Honey

From Wikipedia, the free encyclopedia

Honey is a sweet, viscous food substance produced by bees and some related insects.[1] Bees produce honey from the sugary secretions of plants (floral nectar) or other insects (aphid honeydew) through regurgitation, enzymatic activity, and water evaporation, and store it in wax structures called honeycombs.[1][2] The variety of honey produced by honey bees (the genus *Apis*) is the best-known, due to its worldwide commercial production and human consumption.[3] Honey is collected from wild bee colonies, or from hives of domesticated bees, a practice known as beekeeping.

Honey gets its sweetness from the monosaccharides fructose and glucose, and has about the same relative sweetness as granulated sugar.[4][5] It has attractive chemical properties for baking and a distinctive flavor when used as a sweetener.[4] Most microorganisms do not grow in honey, so sealed honey does not spoil, even after thousands of years.[6][7]

Providing 64 calories in a typical serving of one tablespoon (15 ml) equivalent to 1272 kj per 100 g, honey has no significant nutritional value.[8] Honey is generally safe,[9] but may have various, potentially adverse effects or interactions upon excessive consumption, existing disease conditions, or use of prescription drugs.[10]

Honey use and production have a long and varied history as an ancient activity, depicted in Valencia, Spain by a cave painting of humans foraging for honey at least 8,000 years ago.[11][12]

A jar of honey with a honey dipper and an American biscuit

Honey in honeycomb

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Formation

Honey is produced by bees collecting nectar for use as sugars consumed to support metabolism of muscle activity during foraging or to be stored as a long-term food supply.[13][14] During foraging, bees access part of the nectar collected to support metabolic activity of flight muscles, with the majority of collected nectar destined for regurgitation, digestion, and storage as honey.[13][15] In cold weather or when other food sources are scarce, adult and larval bees use stored honey as food.[14]


A honey bee on calyx of goldenrod

By contriving for bee swarms to nest in man-made hives, people have been able to semidomesticate the insects and harvest excess honey. In the hive or in a wild nest, the three types of bees are:

- a single female queen bee
- a seasonally variable number of male drone bees to fertilize new queens
- 20,000 to 40,000 female worker bees[16]


Sealed frame of honey

Leaving the hive, foraging bees collect sugar-rich flower nectar and return to the hive where they use their "honey stomachs" to ingest and regurgitate the nectar repeatedly until it is partially digested.[13][15][17] Bee digestive enzymes – invertase, amylase, and diastase – along with gastric acid hydrolyze sucrose to a mixture of glucose and fructose.[13][15] The bees work together as a group with the regurgitation and digestion for as long as 20 minutes until the product reaches storage quality.[15] It is then placed in honeycomb cells left unsealed while still high in water content (about 20%) and natural yeasts, which, unchecked, would cause the sugars in the newly formed honey to ferment.[14] The process continues as hive bees flutter their wings constantly to circulate air and evaporate water from the honey to a content around 18%, raising the sugar concentration, and preventing fermentation.[14][15] The bees then cap the cells with wax to seal them.[15] As removed from the hive by a beekeeper, honey has a long shelf life and will not ferment if properly sealed.[14]

Another source of honey is from a number of wasp species, such as the wasps *Brachygastra lecheguana* and *Brachygastra mellifica*, which are found in South and Central America. These species are known to feed on nectar and produce honey.[18]

Some wasps, such as the *Polistes versicolor*, even consume honey themselves, switching from feeding on pollen in the middle of their lifecycles to feeding on honey, which can better provide for their energy needs.[19]

Production

Collection

Honey is collected from wild bee colonies, or from domesticated beehives. The honey is stored in honeycombs. Wild bee nests are sometimes located by following a honeyguide bird. The bees may first be pacified by using smoke from a bee smoker. The smoke triggers a feeding instinct (an attempt to save the resources of the hive from a possible fire), making them less aggressive and the smoke obscures the pheromones the bees use to communicate.

Extraction from a honeycomb

The honeycomb is removed from the hive and the honey may be extracted from that, either by crushing or by using a honey extractor. The honey is then usually filtered to remove beeswax and other debris.

Before the invention of removable frames, bee colonies were often sacrificed to conduct the harvest. The harvester would take all the available honey and replace the entire colony the next spring. Since the invention of removable frames, the principles of husbandry lead most beekeepers to ensure that their bees have enough stores to survive the winter, either by leaving some honey in the beehive or by providing the colony with a honey substitute such as sugar water or crystalline sugar (often in the form of a "candyboard"). The amount of food necessary to survive the winter depends on the variety of bees and on the length and severity of local winters.

Filtering from a honeycomb

A wide range of species other than humans are attracted to wild or domestic sources of honey.[20]

Preservation

Because of its unique composition and chemical properties, honey is suitable for long-term storage, and is easily assimilated even after long preservation. Honey, and objects immersed in honey, have been preserved for centuries.[21][22] The key to preservation is limiting access to humidity. In its cured state, honey has a sufficiently high sugar content to inhibit fermentation. If exposed to moist air, its hydrophilic properties pull moisture into the honey, eventually diluting it to the point that fermentation can begin.

