Honey Composition and Properties

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Honey is essentially a highly concentrated water solution of two sugars, dextrose and levulose, with small amounts of at least 22 other more complex sugars. Many other substances also occur in honey, but the sugars are by far the major components. The principal physical characteristics and behavior of honey are due to its sugars, but the minor constituents – such as flavoring materials, pigments, acids, and minerals – are largely responsible for the differences among individual honey types.

Honey, as it is found in the hive, is a truly remarkable material, elaborated by bees with floral nectar, and less often with honeydew. Nectar is a thin, easily spoiled sweet liquid that is changed ("ripened") by the honey bee to a stable, high-density, high-energy food. The earlier U.S. Food and Drug Act defined honey as "the nectar and saccharine exudation of plants, gathered, modified, and stored in the comb by honey bees (*Apis mellifera* and *A. dorsata*); is levorotatory; contains not more than 25% water, not more than 0.25% ash, and not more than 8% sucrose." The limits established in this definition were largely based on a survey published in 1908. Today, this definition has an advisory status only, but is not totally correct, as it allows too high a content of water and sucrose, is too low in ash, and makes no mention of honeydew.

Colors of honey form a continuous range from very pale yellow through ambers to a darkish red amber to nearly black. The variations are almost entirely due to the plant source of the honey, although climate may modify the color somewhat through the darkening action of heat.

The flavor and aroma of honey vary even more than the color. Although there seems to be a characteristic "honey flavor," almost an infinite number of aroma and flavor variations can exist. As with color, the variations appear to be governed by the floral source. In general, light-colored honey is mild in flavor and a darker honey has a more pronounced flavor. Exceptions to the rule sometimes endow a light honey with very definite specific flavors. Since flavor and aroma judgments are personal, individual preference will vary, but with the tremendous variety available, everyone should be able to find a favorite honey.

Composition of Honey

By far, the largest portion of the dry matter in honey consists of the sugars. This very concentrated solution of several sugars results in the characteristic physical properties of honey – high viscosity, "stickiness," high density, granulation tendencies, tendency to absorb moisture from the air, and immunity from some types of spoilage. Because of its unique character and its considerable difference from other sweeteners, chemists have long been interested in its composition and food technologists sometimes have been frustrated in attempts to include honey in prepared food formulas or products. Limitations of methods available to earlier researchers made their results only approximate in regard to the true sugar composition of honey. Although recent research has greatly improved analytical procedures for sugars, even now some compromises are required to make possible accurate analysis of large numbers of honey samples for sugars.

An analytical survey of U.S. honey is reported in *Composition of American Honeys*, Technical Bulletin 1261, published by the U.S. Department of Agriculture in 1962. In this survey, considerable effort was made to obtain honey samples from all over the United States and to include enough samples of the commercially significant floral types that the results, averaged by floral type, would be useful to the beekeeper and packer and also to the food technologist. In addition to providing tables of composition of U.S. honeys, some general conclusions were reached in the bulletin on various factors affected by honey composition.

Where comparisons were made of the composition of the same types of honey from 2 crop years, relatively small or no differences were found. The same was true for the same type of honey from various locations. As previously known, dark honey is higher than light honey in ash (mineral) and nitrogen content. Averaging results by regions showed that eastern and southern honeys were darker than average, whereas north-central and intermountain honeys were lighter. The north-central honey was higher than average in moisture, and the intermountain honey was more heavy bodied. Honey from the South Atlantic States showed the least tendency to granulate, whereas the intermountain honey had the greatest tendency.

The technical bulletin includes complete analyses of 490 samples of U.S. floral honey and 14 samples of honeydew honey gathered from 47 of the 50 States and representing 82 “single” floral types and 93 blends of “known” composition. For the more common honey types, many samples were available and averages were calculated by computer for many floral types and plant families. Also given in this bulletin are the average honey composition for each State and region and detailed discussions of the effects of crop year, storage, area of production, granulation, and color on composition. Some of the tabular data are included in this handbook.

