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Flavor.—Flavor (composite taste and odor) is an important property of cooked beef but the chemistry is extremely complex. True beef flavor develops during cooking and, in the case of roast beef for example, it appears that the bulk of the flavor constituents is produced in the surface portion of the meat, while the inner portions contribute little to the roast beef flavor. Researchers have met with only limited success in capturing the complex and elusive beef flavor essence which seems to be unstable and present in minute concentrations.

Color.—The consumer equates the color of fresh beef with freshness and wholesomeness. The color of fresh raw meat is due almost entirely to myoglobin, only traces of hemoglobin remain after slaughter. Freshly cut beef is purplish-red and becomes bright red in color minutes after exposure to air and the formation of oxymyoglobin.

When beef has substantially depleted stores of glycogen prior to slaughter, the muscles appear very dark and are classified as dark-cutting beef. A high ultimate pH in the muscles causes this aesthetically unpleasant phenomenon. Dark-cutting beef, although otherwise a wholesome and tender meat, is discounted at the retail level because it is difficult for the consumer to distinguish between dark-cutting beef and beef from old animals or beef held under adverse conditions. There is no practical technological solution to prevent the occurrence of the dark-cutting beef.

Beef color changes gradually during cooking from a bright red appearance to a grey or brown. The color change that occurs during cooking is roughly related to cooking temperature which causes denaturation phenomena in the muscle tissue but no noticeable change in the fat color. The following degrees of cooking may be observed: rare beef, no visual color change—below 60°C; medium rare, decreasing redness—up to 70°C; medium, reddish-brown—up to 75°C; well-done beef, complete loss of red color—above 75°C.

Nutritional Aspects

Beef is an important dietary source of high quality protein, B-group vitamins, and minerals. Beef proteins contain all essential amino acids for balanced nutrition. Upon digestion, proteins are split into elemental units or amino acids in proper proportion, which are then reassembled by the human body for growth and maintenance. About 9 oz of lean beef is enough to provide the daily protein requirement for an adult.

Preservation and Processing

As was mentioned above, about 75% of beef is consumed as fresh meat, including hamburger meat. Fresh meat may be frozen for preservation. The recommended frozen storage time at 0°F is 6–12 months for beef cuts and 3–4 months for ground beef.

The remaining 25% of beef is used in the manufacture of various meat products. The most popular sausage product, either all-beef or containing beef, is the frankfurter. Beef is processed into many other types of sausages, such as bologna, salami, kosher sausages, cervelat, etc. Also various beef loaves may be classified in the sausage group. Typical and popular beef products are corned beef, pastrami, and beef bacon. Many canned products are manufactured containing beef; beef stew may be considered as the most popular.

Future Trends

The beef industry is the fastest expanding segment in the food industry. In recent years there has been considerable interest in the development of more efficient and more economical methods of distributing meats, particularly fresh primal beef cuts. Central processing has been suggested as one of the approaches which offers the greatest opportunity for reducing processing and distribution costs. The term "central packaging" presently means processing of retail cuts of fresh beef in a central plant for a group of retail stores. Instead of moving carcasses to the retail store retail cuts are delivered to the store in boxes in prepackaged form. This development is considered an intermediate step. Ultimately this operation may be expanded from freezing the packaged cuts to the most elaborate central meat processing operations.

ENDEL KARMAS

Cross-Reference: *Meat and Meat Packing.*

BEEKEEPING: HONEY AND HONEY PRODUCTS

Honeybees were brought to the United States from Europe in the early 17th Century, but beekeeping never became rationalized until the movable-frame hive emerged in the middle of the last century through the discovery by Langstroth of the "bee space," the 3/8 in. spacing between parts which the bees would not seal. The new hive allowed inspection for disease, manipulation to prevent swarming, and removal of honey without destruction of the colony. Beekeeping acquired its present form between 1850 and 1914. Two major developments, wax comb foundation in 1857 and the centrifugal honey extractor, com-

In Arnold H. Johnson & Martin S. Peterson, eds., "Encyclopedia of Food Technology." pp. 103-108. Westport, Conn. AVI Publishing Co., 1974.

mercialized in 1870, made large-scale production of liquid honey practical. The bee smoker, the bee escape, and queen excluder were developed in that period and are still in use with only slight change.