The shelf life of honey is due to an enzyme found in the stomach of bees. Glucose oxidase is mixed by the bees with expelled nectar previously consumed by the bees which then creates "two by-products: gluconic acid and hydrogen peroxide" which are responsible for honey's acidity and ability to suppress bacterial growth.[23]

Adulteration

Adulteration of honey is the addition of other sugars, syrups, or compounds into honey to change its flavor or viscosity, make it cheaper to produce, or increase the fructose content to stave off crystallization. According to the Codex Alimentarius of the United Nations, any product labeled as honey or pure honey must be a wholly natural product, although different nations have their own laws concerning labeling.[24] Adulteration of honey is sometimes used as a method of deception when buyers are led to believe that the honey is pure. The practice was common dating back to ancient times, when crystallized honey was often mixed with flour or other fillers,

hiding the adulteration from buyers until the honey was liquefied. In modern times, the most common adulteration-ingredient became clear, almost-flavorless corn syrup, which, when mixed with honey, is often very difficult to distinguish from unadulterated honey.[25]

Isotope ratio mass spectrometry can be used to detect addition of corn syrup and cane sugar by the carbon isotopic signature. Addition of sugars originating from corn or sugar cane (C4 plants, unlike the plants used by bees, and also sugar beet, which are predominantly C3 plants) skews the isotopic ratio of sugars present in honey,[26] but does not influence the isotopic ratio of proteins. In an unadulterated honey, the carbon isotopic ratios of sugars and proteins should match. Levels as low as 7% of addition can be detected.[27]

In one country, the USA, according to the National Honey Board (a USDA-overseen organization), "honey stipulates a pure product that does not allow for the addition of any other substance... this includes, but is not limited to, water or other sweeteners".[28]

Worldwide production

Honey production - 2014
(tonnes)

Country	2014
China	462,028
Turkey	103,525
United States	80,862
Russia	74,868
Ukraine	66,521
World	**1,510,566**
Source: UN Food & Agriculture Organization, FAOSTAT[29]	

In 2014, 1.5 million tonnes of honey were produced worldwide, with China alone accounting for 31% of the world total (table).[29] The next four largest producers – Turkey, United States, Ukraine, and Russia – accounted collectively for 22% of the world total.[29]

Modern uses

Food

Over its history as a food,[11] the main uses of honey are in cooking, baking, desserts, such as *mel i mató*, as a spread on bread, and as an addition to various beverages, such as tea, and as a sweetener in some commercial beverages. Honey barbecue and honey mustard are other common flavors used in sauces.

Fermentation

Possibly the world's oldest fermented beverage dating to 3,000 years ago, mead ("honey wine") is the alcoholic product made by adding yeast to the honey–water must, followed by weeks or months of fermentation.[30][31][32] In modern mead production, the yeast, *Saccharomyces cerevisiae*, is commonly used.[30][31]

Primary fermentation usually takes 28–56 days, after which the must is placed in a secondary fermentation vessel for 6–9 months of aging.[30][31][32] Durations of primary and secondary fermentation producing satisfactory mead may vary considerably according to numerous factors, such as floral origin of the honey and its natural sugar and microorganism contents, must water percentage, pH, additives used, and strain of yeast,

among others.[31][33] Although supplementation of the must with nitrogen, salt or vitamins has been tested to improve mead qualities, there is no evidence that adding nutrients reduced fermentation time or improved quality.[30] Cell immobilization methods, however, proved effective for enhancing mead quality.[31]

Mead varieties include drinks called metheglin (with spices or herbs), melomel (with fruit juices, such as grape, specifically called pyment), hippocras (with cinnamon), and sack mead (high concentration of honey),[31] many of which have been developed as commercial products numbering in the hundreds in the United States as of 2014.[33] Honey is also used to make mead beer, called "braggot".[34]

Physical and chemical properties

The physical properties of honey vary, depending on water content, the type of flora used to produce it (pasturage), temperature, and the proportion of the specific sugars it contains. Fresh honey is a supersaturated liquid, containing more sugar than the water can typically dissolve at ambient temperatures. At room temperature, honey is a supercooled liquid, in which the glucose will precipitate into solid granules. This forms a semisolid solution of precipitated glucose crystals in a solution of fructose and other ingredients.

Crystallized honey: The inset shows a close-up of the honey showing the individual glucose grains in the fructose mixture.

At the temperature of 20 °C, density of honey typically ranges between 1.38 and 1.45 kg/l.[35]

Phase transitions

The melting point of crystallized honey is between 40 and 50 °C (104 and 122 °F), depending on its composition. Below this temperature, honey can be either in a metastable state, meaning that it will not crystallize until a seed crystal is added, or, more often, it is in a "labile" state, being saturated with enough sugars to crystallize spontaneously.[36] The rate of crystallization is affected by many factors, but the primary factor is the ratio of the main sugars: fructose to glucose. Honeys that are supersaturated with a very high percentage of glucose, such as brassica honey, crystallize almost immediately after harvesting, while honeys with a low percentage of glucose, such as chestnut or tupelo honey, do not crystallize. Some types of honey may produce very large but few crystals, while others produce many small crystals.[37]