Table 1 gives the average value for all of the constituents analyzed in the survey and also lists the range of values for each constituent. The range shows the great variability for all honey constituents. Most of the constituents listed are familiar. Levulose and dextrose are the simple sugars making up most of the honey. Fructose and glucose are other commonly used names for these sugars. Sucrose (table sugar) also is present in honey, and is one of the main sugars in nectar, along with levulose and dextrose. “Maltose” is actually a mixture of several complex sugars, which are analyzed collectively and reported as maltose. Higher sugars is a more descriptive term for the material formerly called honey dextrin.

The undetermined value is found by adding all the sugar percentages to the moisture value and subtracting from 100. The active acidity of a material is expressed as pH; the larger the number the lower is the active acidity. The lactone is a newly found component of honey. Lactones may be considered to be a reserve acidity, since by chemically adding water to them (hydrolysis) an acid is formed. The ash is, of course, the material remaining after the honey is burned and represents mineral matter. The nitrogen is a measure of the protein material, including the enzymes, and diastase is a specific starch-digesting enzyme.

Most of these constituents are expressed in percent, that is, parts per hundred of honey. The acidity is reported differently. In earlier times, acidity was reported as percent formic acid. We now know that there are many acids in honey, with formic acid being one of the least important. Since a sugar acid, gluconic acid, has been found to be the principal one in honey, these results could be expressed as “percent gluconic acid” by multiplying the numbers in the table by 0.0196. Since actually there are many acids in honey, the term “milliequivalents per kilogram” is used to avoid implying that only one acid is found in honey. This figure is such that it properly expresses the acidity of a honey sample independently of the kind or kinds of acids present.

In table 1, the differences between floral honey and honeydew honey (2) can be seen. Floral honey is higher in simple sugars (levulose and dextrose), lower in disaccharides and higher sugars (dextrins), and contains much less acid. The higher amount of mineral salts (ash) in honeydew gives it a less active acidity (higher PH). The nitrogen content reflecting the amino acids and protein content is also higher in honeydew.

TABLE 1. *Average composition of floral and honeydew honey and range of values* (1)

Characteristic or constituent		Floral honey		Honeydew honey	
		Average values	Range of values	Average values	Range of values
Color (2)		Dark half of white.	Light half of water white to dark.	Light half of amber.	Dark half of extra light amber to dark.
Granulating tendency (3)		Few clumps of crystals 1/8- to 1/4-inch layer.	Liquid to complete hard granulation.	1/16- to 1/8-inch layer of crystals.	Liquid to complete soft granulation.
Moisture	percent	17.2	13.4-22.9	16.3	12.2-18.2
Levulose	do	38.19	27.25-44.26	31.80	2.91-38.12
Dextrose	do	31.28	22.03-40.75	26.08	19.23-31.86
Sucrose	do	1.31	.25-7.57	.80	.44-1.14
Maltose	do	7.31	2.74-15.98	8.80	5.11-12.48
Higher sugars	do	1.50	.13-8.49	4.70	1.28-11.50
Undetermined	do	3.1	0-13.2	10.1	2.7-22.4
pH		3.91	3.42-6.10	4.45	3.90-4.88
Free acidity		22.03	6.75-47.19	49.07	30.29-66.02
Lactone		7.11	0-18.76	5.80	.36-14.09
Total acidity (4)		29.12	8.68-59.49	54.88	34.62-76.49
Lactone ÷ free acid		.335	0-.950	.127	.007-.385
Ash	percent	.169	.020-1.028	.736	.212-1.185
Nitrogen	do	.041	0-.133	.100	.047-.223
Diastase (5)		20.8	2.1-61.2	31.9	6.7-48.4

Notes:

(1) Based on 490 samples of floral honey and 14 samples of honeydew honey.
(2) Expressed in terms of U.S. Department of Agriculture color classes.
(3) Extent of granulation for heated sample after 6 months' undisturbed storage.
(4) Milliequivalents per kilogram.
(5) 270 samples for floral honey.

Source: Beekeeping in the United States Agriculture Handbook Number 335

The main sugars in the common types of honey are shown in table 2. Levulose is the major sugar in all the samples, but there are a few types, not on the list, that contain more dextrose than levulose (dandelion and the blue curls). This excess of levulose over dextrose is one way that honey differs from commercial invert sugar. Even though honey has less dextrose than levulose, it is dextrose that crystallizes when honey granulates, because it is less soluble in water than is levulose. Even though honey contains an active sucrose-splitting enzyme, the sucrose level in honey never reaches zero.