Popular demand for liquid honey in the latter part of the 19th Century led to its widespread adulteration. Honey was one of the commodities studied by Harvey Wiley, whose efforts led to the Pure Food and Drug Act in 1906. Honey is not now adulterated in the United States; modern testing methods make detection certain.

Space is not available here to describe modern beekeeping methods. Massive changes in U.S. agriculture in the past four decades have greatly reduced the widespread nature of apiaries. Formerly, nearly every farm had a few beehives, which, together with wild bees in hedgerows and woodlots, ensured adequate pollination of the fruit, vegetable, and seed crops. Today, few family farms have beehives; farming practices have eliminated wild bees and escaped bee colonies. The professional beekeeper now provides much of the pollination needed either as a service for a fee, or as a by-product of his acquisition of high-yielding locations for his bee-yards, ever more difficult to find.

Beekeeping is a highly specialized farm enterprise. The full-time beekeeper maintains at least 400 hives, averaging perhaps 1200. They are dispersed over many locations, each holding 20–200 colonies; the bees in a yard normally cover 4000–5000 acres in searching for nectar and pollen. Colony yield varies between 20 and 200 lb per yr depending upon season, location, and climate. Optimal hive density for good honey yield is usually too dispersed for efficient crop pollination. Growers requiring pollination must therefore compensate the beekeeper for reduced honey crop resulting from relatively high hive density and also for costs of moving colonies and providing strong colonies when required before normal colony build-up.

The literature contains many examples of profitable increase in yield and quality of fruit, vegetable, and seed crops brought about by intelligent co-operation between producers and beekeepers.

Beekeeping is practiced in all States and at all scales from the hobbyist with 1 hive to the professional with more than 20,000. About 1/2 of the average annual honey production of 250 million pounds comes from the 1200–1500 full-time beekeepers who operate about 1/3 of the nation's 4.7 million bee colonies. The continuing 25-yr decline in honeybee population, due in part to the complexity and unprofitability of the business, is raising questions about the adequacy of the national pollination force of bees, which is largely responsible for pollinating over $1 billion in crops annually.

Honey

Honey is the sweet, aromatic, viscous syrup produced by the honeybee (*Apis mellifera* L.) from the nectar of flowers. A combined evaporation and sucrose inversion is brought about by the addition of bee enzymes and physical manipulation of the nectar in the hive. As the ripened nectar reaches a solids content of 80–82%, the cells of the comb in which it is deposited are sealed over with beeswax and the honey thus preserved is stored for maintenance of the colony during the winter. Excess over this amount is appropriated by the beekeeper. The color and flavor of honey is closely related to the flower from which it originates. Agricultural practices of large-scale planting of single crops, the differing seasons of bloom, the "constancy" of bees in terms of the flowers they work, and the control exercised by the beekeeper make large amounts of honey of relatively constant floral type available. About 25 floral types of honey are commercially important, and they range in color from nearly water-white (sweet clover) to dark amber (aster-goldenrod) and in flavor from very mild (fireweed, clovers) to pronounced (buckwheat, tulip poplar). The bulk of commercial honey originates from the various legumes (clovers, vetches, alfalfa) with lesser quantities of citrus, tupelo, sage, basswood, cotton, gallberry, and other regional honey types making the balance.

Composition and Properties

The obvious physical aspects of honey—its high viscosity, "stickiness," great sweetness, high density, hygroscopicity, and relative immunity from spoilage—all rise from its nature as a highly concentrated solution of simple sugars. The data below show the gross composition and physical properties of the average U.S. honey.

Composition

Component	%
Water	17.2
Fructose	38.19
Glucose	31.28
Sucrose	1.31
Reducing disaccharides	7.31
Higher sugars	1.50
Organic acids	0.57
Proteins	0.26
Ash	0.17

Physical Properties

	Value
Sp gr 20/20°C	1.4225
RI (20°C)	1.4935
Equilibrium RH at 68°C	60%
Sp ht (20°C)	0.54
Thermal conductivity (21°C)	12.7×10^{-4} cal/ cm sec °C
Viscosity	ca 70 poises
Wt per gal.	11 lb 13.2 oz
Caloric value	1380 cal/lb

Exact values for the properties will depend upon moisture content and floral type. Unheated honey also contains variable levels of enzymes added by the bees, including invertase, α-amylase, glucose oxidase, catalase, and others. Vitamin levels are too low to have nutritional significance.