Crystallization is also affected by water content, because a high percentage of water inhibits crystallization, as does a high dextrin content. Temperature also affects the rate of crystallization, with the fastest growth occurring between 13 and 17 °C (55 and 63 °F). Crystal nuclei (seeds) tend to form more readily if the honey is disturbed, by stirring, shaking, or agitating, rather than if left at rest. However, the nucleation of microscopic seed-crystals is greatest between 5 and 8 °C (41 and 46 °F). Therefore, larger but fewer crystals tend to form at higher temperatures, while smaller but more-numerous crystals usually form at lower temperatures. Below 5 °C, the honey will not crystallize, thus the original texture and flavor can be preserved indefinitely.[37]

Since honey normally exists below its melting point, it is a supercooled liquid. At very low temperatures, honey does not freeze solid. Instead, as the temperatures become lower, the viscosity of honey increases. Like most viscous liquids, the honey becomes thick and sluggish with decreasing temperature. At −20 °C (−4 °F), honey may appear or even feel solid, but it continues to flow at very low rates. Honey has a glass transition between −42 and −51 °C (−44 and −60 °F). Below this temperature, honey enters a glassy state and becomes an amorphous solid (noncrystalline).[38][39]

Viscosity

The viscosity of honey is affected greatly by both temperature and water content. The higher the water percentage, the more easily honey flows. Above its melting point, however, water has little effect on viscosity. Aside from water content, the composition of honey also has little effect on viscosity, with the exception of a few types. At 25 °C (77 °F), honey with 14% water content generally has a viscosity around 400 poise, while a honey containing 20% water has a viscosity around 20 poise. Viscosity increase due to temperature occurs very slowly at first. A honey containing 16% water, at 70 °C (158 °F), has a viscosity around 2 poise, while at 30 °C (86 °F), the viscosity is around 70 poise. As cooling progresses, honey becomes more viscous at an increasingly rapid rate, reaching 600 poise around 14 °C (57 °F). However, while honey is very viscous, it has rather low surface tension.[40][41]

Pouring raw honey. The sheet-like appearance of the flow is the result of high viscosity and low surface tension, contributing to the stickiness of honey

A few types of honey have unusual viscous properties. Honeys from heather or manuka display thixotropic properties. These types of honey enter a gel-like state when motionless, but then liquify when stirred.[42]

Electrical and optical properties

Because honey contains electrolytes, in the form of acids and minerals, it exhibits varying degrees of electrical conductivity. Measurements of the electrical conductivity are used to determine the quality of honey in terms of ash content.[41]

The effect honey has on light is useful for determining the type and quality. Variations in the water content alter the refractive index of honey. Water content can easily be measured with a refractometer. Typically, the refractive index for honey ranges from 1.504 at 13% water content to 1.474 at 25%. Honey also has an effect on polarized light, in that it rotates the polarization plane. The fructose gives a negative rotation, while the glucose gives a positive one. The overall rotation can be used to measure the ratio of the mixture.[41][43] Honey may vary in color between pale yellow and dark brown, but other bright colors may occasionally be found, depending on the source of the sugar harvested by the bees.[44]

Hygroscopy and fermentation

Honey has the ability to absorb moisture directly from the air, a phenomenon called hygroscopy. The amount of water the honey absorbs is dependent on the relative humidity of the air. Because honey contains yeast, this hygroscopic nature requires that honey be stored in sealed containers to prevent fermentation, which usually begins if the honey's water content rises much above 25%. Honey tends to absorb more water in this manner than the individual sugars allow on their own, which may be due to other ingredients it contains.[43]

Fermentation of honey usually occurs after crystallization, because without the glucose, the liquid portion of the honey primarily consists of a concentrated mixture of fructose, acids, and water, providing the yeast with enough of an increase in the water percentage for growth. Honey that is to be stored at room temperature for long periods of time is often pasteurized, to kill any yeast, by heating it above 70 °C (158 °F).[43]

Thermal characteristics

Like all sugar compounds, honey caramelizes if heated sufficiently, becoming darker in color, and eventually burns. However, honey contains fructose, which caramelizes at lower temperatures than glucose.[45] The temperature at which caramelization begins varies, depending on the composition, but is typically between 70 and 110 °C (158 and 230 °F). Honey also contains acids, which act as catalysts, decreasing the caramelization temperature even more.[46] Of these acids, the amino acids, which occur in very small amounts, play an important role in the darkening of honey. The amino acids form darkened compounds called melanoidins,

during a Maillard reaction. The Maillard reaction occurs slowly at room temperature, taking from a few to several months to show visible darkening, but speeds up dramatically with increasing temperatures. However, the reaction can also be slowed by storing the honey at colder temperatures.[47]

Unlike many other liquids, honey has very poor thermal conductivity, taking a long time to reach thermal equilibrium. Melting crystallized honey can easily result in localized caramelization if the heat source is too hot, or if it is not evenly distributed. However, honey takes substantially longer to liquify when just above the melting point than at elevated temperatures.[41] Melting 20 kg of crystallized honey, at 40 °C (104 °F), can take up to 24 hours, while 50 kg may take twice as long. These times can be cut nearly in half by heating at 50 °C (122 °F). However, many of the minor substances in honey can be affected greatly by heating, changing the flavor, aroma, or other properties, so heating is usually done at the lowest temperature possible for the shortest amount of time.[48]