Honey varies tremendously in color and flavor, depending largely on its floral source. Its composition also varies widely, depending on its floral sources (table 2). Although hundreds of kinds of honey are produced in this country, only about 25 or 30 are commercially important and available in large quantities. Until the comprehensive survey of honey composition was published in 1962, the degree of compositional variation was not known. This lack of information hindered the widespread use of honey by the food industry.

TABLE 2. *Carbohydrate composition of honey types*

Number of samples	Floral type	Dextrose	Levulose	Sucrose	Maltose	Higher sugars
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
23	Alfalfa	33.40	39.11	2.64	6.01	.89
25	Alfalfa-sweet clover	33.57	39.29	2.00	6.30	.91
5	Aster	31.33	37.55	.81	8.45	1.04
3	Basswood	31.59	37.88	1.20	6.86	1.44
3	Blackberry	25.94	37.64	1.27	11.33	2.50
5	Buckwheat	29.46	35.30	.78	7.63	2.27
4	Buckwheat, wild	30.50	39.72	.79	7.21	.83
26	“Clover“	32.22	37.84	1.44	6.60	1.39
3	Clover, alsike	30.72	39.18	1.40	7.46	1.55
3	Clover, crimson	30.87	38.21	.91	8.59	1.63
3	Clover, Hubam	33.42	38.69	.86	6.23	.74
10	Cotton	36.74	39.28	1.14	4.87	.50
3	Fireweed	30.72	39.81	1.28	7.12	2.06
6	Gallberry	30.15	39.85	.72	7.71	1.22
3	Goldenrod	33.15	39.57	.51	6.57	.59
2	Heartsease	32.98	37.23	1.95	5.71	.53
2	Holly	25.65	38.98	1.00	10.07	2.16
3	Honeydew, cedar	25.92	25.16	.68	6.20	9.61
5	Honeydew, oak	27.43	34.84	.84	10.45	2.16
2	Horsemint	33.63	37.37	1.01	5.53	.73
3	Locust, black	28.00	40.66	1.01	8.42	1.90
3	Loosestrife, purple	29.90	37.75	.62	8.13	2.35
3	Mesquite	36.90	40.41	.95	5.42	.35
4	Orange, California	32.01	39.08	2.68	6.26	1.23
13	Orange, Florida	31.96	38.91	2.60	7.29	1.40
4	Raspberry	28.54	34.46	.51	8.68	3.58
3	Sage	28.19	40.39	1.13	7.40	2.38
3	Sourwood	24.61	39.79	.92	11.79	2.44
4	Star-thistle	31.14	36.91	2.27	6.92	2.74
8	Sweetclover	30.97	37.95	1.41	7.75	1.40
3	Sweetelover, yellow	32.81	39.22	2.94	6.63	.97
4	Tulip tree	25.85	34.65	.69	11.57	2.96
5	Tupelo	25.95	43.27	1.21	7.97	1.11
7	Vetch	31.67	38.33	1.34	7.23	1.83
9	Vetch, hairy	30.64	38.20	2.03	7.81	2.08
12	White clover	30.71	38.36	1.03	7.32	1.56

Source: Beekeeping in the United States Agriculture Handbook Number 335

Water Content

The natural moisture of honey in the comb is that remaining from the nectar after ripening. The amount of moisture is a function of the factors involved in ripening, including weather conditions and original moisture of the nectar. After extraction of the honey, its moisture content may change, depending on conditions of storage. It is one of the most important characteristics of honey influencing keeping quality, granulation, and body.

Beekeepers as well as honey buyers know that the water content of honey varies greatly. It may range between 13 and 25 percent. According to the United States Standards for Grades of Extracted Honey, honey may not contain more than 18.6 percent moisture to qualify for U.S. grade A (U.S. Fancy) and U.S. grade B (U.S. Choice). Grade C (U.S. Standard) honey may contain up to 20 percent water; any higher amount places a honey in U.S. grade D (Substandard).