Nearly all honey is liquid as stored by the bees. After it is extracted from the comb by the beekeeper, much of it will granulate within a few days or weeks. As a rule of thumb, glucose (dextrose hydrate) will crystallize from honey analyzing more than 30% glucose unless appropriate processing is applied.

Water content of honey is a most important characteristic. A maximum limit of 18.6% is permitted for U.S. Grade A (U.S. Fancy) and Grade B (U.S. Choice) honey. Grade C (U.S. Standard) honey for reprocessing may contain up to 20% water; any higher amount places it in Grade D (Substandard). These limiting values do not represent preferred or proper moisture content for honey. Honey with less than 17.1% water will not ferment within a year regardless of its yeast count. However, fermentation may take place in a honey with 17.1-18% water if it has a yeast content of over 1000 per gm, and between 18.1-19% even though the inoculum is as little as 10 cells per gram. Sugar-tolerant yeasts are a natural contaminant of raw honey. When honey granulates, the water content of the liquid phase may increase as much as 1%. This increases its liability to fermentation at a given yeast content; this granulation is a cause of spring fermentation of originally sound honey held over winter. Unprocessed honey is susceptible to fermentation and this must be kept in mind when any long-term storage of raw honey is undertaken. Honey ferments only between 50° and about 100°F, but storage above 80° is not recommended. Fermenting honey is usually at least partly granulated and has a foam or froth on the surface. It will foam considerably when heated. An odor and flavor of sweet wine or fermenting fruit may be apparent; gas production may be vigorous enough to burst the container. Fermenting honey can sometimes be reclaimed by heating it to 150°F for a short time to kill the yeasts and expel volatile off-flavors.

Commercial Forms of Honey and Their Processing

The two principal forms in which honey is marketed (other than in the comb) are liquid and solid. Processing of each has the common objective: to stabilize against fermentation and change in state with minimal damage to the fine organoleptic qualities of the honey.

Liquid Honey.—This appears to be the preferred U.S. market form, judging by the relative amounts sold. Honey is removed from the combs by the beekeeper using large centrifugal extractors after the wax capping is removed by cutting or mechanical disintegration. Further treatment may be done by the producer or a packer or both. Coarse contaminants are removed by straining of warm (80°-100°F) honey with or without subsequent settling in a series of large tanks. Honey intended by the producer for retail sale may be pasteurized with or without fine straining or filtration and packed in small containers. Honey for the wholesale market is largely handled in 55-gal. full-opening drums, though the older 5-gal. (60 lb) tinned square can is still in use. Some tank-truck handling has been recently noted.

Wholesale marketing is usually based on samples, so that care is required that the sample be representative. Packers of honey may be producer cooperatives, independents, producer-packers, or part of a multiple food packing operation.

The retail honey buyer appears to demand a sparkling clear, light-colored jar of liquid honey that will not granulate while in use. To attain this consistently, honey is blended in bulk by the packer to a color and flavor standard, and to a desired moisture content.

Honey is tested for color, flavor, and moisture when received by the packer and warehoused in bulk containers. Containers are selected for the desired blend, and the honey, usually granulated, is removed by inverting the open container in a warm air room (120°-140°F) or oven, with provision for liquefied material to flow away from the heated area, to reduce undesired heat exposure. Honey at 115°-130°F is gently mixed until liquefaction and blending is complete. It is pumped into one of several holding tanks and held for a few hours to allow air, beeswax, and other impurities to rise to the top.

Honey is heated to destroy yeasts and filtered to remove pollen, impurities, and crystal residues.

The two operations are often combined in a closed system wherein honey is pumped by a positive-displacement pump into the heating section of a plate-type heat exchanger. It rapidly reaches 150°-170°F and is passed through a plate-and-frame or horizontal leaf filter using diatomaceous filter-aid. If needed to extend holding time, a variable-speed pump or a pipeline holding section may be used; the honey temperature is then reduced to 120°F in the cooling section of the heat exchanger. It then moves to holding tanks from which it proceeds to jar or can fillers. Common sizes are 8- and 12-oz, 1-, 1½- and 2-lb jars, and 5-lb cans. Plastic "squeeze-bottles" and novelty shapes are popular containers for liquid honey. The sensitivity of honey to darkening from heat exposure requires care to avoid "stack burn" arising from closing and stacking cases of honey before sufficient cooling has taken place. Water-cooling is generally not used.