Acid content and flavor effects

The average pH of honey is 3.9, but can range from 3.4 to 6.1.[49] Honey contains many kinds of acids, both organic and amino. However, the different types and their amounts vary considerably, depending on the type of honey. These acids may be aromatic or aliphatic (nonaromatic). The aliphatic acids contribute greatly to the flavor of honey by interacting with the flavors of other ingredients.[49]

Organic acids comprise most of the acids in honey, accounting for 0.17–1.17% of the mixture, with gluconic acid formed by the actions of an enzyme called glucose oxidase as the most prevalent.[49] Other organic acids are minor, consisting of formic, acetic, butyric, citric, lactic, malic, pyroglutamic, propionic, valeric, capronic, palmitic, and succinic, among many others.[49][50]

Classification

Honey is classified by its floral source, and divisions are made according to the packaging and processing used. Also, regional honeys are identified. In the USA, honey is also graded on its color and optical density by USDA standards, graded on the Pfund scale, which ranges from 0 for "water white" honey to more than 114 for "dark amber" honey.[51]

Honey

Floral source

Generally, honey is classified by the floral source of the nectar from which it was made. Honeys can be from specific types of flower nectars or can be blended after collection. The pollen in honey is traceable to floral source and therefore region of origin. The rheological and melissopalynological properties of honey can be used to identify the major plant nectar source used in its production.[52]

Blended

Most commercially available honey is blended,[53] meaning it is a mixture of two or more honeys differing in floral source, color, flavor, density, or geographic origin.[54]

Polyfloral

Polyfloral honey, also known as wildflower honey,[55] is derived from the nectar of many types of flowers.[56]

The taste may vary from year to year, and the aroma and the flavor can be more or less intense, depending on which bloomings are prevalent.[57]

Monofloral

Monofloral honey is made primarily from the nectar of one type of flower. Different monofloral honeys have a distinctive flavor and color because of differences between their principal nectar sources.[58] To produce monofloral honey, beekeepers keep beehives in an area where the bees have access to only one type of flower. In practice, because of the difficulties in containing bees, a small proportion of any honey will be from additional nectar from other flower types.[59] Typical examples of North American monofloral honeys are clover, orange blossom, blueberry, sage, tupelo, buckwheat, fireweed, mesquite, and sourwood. Some typical European examples include thyme, thistle, heather, acacia, dandelion, sunflower, lavender, honeysuckle, and varieties from lime and chestnut trees. In North Africa (e.g. Egypt), examples include clover, cotton, and citrus (mainly orange blossoms). The unique flora of Australia yields a number of distinctive honeys, with some of the most popular being yellow box, blue gum, ironbark, bush mallee, Tasmanian leatherwood, and macadamia.

Honeydew honey

Instead of taking nectar, bees can take honeydew, the sweet secretions of aphids or other plant sap-sucking insects. Honeydew honey is very dark brown in color, with a rich fragrance of stewed fruit or fig jam, and is not as sweet as nectar honeys.[58] Germany's Black Forest is a well known source of honeydew-based honeys, as well as some regions in Bulgaria, Tara (mountain) in Serbia, and Northern California in the United States. In Greece, pine honey (a type of honeydew honey) constitutes 60–65% of the annual honey production.[60] Honeydew honey is popular in some areas, but in other areas, beekeepers have difficulty selling the stronger-flavored product.[61]

The production of honeydew honey has some complications and dangers. This honey has a much larger proportion of indigestibles than light floral honeys, thus causing dysentery to the bees, resulting in the death of colonies in areas with cold winters. Good beekeeping management requires the removal of honeydew prior to winter in colder areas. Bees collecting this resource also have to be fed protein supplements, as honeydew lacks the protein-rich pollen accompaniment gathered from flowers.

Classification by packaging and pr ocessing

Generally, honey is bottled in its familiar liquid form. However, honey is sold in other forms, and can be subjected to a variety of processing methods.

- **Crystallized honey** occurs when some of the glucose content has spontaneously crystallized from solution as the monohydrate. It is also called "granulated honey" or "candied honey". Honey that has crystallized (or commercially purchased crystallized) can be returned to a liquid state by warming.[62]
- **Pasteurized honey** has been heated in a pasteurization process which requires temperatures of 161 °F (72 °C) or higher. Pasteurization destroys yeast cells. It also liquefies any microcrystals in the honey, which delays the onset of visible crystallization. However, excessive heat exposure also results in product deterioration, as it increases the level of hydroxymethylfurfural (HMF) and reduces enzyme (e.g. diastase) activity. Heat also affects appearance (darkens the natural honey color), taste, and fragrance.[63]
- **Raw honey** is as it exists in the beehive or as obtained by extraction, settling, or straining, without adding heat (although some honey that has been "minimally processed" is often labeled as raw honey).[64] Raw honey contains some pollen and may contain small particles of wax.
- **Strained honey** has been passed through a mesh material to remove particulate material[65] (pieces of wax, propolis, other defects) without removing pollen, minerals, or enzymes.
- **Filtered honey** of any type has been filtered to the extent that all or most of the fine particles, pollen grains, air bubbles, or other materials normally found in suspension, have been removed.[66] The process typically heats honey to 150–170 °F (66–77 °C) to more easily pass through the filter.[67] Filtered honey is very clear and will not crystallize as quickly,[67] making it preferred by the supermarket trade.[68]
- **Ultrasonicated honey** has been processed by ultrasonication, a nonthermal processing alternative for honey. When honey is exposed to ultrasonication, most of the yeast cells are destroyed. Those cells that survive sonication generally lose their ability to grow, which reduces the rate of honey fermentation substantially. Ultrasonication also eliminates existing crystals and inhibits further crystallization in

