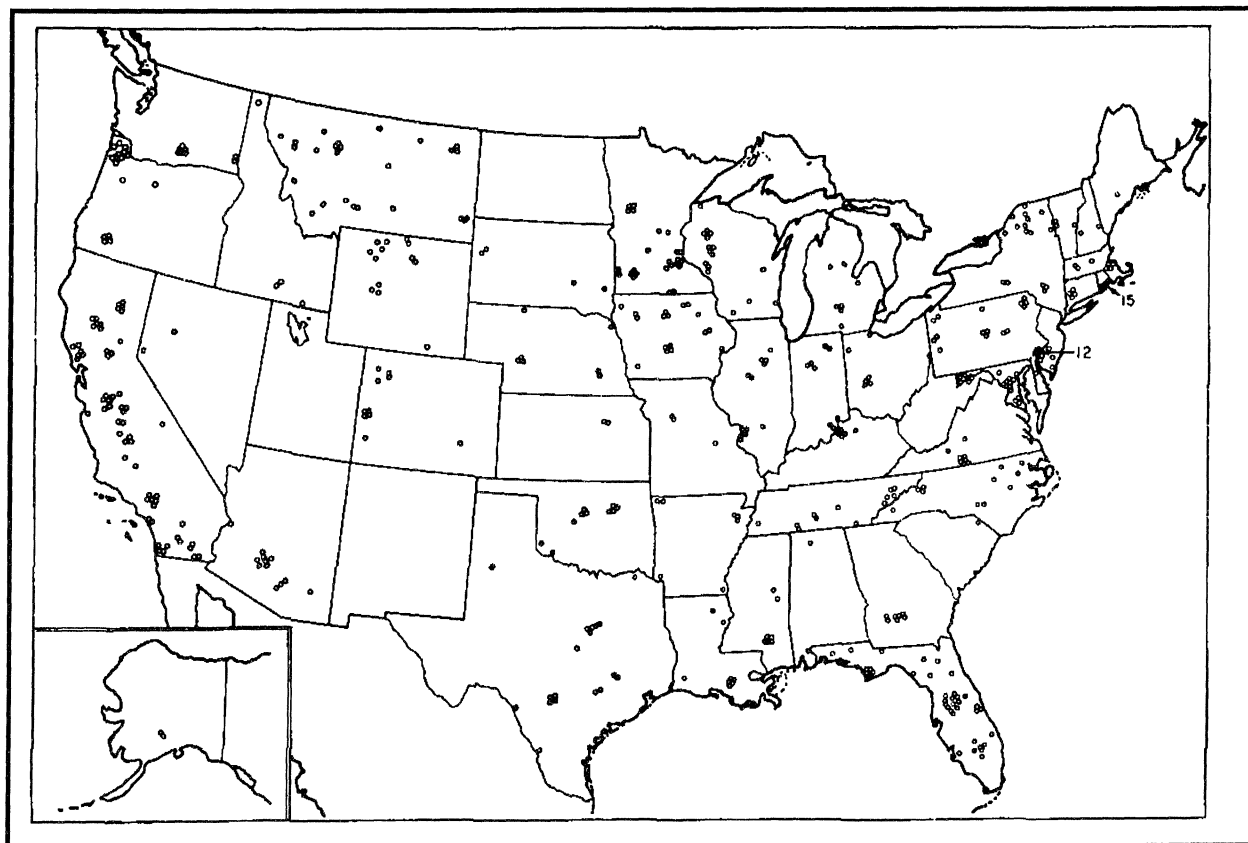


Figure 1. *Origin of honey and honeydew samples.*

## Treatment and Storage

Procedures for handling samples on arrival were occasionally modified during the work. Approximately the first 200 samples were handled as follows: If the sample was liquid; determined by a honey polariscope (White and Maher, 1951) or only slightly granulated when received, it was mixed and a 2-ounce subsample removed and graded for color. This was then stored at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ) within 1 day of arrival. The remainder of the sample was kept at room temperature ( $23^{\circ}\text{--}28^{\circ}\text{C}$ ,  $73^{\circ}\text{--}82^{\circ}\text{F}$ ) in a dark cabinet until analysis. If the sample was partly or completely granulated upon receipt, it was heated with the cap tight in a water bath at  $60^{\circ}\text{C}$  ( $140^{\circ}\text{F}$ ) for 30 minutes. If this did not liquefy the sample, the temperature was raised to  $65^{\circ}\text{C}$  ( $149^{\circ}\text{F}$ ) and heating was continued until liquefaction was complete. The sample was cooled, a two-ounce subsample was graded for color, and stored at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ). The rest of the sample was kept at room temperature as indicated previously.