Controlled heating is the key to a quality commercial honey pack. Honey, having an aromatic but rather delicate flavor, can be damaged by improper handling. It must be warmed to allow efficient pumping, but for this purpose temperatures of 110°-120°F are adequate. Heating for pasteurization must be only to the required exposure, followed by prompt cooling. One recommendation is 170°F for 3 min. Another description of a large commercial operation states that the pasteurization-filtration operation is done at 150°F for 30 sec. Removal of yeast spores by filtration must be implied here, since actual time needed for yeast destruction in honey is reported as 22 min at 140°F, 2.8 min at 150°F, or 0.4 min at 160°F. Honeys vary in the effects of heating upon their color and flavor. Amber or golden types of more definite flavor cannot withstand as much heating without damage as lighter types because they usually contain higher levels of nitrogenous materials that can participate in the Maillard reaction, generating color and off-flavor.

Difficulty with premature regranulation of processed honey may usually be traced to inadvertant seeding of the treated honey, by contact with partly granulated honey in pipeline joints, tanks, pumps, etc. Air in honey packing houses can contain minute "seed" crystals. Examination of freshly processed honey in the retail container by polarized light is quite effective in revealing the presence of traces of introduced crystals.

Crystallized Honey.—Although most honey is sold in the liquid state, the crystallized form is natural for most types of honey produced in the United States and Canada and is the preferred commercial form in Canada. The extent of granulation at equilibrium for a honey is, of course, governed by its degree of glucose (dextrose) supersaturation. This can most easily be expressed by the dextrose:water ratio. Values of 1.7 and less are associated with nongranulating honeys; values of 2.1 and higher predict that a honey will rapidly granulate to a solid unless preventive measures are taken. It must be emphasized that dextrose value for this ratio must be determined by a specific method. Examples of nongranulating honey types are gallberry, the sages, tupelo.

Honey as extracted from the comb is naturally well-seeded with fine dextrose crystals and will usually solidify with a relatively fine grain. After heat processing, without seeding, granulation is delayed for 6-18 months but eventually coarse crystals will accumulate; these require much more severe heating to redissolve than do the natural, fine crystals.

Processing has been developed reproducibly to attain a very fine-grained, fondant-like, relatively soft honey granulation which has several advantages over the liquid form for use as a spread. Methods in commercial use today are primarily based on the Dyce patent (U.S. pat. 1,987,893). Honey is pasteurized, cooled to less than 80°F and 5-15% of a suitably-textured starter honey is mixed in. After filling, the final containers are held for at least 4 days at 57°F, the optimum for crystallization. They may be held thereafter at temperatures not exceeding 80°F, preferably lower. Above this level, softening and phase separation is likely. The starter is a granulated honey with the desired texture, usually with the crystals impalpable to the tongue. This may be from a previous batch or produced by fine grinding of crystallized honey. The most important requirement affecting product quality is the temperature during seeding. If excessive, the most desirable, finest crystals may dissolve and only the largest survive the initial mixing, producing a sandy or grainy product. Commercially, two types of equipment are used: a Canadian cooperative uses the Votator scraped-surface heat transfer equipment to reduce honey temperature in 2 stages from 110° to 83°F and from 83° to 57°F, with seed injection between the stages. Production rate is reported to be about 4000 lb per hr.

The system more commonly used in the United States comprises a batch creamer, capacity 1200-15000 lb, in which a chilled coil immersed in the honey is rotated on a horizontal axis. Starter (10-12%) is added at 80°F and mixing continues until homogeneous. The product is filled into wide-mouth glass jars or bowls, or plastic or waxed-paper tubs of 8-, 12-, 16-oz capacity and held at 57°F at least a week. Because the product is exposed to higher temperatures during summer months, it may be produced at 17½% moisture for that season, and 18% for cold-weather distribution and use.