honey. Ultrasonically aided liquefaction can work at substantially lower temperatures around 95 °F (35 °C) and can reduce liquefaction time to less than 30 seconds.[69]

- **Creamed honey**, also called whipped honey, spun honey, churned honey, honey fondant, and (in the UK) set honey, has been processed to control crystallization. Creamed honey contains a large number of small crystals, which prevent the formation of larger crystals that can occur in unprocessed honey. The processing also produces a honey with a smooth, spreadable consistency.[70]
- **Dried honey** has the moisture extracted from liquid honey to create completely solid, nonsticky granules. This process may or may not include the use of drying and anticaking agents.[71] Dried honey is used in baked goods,[71] and to garnish desserts.[72]
- **Comb honey** is still in the honeybees' wax comb. It is traditionally collected using standard wooden frames in honey supers. The frames are collected and the comb is cut out in chunks before packaging. As an alternative to this labor-intensive method, plastic rings or cartridges can be used that do not require manual cutting of the comb, and speed packaging. Comb honey harvested in the traditional manner is also referred to as "cut-comb honey".[62]:13[73]
- **Chunk honey** is packed in widemouth containers consisting of one or more pieces of comb honey immersed in extracted liquid honey.[62]:13
- **Honey decoctions** are made from honey or honey byproducts which have been dissolved in water, then reduced (usually by means of boiling). Other ingredients may then be added. (For example, abbamele has added citrus.) The resulting product may be similar to molasses.
- **Baker's honey** is outside the normal specification for honey, due to a "foreign" taste or odor, or because it has begun to ferment or has been overheated. It is generally used as an ingredient in food processing. Additional requirements exist for labeling baker's honey, including that it may not be sold labelled simply as "honey".[74]

Honeycomb

A variety of honey flavors and container sizes and styles from the 2008 Texas State Fair

Grading

In the US, honey grading is performed voluntarily (USDA does offer inspection and grading "as on-line (in-plant) or lot inspection...upon application, on a fee-for-service basis.") based upon USDA standards. Honey is graded based upon a number of factors, including water content, flavor and aroma, absence of defects, and clarity. Honey is also classified by color, though it is not a factor in the grading scale.[75] **The honey grade scale is**:

Grade	Soluble solids	Flavor and aroma	Absence of defects	Clarity
A	≥ 81.4%	Good—"has a good, normal flavor and aroma for the predominant floral source or, when blended, a good flavor for the blend of floral sources and the honey is free from caramelized flavor or objectionable flavor caused by fermentation, smoke, chemicals, or other causes with the exception of the predominant floral source"	Practically free—"contains practically no defects that affect the appearance or edibility of the product"	Clear—"may contain air bubbles which do not materially affect the appearance of the product and may contain a trace of pollen grains or other finely divided particles of suspended material which do not affect the appearance of the product"
B	≥ 81.4%	Reasonably good—"has a reasonably good, normal flavor and aroma for the predominant floral source or, when blended, a reasonably good flavor for the blend of floral sources and the honey is practically free from caramelized flavor and is free from objectionable flavor caused by fermentation, smoke, chemicals, or other causes with the exception of the predominant floral source"	Reasonably free—"may contain defects which do not materially affect the appearance or edibility of the product"	Reasonably clear—"may contain air bubbles, pollen grains, or other finely divided particles of suspended material which do not materially affect the appearance of the product"
C	≥ 80.0%	Fairly good—"has a fairly good, normal flavor and aroma for the predominant floral source or, when blended, a fairly good flavor for the blend of floral sources and the honey is reasonably free from caramelized flavor and is free from objectionable flavor caused by fermentation, smoke, chemicals, or other causes with the exception of the predominant floral source"	Fairly free—"may contain defects which do not seriously affect the appearance or edibility of the product"	Fairly clear—"may contain air bubbles, pollen grains, or other finely divided particles of suspended material which do not seriously affect the appearance of the product"
Substandard	Fails Grade C	Fails Grade C	Fails Grade C	Fails Grade C

Other countries may have differing standards on the grading of honey. India, for example, certifies honey grades based on additional factors, such as the Fiehe's test, and other empirical measurements.[76]

Indicators of quality

High-quality honey can be distinguished by fragrance, taste, and consistency. Ripe, freshly collected, high-quality honey at 20 °C (68 °F) should flow from a knife in a straight stream, without breaking into separate drops.[77] After falling down, the honey should form a bead. The honey, when poured, should form small, temporary layers that disappear fairly quickly, indicating high viscosity. If not, it indicates excessive water content (over 20%)[77] of the product. Honey with excessive water content is not suitable for long-term preservation.[78]

In jars, fresh honey should appear as a pure, consistent fluid, and should not set in layers. Within a few weeks to a few months of extraction, many varieties of honey crystallize into a cream-colored solid. Some varieties of honey, including tupelo, acacia, and sage, crystallize less regularly. Honey may be heated during bottling at temperatures of 40–49 °C (104–120 °F) to delay or inhibit crystallization. Overheating is indicated by change in enzyme levels, for instance, diastase activity, which can be determined with the Schade or the Phadebas methods. A fluffy film on the surface of the honey (like a white foam), or marble-colored or white-spotted crystallization on a container's sides, is formed by air bubbles trapped during the bottling process.