After experience with this procedure it was noted that some unheated samples showed signs of fermentation during storage. These were immediately pasteurized at  $60^{\circ}\text{C}$ . ( $140^{\circ}\text{F}$ .) for 30 minutes. The last 300 samples received were therefore handled as follows:

Two-ounce subsamples were removed from producer-unheated liquid samples as before, color graded, and stored at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ). The remainder of the sample was pasteurized as above before storage at room temperature. Liquid samples that had been heated by the producer were not stored in the cold, and the bulk of the sample was pasteurized in the laboratory. Samples requiring liquefaction were handled as before except no subsample was stored at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ). Some samples were received in the comb. These were crushed in a beaker, warmed to  $50^{\circ}\text{C}$  ( $122^{\circ}\text{F}$ ), and strained through two layers of cheesecloth. They were then treated as described for liquid honey unheated by the producer. Extracted honey samples were strained through two layers of cheesecloth before storage if they contained any extraneous material.

The analytical work on these samples was carried out over a period of about 30 months; therefore, many samples required several heatings to liquefy them so that subsamples would be properly representative.

All analyses, except the diastase determination and the storage study (White et al., 1961), were carried out on the samples stored at ordinary temperature. Attempts were made to minimize heat exposure of samples by sub-sampling for as many determinations as possible at one time.

## Analytical Methods

Details of all methods used appear in the appendix. This section is limited to the general principles of the various procedures. Moisture was determined by measuring refractive index on an Abbe refractometer at  $20^{\circ}\text{C}$  ( $68^{\circ}\text{F}$ ) and use of the Chataway table (Association of Official Agricultural Chemists, 1955). Color of all samples was determined by the U.S. Department of Agriculture color classifier (Brice et al., 1956). Each of the six United States color standards for extracted honey (U.S. Agricultural Marketing Service, 1951) was visually split into two zones, light and dark, so that samples were classified into 13 groups ranging from "light Water-White" to Dark Amber". The Pfund values for the official grade limits are accurately determined by our procedure; however, the values for the boundaries between the light and dark portions of each class are only approximate. The classes and their code numbers follow.

Code No.	Color group	Pfund Value
		Millimeters
0	Light half of Water White	Less than 4
1	Dark half of Water White	4-8
2	Light half of Extra White	8-12
3	Dark half of Extra White	12-17
4	Light half of White	17-27
5	Dark half of White	27-34
6	Light half of Extra Light Amber	34-42
7	Dark half of Extra Light Amber	42-50
8	Light half of Light Amber	50-70
9	Dark half of Light Amber	70-85
10	Light half of Amber	85-104
11	Dark half of Amber	104-114
12	Dark Amber	114 and more
13	Blue	---

"Granulation" is recorded in appendix table 27, was estimated empirically as follows: after analysis, the completely liquid sample of honey remained undisturbed for six months after its last heating. At this time, its degree of granulation was judged visually and with the polariscope (Appendix). It was assigned to one of 10 groups, as follows:

Code no.	Degree of granulation
0	None.
1	Few scattered crystals.
2	Layer on bottom 1/16 to 1/8 inch.
3	Few clumps of crystals.
4	Layer on bottom 1/4 to 1/2 inch.
5	1/4 of depth granulated.
6	1/2 of depth granulated.
7	3/4 of depth granulated.
8	Complete soft granulation.
9	Complete hard granulation.

