An apple is a round, edible fruit produced by an apple tree (Malus spp., among them the domestic or orchard apple; Malus domestica). Apple trees are cultivated worldwide and are the most widely grown species in the genus Malus. The tree originated in Central Asia, where its wild ancestor, Malus sieversii, is still found. Apples have been grown for thousands of years in Eurasia and were introduced to North America by European colonists. Apples have religious and mythological significance in many cultures, including Norse, Greek, and European Christian tradition.

Apples grown from seed tend to be very different from those of their parents, and the resultant fruit frequently lacks desired characteristics. For commercial purposes, including botanical evaluation, apple cultivars are propagated by clonal grafting onto rootstocks. Apple trees grown without rootstocks tend to be larger and much slower to fruit after planting. Rootstocks are used to control the speed of growth and the size of the resulting tree, allowing for easier harvesting.

There are more than 7,500 cultivars of apples.[3] Different cultivars are bred for various tastes and uses, including cooking, eating raw, and cider or apple juice production. Trees and fruit are prone to fungal, bacterial, and pest problems, which can be controlled by a number of organic and non-organic means. In 2010, the fruit's genome was sequenced as part of research on disease control and selective breeding in apple production.

From 2014 to 2023, there have been an average of 78 million tonnes of apples globally produced per year. In 2023, the worldwide production of apples was 83 million tonnes, with China accounting for nearly half of the total.[4]

Etymology

The word apple, whose Old English ancestor is æppel, is descended from the Proto-Germanic noun \*aplaz, descended in turn from Proto-Indo-European \*h₂ébōl.[5]

As late as the 17th century, the word also functioned as a generic term for all fruit, including nuts. This can be compared to the 14th-century Middle English expression appel of paradis, meaning a banana.[6]

Description

The apple is a deciduous tree, generally standing 2 to 4.5 metres (6 to 15 feet) tall in cultivation and up to 15 m (49 ft) in the wild, though more typically 2 to 10 m (6.5 to 33 ft).[7][1] When cultivated, the size, shape and branch density are determined by rootstock selection and trimming method.[7] Apple trees may naturally have a rounded to erect crown with a dense canopy of leaves.[8] The bark of the trunk is dark gray or gray-brown, but young branches are reddish or dark-brown with a smooth texture.[1][9] When young twigs are covered in very fine downy hairs and become hairless as they become older.[9]

The buds are egg shaped and dark red or purple in color and range in size from 3 to 5 millimeters, but usually less than 4 mm. The bud scales have very hairy edges. When emerging from the buds the leaves are convolute, that is their edges overlap each other.[1] The shape is ranges from simple ovals (elliptic) medium or wide in width, somewhat egg shaped with the wider portion toward their base (ovate) or even with sides that are more parallel to each other instead of curved (oblong) with a narrow pointed end.[9][1] The edges have broadly angled teeth, but do not have lobes. The top surface of the leaves are glabrescent, almost hairless, while the undersides are densely covered in fine hairs.[1] The leaves are attached alternately by short leaf stems 1-to-3.5 cm (1⁄2-to-1+1⁄2 in) long.[8][1]

Blossoms are produced in spring simultaneously with the budding of the leaves and are produced on spurs and some long shoots.[7] When the flower buds first begin to open the petals are rose-pink and fade to white or light pink when fully open with each flower 3-to-4-centimeter (1-to-1+1⁄2-inch) in diameter.[1] The five petaled flowers are group in an inflorescence consisting of a cyme with 4–6 flowers. The central flower of the inflorescence is called the "king bloom"; it opens first and can develop a larger fruit.[8]

The fruit is a pome that matures in late summer or autumn.[1] The size varies widely for apple trees, but generally with a diameter between 2.5 and 12 cm (1 and 4+3⁄4 in).[9] Even in cultivated varietes the shape is quite variable and may be nearly round, elogated, conical, or short and wide.[10] At the base of the fruit the five sepals remain attached and stand out from the surface of the apple.[1]

The groundcolor of ripe apples is yellow, green, yellow-green or whitish yellow. The overcolor of ripe apples can be orange-red, pink-red, red, purple-red or brown-red. The overcolor amount can be 0–100%.[11] The skin may also be wholly or partly russeted (i.e. rough and brown). The skin is covered in a protective layer of epicuticular wax.[12] The skin may also be marked with scattered dots.[1] The exocarp (flesh) is generally pale yellowish-white, though pink, yellow or green exocarps also occur.[11]

Apples can have any amount of overcolor, a darker tint over a pale groundcolor.