These values represent limits and do not indicate the preferred or proper moisture content for honey. If honey has more than 17 percent moisture and contains a sufficient number of yeast spores, it will ferment. Such honey should be pasteurized, that is, heated sufficiently to kill such organisms. This is particularly important if the honey is to be “creamed” or granulated, since this process results in a slightly higher moisture level in the liquid part. On the other hand, it is possible for honey to be too low in moisture from some points of view. In the West, honey may have a moisture content as low as 13 to 14 percent. Such honey is somewhat difficult to handle, though it is most useful in blending to reduce moisture content. It contains over 6 percent more honey solids than a product of 18.6 percent moisture.

In the 490 samples of honey analyzed in the Department’s Technical Bulletin 1261, the average moisture content was 17.2 percent. Samples ranged between 13.4 and 22.9 percent, and the standard deviation was 1.46. This means that 68 percent of the samples (or of all U.S. honey) will fall within the limits of 17.2 ± 1.46 percent moisture (15.7 – 18.7); 95.5 percent of all U.S. honey will fall within the limits of 17.2 ± 2.92 percent moisture (14.3 – 20.1).

In the same bulletin, a breakdown of average moisture contents by geographic regions is shown. These values (percent) are North Atlantic, 17.3; East North Central, 18.0; West North Central, 18.2; South Atlantic, 17.7; South Central, 17.5; Intermountain West, 16.0; and West, 16.1.

Sugars

Honey is above all a carbohydrate material, with 95 to 99.9 percent of the solids being sugars, and the identity of these sugars has been studied for many years. Sugars are classified according to their size or the complexity of the molecules of which they are made. Dextrose (glucose) and levulose (fructose), the main sugars in honey, are simple sugars, or monosaccharides, and are the building blocks for the more complex honey sugars. Dextrose and levulose account for about 85 percent of the solids in honey.

Until the middle of this century, the sugars of honey were thought to be a simple mixture of dextrose, levulose, sucrose (table sugar), and an ill-defined carbohydrate material called “honey dextrin.” With the advent of new methods for separating and analyzing sugars, workers in Europe, the United States, and Japan have identified many sugars in honey after separating them from the complex honey mixture. This task has been accomplished using a variety of physical and chemical methods.

Dextrose and levulose are still by far the major sugars in honey, but 22 others have been found. All of these sugars are more complex than the monosaccharides, dextrose and levulose. Ten disaccharides have been identified: sucrose, maltose, isomaltose, maltulose, nigerose, turanose, kojibiose, laminaribiose, *a*, *B*-trehalose, and gentiobiose. Ten trisaccharides are present: melezitose, 3-*a*-isomaltosylglucose, maltotriose, l-kestose, panose, isomaltotriose, erlose, theanderose, centose, and isopanose. Two more complex sugars, isomaltotetraose and isomaltopentaose, have been identified. Most of these sugars are present in quite small quantities.

Most of these sugars do not occur in nectar, but are formed either as a result of enzymes added by the honeybee during the ripening of honey or by chemical action in the concentrated, somewhat acid sugar mixture we know as honey.

Acids

The flavor of honey results from the blending of many "notes," not the least being a slight tartness or acidity. The acids of honey account for less than 0.5 percent of the solids, but this level contributes not only to the flavor, but is in part responsible for the excellent stability of honey against microorganisms. Several acids have been found in honey, gluconic acid being the major one. It arises from dextrose through the action of an enzyme called glucose oxidase. Other acids in honey are formic, acetic, butyric, lactic, oxalic, succinic, tartaric, maleic, pyruvic, pyroglutamic, *a*-ketoglutaric, glycollic, citric, malic, 2- or 3-phosphoglyceric acid, *a*- or *B*-glycerophosphate, and glucose 6-phosphate.

Proteins and Amino Acids

It will be noted in table 1 that the amount of nitrogen in honey is low, 0.04 percent on the average, though it may range to 0.1 percent. Recent work has shown that only 40 to 65 percent of the total nitrogen in honey is in protein, and some nitrogen resides in substances other than proteins, namely the amino acids. Of the 8 to 11 proteins found in various honeys, 4 are common to all, and appear to originate in the bee, rather than the nectar. Little is known of many proteins in honey, except that the enzymes fall into this class.

The presence of proteins causes honey to have a lower surface tension than it would have otherwise, which produces a marked tendency to foam and form scum and encourages formation of fine air bubbles. Beekeepers familiar with buckwheat honey know how readily it tends to foam and produce surface scum, which is largely due to its relatively high protein content.