Comb Honey.—Honey is sold in the original comb in several market forms. These are minor in sales volume in comparison with liquid or granulated honey, but will be described here since honey sold in the comb represents the closest approach to its natural state, and therefore the most nearly perfect embodiment of true honey flavor. All honey in combs, of course, is placed therein by the bees who cap the cells containing the fully ripened honey with thin wax covers.

Section comb honey is that placed by bees in combs they have drawn from thin surplus foundation supplied by the beekeeper in 4¼ in. × 4¼ in × 1⅞ in. wood frames. Specially thin foundation is used to minimize the amount of wax eaten with the honey. This form of honey is costly to produce and is considered the aristocrat of comb honey. Sections are removed from the hive when finished, prepared for market by cleaning, weighing, and grading, and are packaged in window boxes or in clear plastic film.

Cut-comb honey is prepared by the beekeeper by cutting full-size (ca 5 in. × 16½ in.) combs into appropriate sizes. After draining to eliminate liquid honey from cut cells, the pieces may be marketed in plastic film wrap or in shallow plastic boxes.

Chunk or bulk comb honey is the name given to cut comb honey immersed in liquid honey. This is also a premium product and is hand packed. The principal marketing problem is premature granulation initiated in the liquid portion by seed crystals on the surface of the comb. Since beeswax softens above 130°F, heat sufficient to destroy seed crystals cannot be applied. A solution to this problem is the use of nongranulating honey as the liquid portion; gallberry honey is a typical choice.

Grades of Honey

There is no FDA standard of identity for honey, though the old (1906) definition still has advisory status. The USDA has established optional grades for extracted (liquid and crystallized) honey and for the comb honey forms described above. There are seven USDA color classes of honey, but color is not a factor in grading. Honey is graded with respect to its moisture content (18.6% maximum), flavor, clarity, and freedom from extraneous material. Copies of USDA grade standards for these products, as well as the color standards, may be obtained from processed products Standardization and Inspection Branch, Fruit and Vegetable Division, Consumer and Marketing Service, USDA, Washington, D.C. 20250.

Storage and Export

Honey can be stored under appropriate conditions for years, but unless at a temperature of below about 75°F, gradual darkening and flavor deterioration takes place over a period of many months. Honey, being hygroscopic, must be protected from atmospheric moisture. Storage conditions must not favor fermentation, granulation, or heat damage. Fermentation is strongly retarded below 50°F and above 100°F. Granulation is accelerated between 55° and 60°F. The best condition for storing unpasteurized honey is below 50°F. Temperatures above about 80°–85°F should be avoided for long-term storage because heat damage can be appreciable in and above this range.

Honey can be kept indefinitely at refrigerator or especially freezer temperatures; granulation is retarded under the latter condition. Finely-granulated honey spread should not be held at temperatures over 80°F for appreciable periods. At refrigerator temperature it is usually too stiff to spread. During long (9–18 months) storage at moderate room temperatures, a chemical reversion of some of the dextrose will bring about a softening of texture, leading in longer periods to partial liquefaction.

Honey for export to countries using the Codex Alimentarius Standards for honey must meet quality standards not used in U.S. domestic trade. Working from a premise that excessive heating damages the health-giving properties of honey, the Codex Standard specifies honey to have a minimum value of 8 for diastase number and a maximum hydroxymethylfurfural content of 40 mg per kg, except that for certain floral types of naturally low enzyme content, values of 3 and 15, respectively, are specified. There are limits on other aspects, such as moisture, reducing sugar, sucrose, ash, acidity, which are not generally restricting to quality honey. It must be realized, however, that natural unheated U.S. honey can pass beyond the limits named by storage for a few months under not unusual conditions. It is of great importance for honey exporters to be aware of the implications of these standards (FAO/WHO Ref. No. CAC/RS-12-1969) and be prepared to meet them by suitable analytical testing and control of storage conditions.

Honey in Food Products

The baking industry probably is the largest user of honey. Use of honey imparts moisture retention due to its high fructose level, a desirable degree of browning, and a flavor unobtainable elsewhere. Breads, cakes, yeast-raised sweet goods, and cookies, all are improved by honey. A spread consisting of blended butter and honey is available. Several breakfast cereal products use honey in their formulas and several pharmaceutical preparations have honey as a useful adjunct.