Chemistry

Important volatile compounds in apples that contribute to their scent and flavour include acetaldehyde, ethyl acetate, 1-butanal, ethanol, 2-methylbutanal, 3-methylbutanal, ethyl propionate, ethyl 2-methylpropionate, ethyl butyrate, ethyl 2-methyl butyrate, hexanal, 1-butanol, 3-methylbutyl acetate, 2-methylbutyl acetate, 1-propyl butyrate, ethyl pentanoate, amyl acetate, 2-methyl-1-butanol, trans-2-hexenal, ethyl hexanoate, hexanol.[13][14]

Taxonomy

The apple as a species has more than 100 alternative scientific names, or synonyms.[15] In modern times, Malus pumila and Malus domestica are the two main names in use. M. pumila is the older name, but M. domestica has become much more commonly used starting in the 21st century, especially in the western world. Two proposals were made to make M. domestica a conserved name: the earlier proposal was voted down by the Committee for Vascular Plants of the IAPT in 2014, but in April 2017 the Committee decided, with a narrow majority, that the newly popular name should be conserved.[16] The General Committee of the IAPT decided in June 2017 to approve this change, officially conserving M. domestica.[17] Nevertheless, some works published after 2017 still use M. pumila as the correct name, under an alternate taxonomy.[2]

When first classified by Linnaeus in 1753, the pears, apples, and quinces were combined into one genus that he named Pyrus and he named the apple as Pyrus malus. This was widely accepted, however the botanist Philip Miller published an alternate classification in The Gardeners Dictionary with the apple species separated from Pyrus in 1754. He did not clearly indicate that by Malus pumila he meant the domesticated apple. Nonetheless it was used as such by many botanists. When Moritz Balthasar Borkhausen published his scientific description of the apple in 1803 it may have been a new combination of P. malus var. domestica, but this was not directly referenced by Borkhausen.[15] The earliest use of this name for the apple was by Georg Adolf Suckow in 1786.[2]

Genome

Apples are diploid, with two sets of chromosomes per cell (though triploid cultivars, with three sets, are not uncommon), have 17 chromosomes and an estimated genome size of approximately 650 Mb. Several whole genome sequences have been completed and made available. The first one in 2010 was based on the diploid cultivar 'Golden Delicious'.[18] However, this first whole genome sequence turned out to contain several errors[19] in part owing to the high degree of heterozygosity in diploid apples which, in combination with an ancient genome duplication, complicated the assembly. Recently, double- and trihaploid individuals have been sequenced, yielding whole genome sequences of higher quality.[20][21]

The first whole genome assembly was estimated to contain around 57,000 genes,[18] though the more recent genome sequences support estimates between 42,000 and 44,700 protein-coding genes.[20][21] The availability of whole genome sequences has provided evidence that the wild ancestor of the cultivated apple most likely is Malus sieversii. Re-sequencing of multiple accessions has supported this, while also suggesting extensive introgression from Malus sylvestris following domestication.[22]

Cultivation

History

Map of the origins of the cultivated apple. The wild origin is in Kazakhstan; hybridisations and repeated domestications followed, modifying many attributes of the fruit.[22]

color photograph of a hand holding a red apple

Wild Malus sieversii apple in Kazakhstan

Central Asia is generally considered the center of origin for apples due to the genetic variability in specimens there.[23] The wild ancestor of Malus domestica was Malus sieversii, found growing wild in the mountains of Central Asia in southern Kazakhstan, Kyrgyzstan, Tajikistan, and northwestern China.[7][24] Cultivation of the species, most likely beginning on the forested flanks of the Tian Shan mountains, progressed over a long period of time and permitted secondary introgression of genes from other species into the open-pollinated seeds. Significant exchange with Malus sylvestris, the crabapple, resulted in populations of apples being more related to crabapples than to the more morphologically similar progenitor Malus sieversii. In strains without recent admixture the contribution of the latter predominates.[25][26][27]

The apple is thought to have been domesticated 4,000–10,000 years ago in the Tian Shan mountains, and then to have travelled along the Silk Road to Europe, with hybridization and introgression of wild crabapples from Siberia (M. baccata), the Caucasus (M. orientalis), and Europe (M. sylvestris). Only the M. sieversii trees growing on the western side of the Tian Shan mountains contributed genetically to the domesticated apple, not the isolated population on the eastern side.[22]

Chinese soft apples, such as M. asiatica and M. prunifolia, have been cultivated as dessert apples for more than 2,000 years in China. These are thought to be hybrids between M. baccata and M. sieversii in Kazakhstan.[22]