The amino acids are simple compounds obtained when proteins are broken down by chemical or digestive processes. They are the "building blocks" of the proteins. Several of them are essential to life and must be obtained in the diet. The quantity of free amino acids in honey is small and of no nutritional significance. Breakthroughs in the separation and analysis of minute quantities of material (chromatography) have revealed that various honeys contain 11 to 21 free amino acids. Proline, glutamic acid, alanine, phenylalanine, tyrosine, leucine, and isoleucine are the most common, with proline predominating.

Amino acids are known to react slowly, or more rapidly by heating, with sugars to produce yellow or brown materials. Part of the darkening of honey with age or heating may be due to this.

Minerals

When honey is dried and burned, a small residue of ash invariably remains, which is the mineral content. As shown in table 1, it varies from 0.02 to slightly over 1 percent for a floral honey, averaging about 0.17 percent for the 490 samples analyzed.

Honeydew honey is richer in minerals, so much so that its mineral content is said to be a prime cause of its unsuitability for winter stores. Schuette and his colleagues at the University of Wisconsin have examined the mineral content of light and dark honey. They reported the following average values:

Enzymes

One of the characteristics that sets honey apart from all other sweetening agents is the presence of enzymes. These conceivably arise from the bee, pollen, nectar, or even yeasts or micro-organisms in the honey. Those most prominent are added by the bee during the conversion of nectar to honey. Enzymes are complex protein materials that under mild conditions bring about chemical changes, which may be very difficult to accomplish in a chemical laboratory without their aid. The changes that enzymes bring about throughout nature are essential to life.

Some of the most important honey enzymes are invertase, diastase, and glucose oxidase.

Invertase, also known as sucrase or saccharase splits sucrose into its constitutent simple sugars, dextrose, and levulose. Other more complex sugars have been found recently to form in small amounts during this action and in part explain the complexity of the minor sugars of honey. Although the work of invertase is completed when honey is ripened, the enzyme remains in the honey and retains its activity for some time. Even so, the sucrose content of honey never reaches zero. Since the enzyme also synthesizes sucrose, perhaps the final low value for the sucrose content of honey represents an equilibrium between splitting and forming sucrose.

Diastase (amylase) digests starch to simpler compounds but no starch is found in nectar. What its function is in honey is not clear. Diastase appears to be present in varying amounts in nearly all honey and it can be measured. It has probably had the greatest attention in the past, because it has been used as a measure of honey quality in several European countries.

Glucose oxidase converts dextrose to a related material, a gulconolactone, which in turn forms gluconic acid, the principal acid in honey. Since this enzyme previously was shown to be in the pharyngeal gland of the honey bee, this is probably the source. Here, as with other enzymes, the amount varies in different honeys. In addition to gluconolactone, glucose oxidase forms hydrogen peroxide during its action on dextrose, which has been shown to be the basis of the heat-sensitive antibacterial activity of honey.

Other enzymes are reported to be present in honey, including catalase and an acid phosphatase. All the honey enzymes can be destroyed or weakened by heat.

Properties of Honey

Because of honey's complex and unusual composition, it has several interesting attributes. In addition, honey has some properties, because of its composition, that make it difficult to handle and use. With modern technology, however, methods have been established to cope with many of these problems.

Antibacterial Activity

An ancient use for honey was in medicine as a dressing for wounds and inflammations. Today, medicinal uses of honey are largely confined to folk medicine. On the other hand, since milk can be a carrier of some diseases, it was once thought that honey might likewise be such a carrier. Some years ago this idea was examined by adding nine common pathogenic bacteria to honey. All the bacteria died within a few hours or days. Honey is not a suitable medium for bacteria for two reasons – it is fairly acid and it is too high in sugar content for growth to occur. This killing of bacteria by high sugar content is called osmotic effect. It seems to function by literally drying out the bacteria. Some bacteria, however, can survive in the resting spore form, though not grown in honey.

Another type of antibacterial property of honey is that due to inhibine. The presence of an antibacterial activity in honey was first reported about 1940 and confirmed in several laboratories. Since then, several papers were published on this subject. Generally, most investigators agree that inhibine (name used by Dold, its discoverer, for antibacterial activity) is sensitive to heat and light. The effect of heat on the inhibine content, of honey was studied by several investigators. Apparently, heating honey sufficiently to reduce markedly or to destroy its inhibine activity would deny it a market as first-quality honey in several European countries. The use of sucrase and inhibine assays together was proposed to determine the heating history of commercial honey.