For carbohydrate analysis, the sample was dissolved in dilute alcohol and passed through a column of activated charcoal under controlled conditions. The column was then washed with two solvents of higher alcohol content, with the result that three solutions were obtained from each sample. Dextrose was determined by hypiodite oxidation and levulose was determined directly, after hypiodite destruction of dextrose, by a micro copper-reduction method. On another fraction from the charcoal column, reducing disaccharide sugars were determined directly by the micro copper-reduction method and reported as maltose. In the same fraction, sucrose was determined by increase in reducing power after a mild acid hydrolysis. Where sample identity or high sucrose and higher sugar values (each over one percent) indicated its desirability, true sucrose was estimated by invertase hydrolysis, and melezitose was calculated from the difference between apparent "sucrose" and true sucrose. A third fraction collected from the charcoal column contained all other sugars from the sample, i.e., most trisaccharides and higher sugars. These carbohydrates were hydrolyzed by acid and determined collectively as dextrose by copper reduction.

A portion of each fraction analyzed for all samples was evaporated to dryness and subjected to paper chromatography to monitor the efficiency of the charcoal column separation and to detect any departure from normal of the distribution of the several sugars within each fraction. The "undetermined" value is the difference between 100 and the total sugars plus the moisture content; its significance is discussed later.

A study of the accuracy of the selective adsorption method is given in detail in the appendix. For determination of free acid, lactone, total acidity, and pH, a recently developed procedure was used (White et al., 1958). A honey sample was diluted, its pH noted, and a rapid electrometric titration used to determine free acidity. A back-titration following the addition of an excess of alkali measured lactone content; the total acidity is the sum of these two values.

Diastase was determined on all samples stored at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ) and also on a limited number of other samples. The procedure used was that described by Schade et al. (1958), as adopted by the Association of Official Agricultural Chemists (Osborn et al., 1959; White, 1959). It has also been used by Duisberg and Gebelein (1958). Two advantages over the old modified Gothe procedure are the objectivity of the method and its provision of a continuous scale of diastase activity rather than a limited number of discrete "steps."

For the ash determination, honey samples were slowly dried and charred under infrared heating lamps, then subjected to the usual ashing process. This prevented loss of sample by foaming.

A micro-Kjeldahl method was used for determination of nitrogen.

## RESULTS

The results of the analyses are presented in detail in Appendix Tables 26 and 27, and graphically in Figures 2 to 5. The figures show the relative spread of values for all the characteristics listed in appendix Table 27. The complete range of values is divided into a number of intervals and the number of samples in each interval is shown. The average values for each characteristic and the standard deviations are also indicated on the graphs. Honeydew samples are not included in these distributions. [Sixteen samples later identified as honeydews are not included in these graphs.] .....

## CHARACTERIZATION OF INDIVIDUAL TYPES OF HONEY AND HONEYDEW

Table 1 shows the average values obtained for the honey samples analyzed, the highest and lowest values found, and the standard deviation for each measurement.

**TABLE 1.-Average composition of 475 samples of honey and range of values<sup>1</sup>**

Characteristics measured		Average	Standard Deviation	Range
Color <sup>1</sup>		5	2,8	0 - 12
Granulation <sup>1</sup>		3	2.8	0- 9
Age <sup>2</sup>	months	12	5.6	1 - 33
Composition:				
Moisture	%	17.23	1.46	13.4 - 22.9
Levulose	%	38.38	2.07	30.91 - 44.26
Dextrose	%	31.46	3.03	22.04 - 40.75
Sucrose	%	1.32	0.94	0.25 - 7.57
Maltose	%	7.22	2.00	2.74 - 17.64
Higher sugars	%	1.38	0.77	0.13 - 6.39
pH		3.99	--	3.30 - 6.10
Free Acid	meq/kg	22.03	8.22	6.75 - 7.19
Lactone	meq/kg	7.16	3.52	7.16 - 19.37
Total acid	meq/kg	28.50	10.17	8.68 - 59.99
Ash	%	.158	0.130	0.01 - 0.94
Nitrogen	%	0.41	0.02	0.00 - 0.13
Diastase value		20.8	9.76	2.1 - 61.2

<sup>1</sup> 21 honeydews removed from Table 26, (see Table 26a)

<sup>2</sup> See Page 6 for color and granulation codes.

<sup>3</sup> Age is time between sample receipt and analysis.