A 2008 Italian study determined nuclear magnetic resonance spectroscopy can be used to distinguish between different honey types, and can be used to pinpoint the area where it was produced. Researchers were able to identify differences in acacia and polyfloral honeys by the differing proportions of fructose and sucrose, as well as differing levels of aromatic amino acids phenylalanine and tyrosine. This ability allows greater ease of selecting compatible stocks.[79]

Nutritional and sugar profile

In a 100-gram serving, honey provides 304 kilocalories with no essential nutrients in significant content.[8] Composed of 17% water and 82% carbohydrates, honey has low content of fat, dietary fiber, and protein.

A mixture of sugars and other carbohydrates, honey is mainly fructose (about 38%) and glucose (about 32%),[4] with remaining sugars including maltose, sucrose, and other complex carbohydrates.[4] Its glycemic index ranges from 31 to 78, depending on the variety.[80] The specific composition, color, aroma, and flavor of any batch of honey depend on the flowers foraged by bees that produced the honey.[11]

One 1980 study found that mixed floral honey from several United States regions typically contains:[81]

- Fructose: 38.2%
- Glucose: 31.3%
- Maltose: 7.1%
- Sucrose: 1.3%
- Water: 17.2%
- Higher sugars: 1.5%
- Ash: 0.2%
- Other/undetermined: 3.2%

A 2013 NMR spectroscopy study of 20 different honeys from Germany found that their sugar contents comprised:

- Fructose: 28% to 41%
- Glucose: 22% to 35%

The average ratio was 56% fructose to 44% glucose, but the ratios in the individual honeys ranged from a high of 64% fructose and 36% glucose (one type of flower honey; table 3 in reference) to a low of 50% fructose and 50% glucose (a different floral source). This NMR method was not able to quantify maltose, galactose, and the other minor sugars as compared to fructose and glucose.[82]

Honey

Nutritional value per 100 g (3.5 oz)		
Energy	1,272 kJ (304 kcal)	
Carbohydrates	82.4 g	
Sugars	82.12 g	
Dietary fiber	0.2 g	
Fat	0 g	
Protein	0.3 g	
Vitamins		
Riboflavin (B_2)	0.038 mg	(3%)
Niacin (B_3)	0.121 mg	(1%)
Pantothenic acid (B_5)	0.068 mg	(1%)
Vitamin B_6	0.024 mg	(2%)
Folate (B_9)	2 µg	(1%)
Vitamin C	0.5 mg	(1%)
Minerals		
Calcium	6 mg	(1%)
Iron	0.42 mg	(3%)
Magnesium	2 mg	(1%)
Phosphorus	4 mg	(1%)
Potassium	52 mg	(1%)
Sodium	4 mg	(0%)
Zinc	0.22 mg	(2%)
Other constituents		
Water	17.10 g	

Full Link to USDA Database entry

Units
µg = micrograms • mg = milligrams
IU = International units

Percentages are roughly approximated using US recommendations for adults.

Medical

Uses

Wounds and burns

Honey contains trace amount of compounds implicated in preliminary studies to have wound-healing properties, such as hydrogen peroxide[83] and methylglyoxal.[84]

Some evidence shows that honey may help healing in skin wounds after surgery and mild (partial thickness) burns when used in a dressing, but in general, the evidence for the use of honey in wound treatment is of such low quality that firm conclusions cannot be drawn.[85][86]

Evidence does not support the use of honey-based products in the treatment of venous stasis ulcers or ingrowing toenail.[87][88]

Research into medical uses for honey is ongoing, particularly because of antimicrobial resistance to modern antibiotics.[89]

Cough

For chronic and acute coughs, a Cochrane review found no strong evidence for or against the use of honey.[90][91] For treating children, the study concluded that honey possibly helps more than no treatment.[91]

The UK Medicines and Healthcare Products Regulatory Agency recommends avoiding giving over the counter cough and common cold medication to children under six, and suggests "a homemade remedy containing honey and lemon is likely to be just as useful and safer to take", but warns that honey should not be given to babies because of the risk of infant botulism.[92] The World Health Organization recommends honey as a treatment for coughs and sore throats, including for children, stating that no reason exists to believe it is less effective than a commercial remedy.[93] Honey is recommended by one Canadian physician for children over the age of one for the treatment of coughs, as it is deemed as effective as dextromethorphan and more effective than diphenhydramine.[9]