Among the traits selected for by human growers are size, fruit acidity, color, firmness, and soluble sugar. Unusually for domesticated fruits, the wild M. sieversii origin is only slightly smaller than the modern domesticated apple.[22]

At the Sammardenchia-Cueis site near Udine in Northeastern Italy, seeds from some form of apples have been found in material carbon dated to around 4000 BCE.[28] Genetic analysis has not yet been successfully used to determine whether such ancient apples were wild Malus sylvestris or Malus domesticus containing Malus sieversii ancestry. It is hard to distinguish in the archeological record between foraged wild apples and apple plantations.[29]

There is indirect evidence of apple cultivation in the third millennium BCE in the Middle East. There was substantial apple production in European classical antiquity, and grafting was certainly known then.[29] Grafting is an essential part of modern domesticated apple production, to be able to propagate the best cultivars; it is unclear when apple tree grafting was invented.[29]

Winter apples, picked in late autumn and stored just above freezing, have been an important food in Asia and Europe for millennia.[30] Of the many Old World plants that the Spanish introduced to Chiloé Archipelago in the 16th century, apple trees became particularly well adapted.[31] Apples were introduced to North America by colonists in the 17th century,[7] and the first apple orchard on the North American continent was planted in Boston by Reverend William Blaxton in 1625.[32] The only apples native to North America are crab apples, which were once called "common apples".[33]

Apple cultivars brought as seed from Europe were spread along Native American trade routes, as well as being cultivated on colonial farms. An 1845 United States apples nursery catalogue sold 350 of the "best" cultivars, showing the proliferation of new North American cultivars by the early 19th century.[33] In the 20th century, irrigation projects in Eastern Washington began and allowed the development of the multibillion-dollar fruit industry, of which the apple is the leading product.[7]

Until the 20th century, farmers stored apples in frostproof cellars during the winter for their own use or for sale. Improved transportation of fresh apples by train and road replaced the necessity for storage.[34][35] Controlled atmosphere facilities are used to keep apples fresh year-round. Controlled atmosphere facilities use high humidity, low oxygen, and controlled carbon dioxide levels to maintain fruit freshness. They were first used in the United States in the 1960s.[36]

Many apples grow readily from seeds. However, apples must be propagated asexually to obtain the sweetness and other desirable characteristics of the parent. This is because seedling apples are "extreme heterozygotes". Rather than resembling their parents, seedlings are all different from each other and from their parents.[37] Triploid cultivars have an additional reproductive barrier in that three sets of chromosomes cannot be divided evenly during meiosis, yielding unequal segregation of the chromosomes (aneuploids). Even in the case when a triploid plant can produce a seed (apples are an example), it occurs infrequently, and seedlings rarely survive.[38]

Because apples are not true breeders when planted as seeds, grafting is usually used. The rootstock used for the bottom of the graft can be selected to produce trees of a large variety of sizes, as well as changing the winter hardiness, insect and disease resistance, and soil preference of the resulting tree. Dwarf rootstocks can be used to produce very small trees (less than 3.0 m or 10 ft high at maturity), which bear fruit many years earlier in their life cycle than full size trees, and are easier to harvest.[39]

Dwarf rootstocks for apple trees can be traced as far back as 300 BCE, to the area of Persia and Asia Minor. Alexander the Great sent samples of dwarf apple trees to Aristotle's Lyceum. Dwarf rootstocks became common by the 15th century and later went through several cycles of popularity and decline throughout the world.[40] The majority of the rootstocks used to control size in apples were developed in England in the early 1900s. The East Malling Research Station conducted extensive research into rootstocks, and their rootstocks are given an "M" prefix to designate their origin. Rootstocks marked with an "MM" prefix are Malling-series cultivars later crossed with trees of 'Northern Spy' in Merton, England.[41]

Most new apple cultivars originate as seedlings, which either arise by chance or are bred by deliberately crossing cultivars with promising characteristics.[42] The words "seedling", "pippin", and "kernel" in the name of an apple cultivar suggest that it originated as a seedling. Apples can also form bud sports (mutations on a single branch). Some bud sports turn out to be improved strains of the parent cultivar. Some differ sufficiently from the parent tree to be considered new cultivars.[43]

Apples have been acclimatized in Ecuador at very high altitudes, where they can often, with the needed factors, provide crops twice per year because of constant temperate conditions year-round.[44]