Until 1963, when White showed that the inhibine effect was due to hydrogen peroxide produced and accumulated in diluted honey, its identity remained unknown. This material, well known for its antiseptic properties, is a byproduct of the formation of gluconic acid by an enzyme that occurs in honey, glucose oxidase. The peroxide can inhibit the growth of certain bacteria in the diluted honey. Since it is destroyed by other honey constituents, an equilibrium level of peroxides will occur in a diluted honey, its magnitude depending on many factors such as enzyme activity, oxygen availability, and amounts of peroxide-destroying materials in the honey. The amount of inhibine (peroxide accumulation) in honey depends on floral type, age, and heating.

A chemical assay method has been developed that rapidly measures peroxide accumulation in diluted honey. By this procedure, different honeys have been found to vary widely in the sensitivity of their inhibine to heat. In general, the sensitivity is about the same as or greater than that of invertase and diastase in honey.

Food Value

Honey is primarily a high-energy carbohydrate food. Because its distinct flavors cannot be found elsewhere, it is an enjoyable treat. The honey sugars are largely the easily digestible "simple sugars," similar to those in many fruits. Honey can be regarded as a good food for both infants and adults.

The protein and enzymes of honey, though used as indicators of heating history and hence table quality in some countries, are not present in sufficient quantities to be considered nutritionally significant. Several of the essential vitamins are present in honey, but in insignificant levels. The mineral content of honey is variable, but darker honeys have significant quantities of minerals.

Granulation

Dextrose, a major sugar in honey, can spontaneously crystallize from any honeys in the form of its monohydrate. This sometimes occurs when the moisture level in honey is allowed to drop below a certain level.

A large part of the honey sold to consumers in the United States is in the liquid form, much less in a finely granulated form known as "honey spread" or finely granulated honey, and even less as comb honey. The consumer appears to be conditioned to buying liquid honey. At least sales of the more convenient spread form have never approached those of liquid honey.

Since the granulated state is natural for most of the honey produced in this country, processing is required to keep it liquid. Careful application of heat to dissolve "seed" crystals and avoidance of subsequent "seeding" will usually suffice to keep a honey liquid for 6 months. Damage to color and flavor can result from excessive or improperly applied heat. Honey that has granulated can be returned to liquid by careful heating. Heat should be applied indirectly by hot water or air, not by direct flame or high-temperature electrical heat. Stirring accelerates the dissolution of crystals. For small containers, temperatures of 140ºF for 30 minutes usually will suffice.

If unheated honey is allowed to granulate naturally, several difficulties may arise. The texture may be fine and smooth or granular and objectionable to the consumer. Furthermore, a granulated honey becomes more susceptible to spoilage by fermentation, caused by natural yeast found in all honeys and apiaries. Quality damage from poor texture and fermented flavors usually is far greater than any caused by the heat needed to eliminate these problems.

Finely granulated honey may be prepared from a honey of proper moisture content (17.5 percent in summer, 15 percent in winter) by several processes. All involve pasteurization to eliminate fermentation, followed by addition at room temperature of 5 to 10 percent of a finely granulated "starter" of acceptable texture, thorough mixing, and storage at 55º to 60ºF in the retail containers for about a week. The texture remains acceptable if storage is below about 80º to 85º.

Deterioration of Quality

Fermentation. – Fermentation of honey is caused by the action of sugar-tolerant yeasts upon the sugars dextrose and levulose, resulting in the formation of ethyl alcohol and carbon dioxide. The alcohol in the presence of oxygen then may be broken down into acetic acid and water. As a result, honey that has fermented may taste sour.

The yeasts responsible for fermentation occur naturally in honey, in that they can germinate and grow at much higher sugar concentrations than other yeasts, and, therefore, are called "osmophilic." Even so there are upper limits of sugar concentration beyond which these yeasts will not grow. Thus, the water content of a honey is one of the factors concerned in spoilage by fermentation. The others are extent of contamination by yeast spores (yeast count) and temperature of storage.