Other

No evidence shows the benefit of using honey to treat cancer,[10] although honey may be useful for controlling side effects of radiation therapy or chemotherapy applied in cancer treatment.[94]

Consumption is sometimes advocated as a treatment for seasonal allergies due to pollen, but scientific evidence to support the claim is inconclusive.[10][95] Honey is generally considered ineffective for the treatment of allergic conjunctivitis.[10][96]

Preliminary studies found honey to contain an antimicrobial peptide called bee defensin-1.[97] Some *in vitro* studies show that honey can kill methicillin-resistant *Staphylococcus aureus* (MRSA), β-haemolytic streptococci and vancomycin-resistant *Enterococci*.[98]

Health hazards

Although honey is generally safe when taken in typical food amounts,[10][9] there are various, potential adverse effects or interactions it may have in combination with excessive consumption, existing disease conditions or drugs.[10] Included among these are mild reactions to high intake, such as anxiety, insomnia, or hyperactivity in about 10% of children, according to one study.[9] No symptoms of anxiety, insomnia, or hyperactivity were detected with honey consumption compared to placebo, according to another study.[9] Honey consumption may interact adversely with existing allergies, high blood sugar levels (as in diabetes), or anticoagulants used to control bleeding, among other clinical conditions.[10]

People who have a weakened immune system may be at risk of bacterial or fungal infection from eating honey,[99] although there is no high-quality clinical evidence that this occurs commonly.[10]

Botulism

Infants can develop botulism after consuming honey contaminated with *Clostridium botulinum* endospores.[100]

Infantile botulism shows geographical variation. In the UK, only six cases have been reported between 1976 and 2006,[101] yet the U.S. has much higher rates: 1.9 per 100,000 live births, 47.2% of which are in California.[102] While the risk honey poses to infant health is small, taking the risk is not recommended until after one year of age, and then giving honey is considered safe.[103]

Toxic honey

Mad honey intoxication is a result of eating honey containing grayanotoxins.[104] Honey produced from flowers of rhododendrons, mountain laurels, sheep laurel, and azaleas may cause honey intoxication. Symptoms include dizziness, weakness, excessive perspiration, nausea, and vomiting. Less commonly, low blood pressure, shock, heart rhythm irregularities, and convulsions may occur, with rare cases resulting in death. Honey intoxication is more likely when using "natural" unprocessed honey and honey from farmers who may have a small number of hives. Commercial processing, with pooling of honey from numerous sources, is thought to dilute any toxins.[105]

Toxic honey may also result when bees are proximate to tutu bushes (*Coriaria arborea*) and the vine hopper insect (*Scolypopa australis*). Both are found throughout New Zealand. Bees gather honeydew produced by the vine hopper insects feeding on the tutu plant. This introduces the poison tutin into honey.[106] Only a few areas in New Zealand (the Coromandel Peninsula, Eastern Bay of Plenty and the Marlborough Sounds) frequently produce toxic honey. Symptoms of tutin poisoning include vomiting, delirium, giddiness, increased excitability, stupor, coma, and violent convulsions. To reduce the risk of tutin poisoning, humans should not eat honey taken from feral hives in the risk areas of New Zealand. Since December 2001, New Zealand beekeepers have been required to reduce the risk of producing toxic honey by closely monitoring tutu, vine hopper, and foraging conditions within 3 km (1.9 mi) of their apiary. Intoxication is rarely dangerous.[104]

History and culture

Honey use and production has a long and varied history.[11] In many cultures, honey has associations that go beyond its use as a food. It is frequently used as a talisman and symbol of sweetness.[107]

Ancient times

Honey collection is an ancient activity.[12] Humans apparently began hunting for honey at least 8,000 years ago, as evidenced by a cave painting in Valencia, Spain.[12] The painting is a Mesolithic rock painting, showing two honey hunters collecting honey and honeycomb from a wild bee nest. The figures are depicted carrying baskets or gourds, and using a ladder or series of ropes to reach the wild nest.

Honey seeker depicted in an 8000-year-old cave painting at Araña Caves in Spain

The greater honeyguide bird guides humans to wild bee hives[108] and this behavior may have evolved with early hominids.[109][110]

The oldest honey remains to have been found were in the country of Georgia. Archaeologists found honey remains on the inner surface of clay vessels unearthed in an ancient tomb, dating back some 4,700–5,500 years.[111][112][113] In ancient Georgia, several types of honey were buried with a person for their journey into the afterlife, including linden, berry, and meadow-flower varieties.[114]

In ancient Egypt, honey was used to sweeten cakes and biscuits, and was used in many other dishes. Ancient Egyptian and Middle Eastern peoples also used honey for embalming the dead.[115] The fertility god of Egypt, Min, was offered honey.

In ancient Greece, honey was produced from the Archaic to the Hellenistic periods. In 594 BC,[116] beekeeping around Athens was so widespread that Solon passed a law about it: "He who sets up hives of bees must put them 300 feet (91 metres) away from those already installed by another".[117][3] Greek archaeological

excavations of pottery located ancient hives.[118] According to Columella, Greek beekeepers of the Hellenistic period did not hesitate to move their hives over rather long distances to maximise production, taking advantage of the different vegetative cycles in different regions.[118]

In the absence of sugar, honey was an integral sweetening ingredient in Greek and Roman cuisine. During Roman times, honey was part of many recipes and it is mentioned in the work of many authors, such as Virgil, Pliny, Cicero, and others.