Pollination

See also: Fruit tree pollination

Apple blossom from an old Ayrshire cultivar

An orchard mason bee on an apple bloom in British Columbia, Canada

Apples are self-incompatible; they must cross-pollinate to develop fruit. During the flowering each season, apple growers often utilize pollinators to carry pollen. Honey bees are most commonly used. Orchard mason bees are also used as supplemental pollinators in commercial orchards. Bumblebee queens are sometimes present in orchards, but not usually in sufficient number to be significant pollinators.[43][45]

Cultivars are sometimes classified by the day of peak bloom in the average 30-day blossom period, with pollinizers selected from cultivars within a 6-day overlap period. There are four to seven pollination groups in apples, depending on climate:

L. K. Relander, the former President of Finland, with his family picking apples in the 1930s

Cultivars vary in their yield and the ultimate size of the tree, even when grown on the same rootstock. Some cultivars, if left unpruned, grow very large—letting them bear more fruit, but making harvesting more difficult. Depending on tree density (number of trees planted per unit surface area), mature trees typically bear 40–200 kg (90–440 lb) of apples each year, though productivity can be close to zero in poor years. Apples are harvested using three-point ladders that are designed to fit amongst the branches. Trees grafted on dwarfing rootstocks bear about 10–80 kg (20–180 lb) of fruit per year.[43]

Some farms with apple orchards open them to the public so consumers can pick their own apples.[47]

Crops ripen at different times of the year according to the cultivar. Cultivar that yield their crop in the summer include 'Gala', 'Golden Supreme', 'McIntosh', 'Transparent', 'Primate', 'Sweet Bough', and 'Duchess'; fall producers include 'Fuji', 'Jonagold', 'Golden Delicious', 'Red Delicious', 'Chenango', 'Gravenstein', 'Wealthy', 'McIntosh', 'Snow', and 'Blenheim'; winter producers include 'Winesap', 'Granny Smith', 'King', 'Wagener', 'Swayzie', 'Greening', and 'Tolman Sweet'.[33]

Storage

Different apple cultivars in a wholesale food market

Commercially, apples can be stored for a few months in controlled atmosphere chambers to delay ethylene-induced ripening. Apples are commonly stored in chambers with higher concentrations of carbon dioxide and high air filtration. This prevents ethylene concentrations from rising to higher amounts and preventing ripening from occurring too quickly.

For home storage, most cultivars of apple can be held for approximately two weeks when kept at the coolest part of the refrigerator (i.e. below 5 °C).[48] Some varieties of apples (e.g. 'Granny Smith' and 'Fuji') have more than three times the storage life of others.[49]

Non-organic apples may be sprayed with a substance 1-methylcyclopropene blocking the apples' ethylene receptors, temporarily preventing them from ripening.[50]

Pests and diseases

Main article: List of apple diseases

Leaves with significant insect damage

Apple trees are susceptible to a number of fungal and bacterial diseases and insect pests. Many commercial orchards pursue a program of chemical sprays to maintain high fruit quality, tree health, and high yields. These prohibit the use of synthetic pesticides, though some older pesticides are allowed. Organic methods include, for instance, introducing its natural predator to reduce the population of a particular pest.

A wide range of pests and diseases can affect the plant. Three of the more common diseases or pests are mildew, aphids, and apple scab.

Mildew is characterized by light grey powdery patches appearing on the leaves, shoots and flowers, normally in spring. The flowers turn a creamy yellow color and do not develop correctly. This can be treated similarly to Botrytis—eliminating the conditions that caused the disease and burning the infected plants are among recommended actions.[51]

Aphids are a small insect. Five species of aphids commonly attack apples: apple grain aphid, rosy apple aphid, apple aphid, spirea aphid, and the woolly apple aphid. The aphid species can be identified by color, time of year, and by differences in the cornicles (small paired projections from their rear).[51] Aphids feed on foliage using needle-like mouth parts to suck out plant juices. When present in high numbers, certain species reduce tree growth and vigor.[52]

Apple scab: Apple scab causes leaves to develop olive-brown spots with a velvety texture that later turn brown and become cork-like in texture. The disease also affects the fruit, which also develops similar brown spots with velvety or cork-like textures. Apple scab is spread through fungus growing in old apple leaves on the ground and spreads during warm spring weather to infect the new year's growth.[53]