Honey has long been used in confections, especially nougats, but its invert sugar content limits its applicability. It is an optional sweetener in jellies, jams, and preserves. It has long been recommended in infant formulas, but no such products are presently available. Honey as a food ingredient deserves serious consideration, with its combination of interesting physical properties, fine flavor, and connotation of old-fashioned goodness.

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Recommended USDA Publications

Beekeeping in the United States, Agr. Handbook *335*. Agr. Res. Serv., USDA, Washington, D.C.
Composition of American Honeys, Tech. Bull. *1261*. Agr. Res. Serv. USDA, Washington, D.C.
Honey Market News, Monthly Rept. Fruit and Vegetable Div., Consumer and Marketing Serv., USDA, Washington, D.C.
An Appraisal of the Beekeeping Industry, *ARS 42-150*. Agr. Res. Serv., USDA, Washington, D.C.

Cross-reference: *Sugars and Sweeteners.*

BERRIES AND BERRY PROCESSING

Botanically speaking a berry is a fruit which comes from a single many-seeded pistil in which all parts become fleshy. In food fields the word "berry" means any pulpy and usually edible small soft fruit irrespective of its structure. In this article the latter definition will be intended whenever the word "berry" is used.

Strawberries

The strawberry, the most widely-grown berry of the world, is not a true berry as the seeds grow on the outside, rather than on the inside of the receptacle of the flower. Some varieties produce well at sea level, while others are known which are adapted to 12,000-ft elevations. The strawberry is grown commercially in every state of the United States and is widely used as fresh fruit. Its main uses as processed fruit are for freezing, preserving, ice cream, and bakery goods. It is a good source of ascorbic acid or vitamin C, some varieties regularly assaying out at 60 mg%.

The varietal picture is slowly, but constantly changing. Between 1900 and 1950 there were nine notable strawberry varieties grown in North America (Darrow 1966). These were: Marshall, Klondike, Missionary, Dunlap, Premier, Aberdeen, Blakemore, Fairfax, and Aroma. In 1966, Blakemore was the only one of these accounting for more than 3% of the acreage grown in the United States (Darrow and Scott 1967). In 1970, the most important varieties, based on tonnage, were Northwest, Tioga, Shasta, Midway, Tennessee Beauty, Fresno, Surecrop, Florida 90, Blakemore and Siletz. Northwest in Western United States and Surecrop in Eastern United States accounted for the greatest acreage in their parts of the country. Two hardy winter varieties, Shuksan and Totem, appear to be well-adapted to the Pacific Northwest (Barritt *et al.* 1972), while Raritan has taken on well in New Jersey, Maryland, and Ohio. Earlibelle was highly rated by Sistrunk and Moore (1971) in Arkansas. The leading California varieties in 1970 were Tioga, Shasta and Fresno according to the California Department of Agriculture.

For processing, a strawberry variety must be productive enough that the grower can afford to produce it. It must have a bright red color which does not appear to be "washed out" or too dark in the product, have a good balance between sweetness, acidity, and aromatic character in its flavor and maintain a texture which gives pleasing mouth feel when eaten. At present, most of the processed berries are frozen while only small amounts are canned. The frozen pack is divided fairly evenly between retail pack and the industrial pack for remanufacture into jams, jellies, ice cream, bakery, and other products.

Processing.—The berries, upon delivery to the freezing plant, are washed, dewatered, and inspected for rots and other defective fruit which is discarded. In some plants the berries are size graded and the very small fruit is diverted to juice or purée lines. Berries packed for retail trade are normally sliced, either into $^3/_8$-in. slices or cut into half. The cut fruit is mixed with sugar at the ratio of 1 lb of sugar for every 4 lb of fruit (4 + 1). The sugared fruit is then packaged, usually in metal-end, fiber-bodied containers. The filled containers may be tray frozen and then cased for storage; they may be cased and frozen by individual case, or palleted and frozen by the pallet. Some chain store buyers specify pallet freezing, because the slower freeze allows more time for the sugar to equilibrate with the berries. However, investigations have shown that as much as a week's time may be required to completely freeze some of the strawberries in the pallet loads (Durkee *et al.* 1961). Subjective appraisal showed the slowest frozen berries to have lost as much quality during freezing as would happen during more rapid freezing and 1 yr of 0°F storage (Guadagni *et al.* 1961).