The spiritual and therapeutic use of honey in ancient India is documented in both the Vedas and the Ayurveda texts, which were both composed at least 4,000 years ago.[119]

The art of beekeeping in ancient China has existed since time immemorial and appears to be untraceable to its origin. In the book *Golden Rules of Business Success* written by Fan Li (or Tao Zhu Gong) during the Spring and Autumn period, some parts mention the art of beekeeping and the importance of the quality of the wooden box for beekeeping that can affect the quality of its honey.

Honey was also cultivated in ancient Mesoamerica. The Maya used honey from the stingless bee for culinary purposes, and continue to do so today. The Maya also regard the bee as sacred (see Mayan stingless bees of Central America).

Some cultures believed honey had many practical health uses. It was used as an ointment for rashes and burns, and to help soothe sore throats when no other practices were available.

Folk medicine and wound r esearch

In myths and folk medicine, honey has been used both orally and topically to treat various ailments including gastric disturbances, ulcers, skin wounds, and skin burns by ancient Greeks and Egyptians, and in Ayurveda and traditional Chinese medicine.[119]

Proposed for treating wounds and burns, honey may have antimicrobial properties as first reported in 1892 and be useful as a safe, improvisational wound treatment.[120][121] Though its supposed antimicrobial properties may be due to high osmolarity even when diluted with water, it is more effective than plain sugar water of a similar viscosity.[120][121] Definitive clinical conclusions about the efficacy and safety of treating wounds, however, are not possible from this limited research.[85]

The flora that bees use to make the honey may have a role in its properties, particularly by bees foraging from the manuka myrtle, *Leptospermum scoparium*, as proposed in one study.[120]

Religious significance

In ancient Greek religion, the food of Zeus and the 12 Gods of Olympus was honey in the form of nectar and ambrosia.[122]

In Hinduism, honey (*Madhu*) is one of the five elixirs of immortality (*Panchamrita*). In temples, honey is poured over the deities in a ritual called *Madhu abhisheka*. The *Vedas* and other ancient literature mention the use of honey as a great medicinal and health food.[123]

In Jewish tradition, honey is a symbol for the new year, *Rosh Hashanah*. At the traditional meal for that holiday, apple slices are dipped in honey and eaten to bring a sweet new year. Some *Rosh Hashanah* greetings show honey and an apple, symbolizing the feast. In some congregations, small straws of honey are given out to usher in the new year.[124]

The Hebrew Bible contains many references to honey. In the Book of Judges, Samson found a swarm of bees and honey in the carcass of a lion (14:8). In Old Testament law, offerings were made in the temple to God. The Book of Leviticus says that "Every grain offering you bring to the Lord must be made without yeast, for you are not to burn any yeast or honey in a food offering presented to the Lord" (2:11). In the Books of Samuel,

Jonathan is forced into a confrontation with his father King Saul after eating honey in violation of a rash oath Saul has made (1 Samuel 14:24–47). Proverbs 16:24 in the JPS Tanakh 1917 version says "Pleasant words are as a honeycomb, Sweet to the soul, and health to the bones." Book of Exodus famously describes the Promised Land as a "land flowing with milk and honey" (33:3). However, most Biblical commentators write that the original Hebrew in the Bible (דבש *devash*) refers to the sweet syrup produced from the juice of dates (*silan*).[125] In 2005 an apiary dating from the 10th century B.C. was found in Tel Rehov, Israel that contained 100 hives and is estimated to produce half a ton of honey annually.[126][127] Pure honey is considered kosher, though it is produced by a flying insect, a non-kosher creature; other products of non-kosher animals are not kosher.[128]

In Buddhism, honey plays an important role in the festival of *Madhu Purnima*, celebrated in India and Bangladesh. The day commemorates Buddha's making peace among his disciples by retreating into the wilderness. The legend has it that while he was there, a monkey brought him honey to eat. On *Madhu Purnima*, Buddhists remember this act by giving honey to monks. The monkey's gift is frequently depicted in Buddhist art.[123]

In the Christian New Testament, Matthew 3:4, John the Baptist is said to have lived for a long period of time in the wilderness on a diet consisting of locusts and wild honey.

In Islam, an entire chapter (Surah) in the Qur'an is called *an-Nahl* (the Bee). According to his teachings (*hadith*), Muhammad strongly recommended honey for healing purposes.[129] The Qur'an promotes honey as a nutritious and healthy food. Below is the English translation of those specific verses:

> And thy Lord taught the Bee to build its cells in hills, on trees, and in (men's) habitations; Then to eat of all the produce (of the earth), and find with skill the spacious paths of its Lord: there issues from within their bodies a drink of varying colours, wherein is healing for men: verily in this is a Sign for those who give thought [Al-Quran 16:68–69].[130]

See also

- Bee bread
- Honey hunting
- List of spreads
- *More than Honey*—a 2012 Swiss documentary film on the current state of honey bees and beekeeping
- National Honey Show
- Royal jelly

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