Among the most serious disease problems is a bacterial disease called fireblight, and three fungal diseases: Gymnosporangium rust, black spot,[52] and bitter rot.[54] Other pests that affect apple trees include Codling moths and apple maggots. Young apple trees are also prone to mammal pests like mice and deer, which feed on the soft bark of the trees, especially in winter.[53] The larvae of the apple clearwing moth (red-belted clearwing) burrow through the bark and into the phloem of apple trees, potentially causing significant damage.[55]

Cultivars

Main article: List of apple cultivars

There are more than 7,500 known cultivars (cultivated varieties) of apples.[56] Cultivars vary in their yield and the ultimate size of the tree, even when grown on the same rootstock.[57] Different cultivars are available for temperate and subtropical climates. The UK's National Fruit Collection, which is the responsibility of the Department of Environment, Food, and Rural Affairs, includes a collection of over 2,000 cultivars of apple tree in Kent.[58] The University of Reading, which is responsible for developing the UK national collection database, provides access to search the national collection. The University of Reading's work is part of the European Cooperative Programme for Plant Genetic Resources of which there are 38 countries participating in the Malus/Pyrus work group.[59]

The UK's national fruit collection database contains much information on the characteristics and origin of many apples, including alternative names for what is essentially the same "genetic" apple cultivar. Most of these cultivars are bred for eating fresh (dessert apples), though some are cultivated specifically for cooking (cooking apples) or producing cider. Cider apples are typically too tart and astringent to eat fresh, but they give the beverage a rich flavor that dessert apples cannot.[60]

In the United States there are many apple breeding programs associated with universities. Cornell University has had a program operating in 1880 in Geneva, New York. Amoung their recent well known apples is the 'SnapDragon' cultivar released in 2013. In the west Washington State University started a program to support their apple industry in 1994 and released the 'Cosmic Crisp' cultivar in 2017. The third most grown apple cultivar in the United States is the 'Honeycrisp' released by the University of Minnesota program in 1991.[61] Unusually for a popular cultivar, the 'Honeycrisp' is not directly related to another popular apple cultivar but instead to two unsucessful cultivars.[62] In Europe there are also many breeding programs such as the Julius Kühn-Institut, the German federal research center for cultivated plants.[63]

Commercially popular apple cultivars are soft but crisp. Other desirable qualities in modern commercial apple breeding are a colorful skin, absence of russeting, ease of shipping, lengthy storage ability, high yields, disease resistance, common apple shape, and developed flavor.[57] Modern apples are generally sweeter than older cultivars, as popular tastes in apples have varied over time. Most North Americans and Europeans favor sweet, subacid apples, but tart apples have a strong minority following.[64] Extremely sweet apples with barely any acid flavor are popular in Asia,[64] especially the Indian subcontinent.[60]

Old cultivars are often oddly shaped, russeted, and grow in a variety of textures and colors. Some find them to have better flavor than modern cultivars, but they may have other problems that make them commercially unviable—low yield, disease susceptibility, poor tolerance for storage or transport, or just being the "wrong" size.[65] A few old cultivars are still produced on a large scale, but many have been preserved by home gardeners and farmers that sell directly to local markets. Many unusual and locally important cultivars with their own unique taste and appearance exist; apple conservation campaigns have sprung up around the world to preserve such local cultivars from extinction. In the United Kingdom, old cultivars such as 'Cox's Orange Pippin' and 'Egremont Russet' are still commercially important even though by modern standards they are low yielding and susceptible to disease.[7]

World production of apples in 2022 was 95 million tonnes, with China producing 50% of the total (table).[66] Secondary producers were the United States and Turkey.[66]

Toxicity

Amygdalin

Apple seeds contain small amounts of amygdalin, a sugar and cyanide compound known as a cyanogenic glycoside. Ingesting small amounts of apple seeds causes no ill effects, but consumption of extremely large doses can cause adverse reactions. It may take several hours before the poison takes effect, as cyanogenic glycosides must be hydrolyzed before the cyanide ion is released.[67] The U.S. National Library of Medicine's Hazardous Substances Data Bank records no cases of amygdalin poisoning from consuming apple seeds.[68]

Allergy

One form of apple allergy, often found in northern Europe, is called birch-apple syndrome and is found in people who are also allergic to birch pollen.[69] Allergic reactions are triggered by a protein in apples that is similar to birch pollen, and people affected by this protein can also develop allergies to other fruits, nuts, and vegetables. Reactions, which entail oral allergy syndrome (OAS), generally involve itching and inflammation of the mouth and throat,[69] but in rare cases can also include life-threatening anaphylaxis.[70] This reaction only occurs when raw fruit is consumed—the allergen is neutralized in the cooking process. The variety of apple, maturity and storage conditions can change the amount of allergen present in individual fruits. Long storage times can increase the amount of proteins that cause birch-apple syndrome.[69]