Honey with less than 17.1 percent water will not ferment in a year, irrespective of the yeast count. Between 17.1 and 18 percent moisture, honey with 1,000 yeast spores or less per gram will be safe for a year. When moisture is between 18.1 and 19 percent, not more than 10 yeast spores per gram can be present for safe storage. Above 19 percent water, honey can be expected to ferment even with only one spore per gram of honey, a level so low as to be very rare.

When honey granulates, the resulting increased moisture content of the liquid part is favorable for fermentation. Honey with a high moisture content will not ferment below 50ºF or above about 80º. Honey even of relatively low water content will ferment at 60º. Storing at temperatures over 80º to avoid fermentation is not practical as it will damage honey.

E. C. Martin has studied the mechanism and course of yeast fermentation in honey in conjunction with his work on the hygroscopicity of honey. He confirmed that when honey absorbs moisture, which occurs when it is stored above 60-percent relative humidity, the moisture content at first increases mostly at the surface before the water diffuses into the bulk of the honey. When honey absorbs moisture, yeasts grow aerobically (using oxygen) at the surface and multiply rapidly, whereas below the surface the growth is slower.

Fermenting honey is usually at least partly granulated and is characterized by a foam or froth on the surface. It will foam considerably when heated. An odor as of sweet wine or fermenting fruit may be detected. Gas production may be so vigorous as to cause honey to overflow or burst a container. The off-flavors and odors associated with fermentation probably arise from the acids produced by the yeasts.

Honey that has been fermented can sometimes be reclaimed by heating it to 150ºF for a short time. This stops the fermentation and expels some of the off-flavor. Fermentation in honey may be avoided by heating to kill yeasts. Minimal treatments to pasteurize honey are as follows:
The following summarize the important aspects of fermentation:

1. All honey should be considered to contain yeasts.
2. Honey is more liable to fermentation after granulation.
3. Honey of over 17 percent water may ferment and over 19 percent water will ferment.
4. Storage below 50ºF will prevent fermentation during such storage, but not later.
5. Heating honey to 150ºF for 30 minutes will destroy honey yeasts and thus prevent fermentation.

Quality loss by heating and storing – The other principal types of honey spoilage, damage by over-heating and by improper storing, are related to each other. In general, changes that take place quickly during heating also occur over a longer period during storage with the rate depending on the temperature. These include darkening, loss of fresh flavor, and formation of off-flavor (caramelization).

To keep honey in its original condition of high quality and delectable flavor and fragrance is possibly the greatest responsibility of the beekeeper and honey packer. At the same time it is an operation receiving perhaps less attention from the producer than any other and one requiring careful consideration by packers and wholesalers. To do an effective job, one must know the factors that govern honey quality, as well as the effects of various beekeeping and storage practices on honey quality. The factors are easily determined, but only recently are the facts becoming known regarding the effects of processing temperatures and storage on honey quality.

To be of highest quality, a honey – whether liquid, crystallized, or comb – must be well ripened with proper moisture content; it must be free of extraneous materials, such as excessive pollen, dust, insect parts, wax, and crystals if liquid; it must not ferment; and above all it must be of excellent flavor and aroma, characteristic of the particular honey type. It must, of course, be free of off-flavors or odors of any origin. In fact, the more closely it resembles the well-ripened honey as it exists in the cells of the comb, the better it is.

Several beekeeping practices can reduce the quality of the extracted product. These include combining inferior floral types, either by mixing at extracting time or removing the crop at incorrect times, extraction of unripe honey, extraction of brood combs, and delay in settling and straining. However, we are concerned here with the handling of honey from its extraction to its sale. During this time improper settling, straining, heating, and storage conditions can make a superb honey into just another commercial product.

The primary objective of all processing of honey is simple – to stabilize it. This means to keep it free of fermentation and to keep the desired physical state, be it liquid or finely granulated. Methods for accomplishing these objectives have been fairly well worked out and have been used for many years. Probably improvements can be made. The requirements for stability of honey are more stringent now than in the past, with honey a world commodity and available in supermarkets the year around. Government price support and loan operations require storage of honey, and market conditions also may require storage at any point in the handling chain, including the producer, packer, wholesaler, and exporter.

The primary operation in the processing of honey is the application and control of heat. If we consider storage to be the application of or exposure to low amounts of heat over long periods, it can be seen that a study of the effects of heat on honey quality can have a wide application.