In other areas, such as the Mediterranean, some individuals have adverse reactions to apples because of their similarity to peaches.[69] This form of apple allergy also includes OAS, but often has more severe symptoms, such as vomiting, abdominal pain and urticaria, and can be life-threatening. Individuals with this form of allergy can also develop reactions to other fruits and nuts. Cooking does not break down the protein causing this particular reaction, so affected individuals cannot eat raw or cooked apples. Freshly harvested, over-ripe fruits tend to have the highest levels of the protein that causes this reaction.[69]

Breeding efforts have yet to produce a hypoallergenic fruit suitable for either of the two forms of apple allergy.[69]

†Percentages estimated using US recommendations for adults,[71] except for potassium, which is estimated based on expert recommendation from the National Academies.[72]

A raw apple is 86% water and 14% carbohydrates, with negligible content of fat and protein (table). A reference serving of a raw apple with skin weighing 100 grams provides 52 calories and a moderate content of dietary fiber.[73] Otherwise, there is low content of micronutrients, with the Daily Values of all falling below 10%.[74]

Culinary

Machine for paring, coring, and slicing apples, from Henry B. Scammell's 1897 handbook Cyclopedia of Valuable Receipts

All parts of the fruit, including the skin, except for the seeds, are suitable for human consumption. The core, from stem to bottom, containing the seeds, is usually not eaten and is discarded.[citation needed]

Apples can be consumed in various ways: juice, raw in salads, baked in pies, cooked into sauces and spreads like apple butter, and other baked dishes.[75] They are sometimes used as an ingredient in savory foods, such as sausage and stuffing.[76]

An apple core, part of an apple not usually eaten, containing the seeds

Several techniques are used to preserve apples and apple products. Apples can be canned, dried or frozen. Canned or frozen apples are eventually baked into pies or other cooked dishes. Apple juice or cider is also bottled. Apple juice is often concentrated and frozen.[citation needed]

Apples are often eaten raw. Cultivars bred for raw consumption are termed dessert or table apples. Apples also figure into many traditional or festival occasions. In the UK, a toffee apple is a traditional confection made by coating an apple in hot toffee and allowing it to cool. Similar treats in the U.S. are candy apples (coated in a hard shell of crystallized sugar syrup) and caramel apples (coated with cooled caramel) and are usually consumed during the autumn season or Halloween. Apples and honey are a ritual food pairing eaten during the Jewish New Year of Rosh Hashanah to symbolize a sweet new year.[citation needed]

Apples are an important ingredient in many desserts, such as apple pie, apple crumble, apple crisp and apple cake. When cooked, some apple cultivars easily form a puree known as apple sauce. Apples are also made into apple butter and apple jelly. They are often baked or stewed and are also (cooked) in some meat dishes. Dried apples can be eaten or reconstituted (soaked in water, alcohol or some other liquid).[citation needed]

Apple

Apples are milled or pressed to produce apple juice, which may be drunk unfiltered (called apple cider in North America), or filtered. Filtered juice is often concentrated and frozen, then reconstituted later and consumed. Apple juice can be fermented to make cider (called hard cider in North America), ciderkin, and vinegar. Through distillation, various alcoholic beverages can be produced, such as applejack, Calvados, and apfelwein.[77]

Organic production

Organic apples are commonly produced in the United States.[78] Due to infestations by key insects and diseases, organic production is difficult in Europe.[79] The use of pesticides containing chemicals, such as sulfur, copper, microorganisms, viruses, clay powders, or plant extracts (pyrethrum, neem) has been approved by the EU Organic Standing Committee to improve organic yield and quality.[79] A light coating of kaolin, which forms a physical barrier to some pests, also may help prevent apple sun scalding.[43]

Non-browning apples

Apple skins and seeds contain polyphenols.[80] These are oxidised by the enzyme polyphenol oxidase, which causes browning in sliced or bruised apples, by catalyzing the oxidation of phenolic compounds to o-quinones, a browning factor.[81] Browning reduces apple taste, color, and food value. Arctic apples, a non-browning group of apples introduced to the United States market in 2019, have been genetically modified to silence the expression of polyphenol oxidase, thereby delaying a browning effect and improving apple eating quality.[82][83] The US Food and Drug Administration in 2015, and Canadian Food Inspection Agency in 2017, determined that Arctic apples are as safe and nutritious as conventional apples.