Any assessment of honey quality must include flavor considerations. The objective measurement of changes in flavor, particularly where they are gradual, is most difficult. We have measured the accumulation of a decomposition product of the sugars (hydroxymethylfurfural or HMF) as an index of heat-induced chemical change in the honey. Changes in flavor, other than simple loss by evaporation, also may be considered heat-induced chemical changes.

To study the effects of treatment on honey, we must use some properties of honey as indices of change. Such properties should relate to the quality or commercial value of honey. The occurrence of granulation of liquid honey, liquefaction or softening of granulated honey, and fermentation as functions of storage conditions has been reported; also, color is easily measured.

As indicators of the acceptability of honey for table use, Europeans have for many years used the amount of certain enzymes and HMF in honey. They considered that heating honey sufficiently to destroy or greatly lower its enzyme content or produce HMF reduced its desirability for most uses. A considerable difference has been noted in the reports by various workers on the sensitivity to heat of enzymes, largely diastase and invertase, in honey. Only recently has it been noted that storage alone is sufficient to reduce enzyme content and produce HMF in honey. Since some honey types frequently exported to Europe are naturally low in diastase, the response of diastase and invertase to storage and processing is of great importance for exporters.

A study was made of the effects of heating and storage on honey quality and was based on the results with three types of honey stored at six temperatures for 2 years. The results were used to obtain predictions of the quality life of honey under any storage conditions. The following information is typical of the calculations based on this work.

At 68ºF, diastase in honey has a half-life of 1,500 days, nearly 4 years. Invertase is more heat sensitive, with a half-life at 68º of 800 days, or about 2-1/4 years. Thus there are no problems here. By increasing the storage temperature to 77º, half the diastase is gone in 540 days, or 1-1/3 years, and half the invertase disappears in 250 days, or about 8 months. These periods are still rather long and there would seem to be nothing to be concerned about. However, temperatures in the 90′s for extended periods are not at all uncommon: 126 days (4 months) will destroy half the diastase and about 50 days (2 months) will eliminate half the invertase. As the temperature increases, the periods involved become shorter and shorter until the processing temperatures are reached. At 130º, 2-1/2 days would account for half the diastase and in 13 hours half the invertase is gone.

A recommended temperature for pasteurization of honey is 145ºF for 30 minutes. At this temperature diastase has a half-life of 16 hours and invertase only 3 hours. At first glance this might seem to present no problems, but it must be remembered that unless flash heating and immediate cooling are used, many hours will be required for a batch of honey to cool from 145º to a safe temperature.

If we proceed further to a temperature often recommended for preventing granulation, 160ºF for 30 minutes, the necessity of prompt cooling becomes highly important. At 160º, 2-1/2 hours will destroy half of the diastase, but half of the more sensitive invertase will be lost in 40 minutes. This treatment then cannot be recommended for any honey in which a good enzyme level is needed, as for export.

The damage done to honey by heating and by storage is the same. For the lower storage temperatures, simply a much longer time is required to obtain the same result. It must be remembered that the effects of processing and storage are additive. It is for this reason that proper storage is so important. A few periods of hot weather can offset the benefits of months of cool storage – 10 days at 90ºF are equivalent to 100 to 120 days at 70º. An hour at 145º in processing will cause changes equivalent to 40 days' storage at 77º.

An easy way for beekeepers to decide whether they have storage or processing deterioration is to take samples of the fresh honey, being careful that the samples are fairly representative of the batch, and place them in a freezer for the entire period. At the end of this time, they should warm the samples to room temperature and compare them by color, flavor, and aroma with the honey in common storage. In some parts of the United States, the value of the difference can reach 1-1/2 cents per pound in a few months. Such figures certainly would justify expenditures for temperature control.

People who store honey are in a dilemma. They must select conditions that will minimize fermentation, undesirable granulation, and heat damage. Fermentation is strongly retarded below 50ºF and above 100º. Granulation is accelerated between 55º and 60º and initiated by fluctuation at 50º to 55º. The best condition for storing unpasteurized honey seems to be below 50º, or winter temperatures over much of the United States. Warming above this range in the spring can initiate active fermentation in such honey, which is usually granulated and thus even more susceptible.

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