



# Artificial Food Preservatives, Additives and Their Chemical Toxicity

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**ABSTRACT:** Food preservation includes processes that make food more resistant to microorganism growth and slow the oxidation of fats. This slows down the decomposition and rancidification process. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation. By preserving food, food waste can be reduced, which is an important way to decrease production costs and increase the efficiency of food systems, improve food security and nutrition and contribute towards environmental sustainability.<sup>[1]</sup> For instance, it can reduce the environmental impact of food production.<sup>[2]</sup>

**KEYWORDS:** food, preservatives, chemical, toxicity, health, impact

## I. INTRODUCTION

Preservative food additives can be *antimicrobial* – which inhibit the growth of bacteria or fungi, including mold – or *antioxidant*, such as oxygen absorbers, which inhibit the oxidation of food constituents. Common antimicrobial preservatives include calcium propionate, sodium nitrate, sodium nitrite, sulfites (sulfur dioxide, sodium bisulfite, potassium hydrogen sulfite, etc.), and EDTA. Antioxidants include butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Other preservatives include formaldehyde (usually in solution), glutaraldehyde (insecticide), ethanol, and methylchloroisothiazolinone. There is also another approach of impregnating packaging materials (plastic films or other) with antioxidants and antimicrobials, such as butylated hydroxyanisole, butylated hydroxytoluene, tocopherols, hinokitiol, lysozyme, nisin, natamycin, chitosan, and  $\epsilon$ -polylysine.<sup>[17][18]</sup>

Antimicrobial preservatives prevent degradation by bacteria. This method is the most traditional and ancient type of preserving—ancient methods such as pickling and adding honey prevent microorganism growth by modifying the pH level. The most commonly used antimicrobial preservative is lactic acid. Common antimicrobial preservatives are presented in the table.<sup>[5][6][7]</sup> Nitrates and nitrites are also antimicrobial.<sup>[8]</sup> The detailed mechanism of these chemical compounds range from inhibiting growth of the bacteria to the inhibition of specific enzymes. Water-based home and personal care products use broad-spectrum preservatives, such as isothiazolinones and formaldehyde releasers, which may cause sensitization, leading to allergic skin.<sup>[9]</sup>

E number	chemical compound	comment
E200 – E203	sorbic acid, sodium sorbate and sorbates	common for cheese, wine, baked goods, personal care products
E210 – E213	benzoic acid and benzoates	used in acidic foods such as jams, salad dressing, juices, pickles, carbonated drinks, soy sauce
E214 – E219	parabens	stable at a broad pH range, personal care products
E220 – E228	sulfur dioxide and sulfites	common for fruits, wine
E249 – E250	nitrites	speed up the curing of meat and also impart an attractive colour, no effect on botulism bacteria <sup>[10][11]</sup>
E251 – E252	nitrates	used in meats
E270	lactic acid	-
E280 –	propionic acid and propionates	baked goods



E283		
E338	phosphoric acid	used in some jams, preserves and carbonated drinks; also used for acidification and for flavouring.
n/a	isothiazolinones (MIT, CMIT, BIT)	home and personal care products, paints/coatings
n/a	formaldehyde releasers (DMDM hydantoin)	home and personal care products

**Antioxidants**

The free radical pathway for the first phase of the oxidative rancidification of fats. This process is slowed by antioxidants.

The oxidation process spoils most food, especially those with a high fat content. Fats quickly turn rancid when exposed to oxygen. Antioxidants prevent or inhibit the oxidation process. The most common antioxidant additives are ascorbic acid (vitamin C) and ascorbates.<sup>[12]</sup> Thus, antioxidants are commonly added to oils, cheese, and chips.<sup>[5]</sup> Other antioxidants include the phenol derivatives BHA, BHT, TBHQ and propyl gallate. These agents suppress the formation of hydroperoxides.<sup>[6]</sup> Other preservatives include ethanol and methylchloroisothiazolinone.

E number	chemical compound	comment
E300-304	ascorbic acid, sodium ascorbate	cheese, chips
E321	butylated hydroxytoluene, butylated hydroxyanisole	also used in food packaging
E310-312	gallic acid and sodium gallate	oxygen scavenger
E220 – E227	sulfur dioxide and sulfites	beverages, wine
E306 – E309	tocopherols	vitamin E activity

A variety of agents are added to sequester (deactivate) metal ions that otherwise catalyze the oxidation of fats. Common sequestering agents are disodium EDTA, citric acid (and citrates), tartaric acid, and lecithin.<sup>[1]</sup>

Citric and ascorbic acids target enzymes that degrade fruits and vegetables, e.g., mono/polyphenol oxidase which turns surfaces of cut apples and potatoes brown. Ascorbic acid and tocopherol, which are vitamins, are common preservatives. Smoking entails exposing food to a variety of phenols, which are antioxidants. Natural preservatives include rosemary and oregano extract,<sup>[13]</sup> hops, salt, sugar, vinegar, alcohol, diatomaceous earth and castor oil.

Traditional preservatives, such as sodium benzoate have raised health concerns in the past. Benzoate was shown in a study to cause hypersensitivity in some asthma sufferers. This has caused reexamination of natural preservatives which occur in vegetables.<sup>[14]</sup>

Public awareness of food preservatives is uneven.<sup>[15]</sup> Americans have a perception that food-borne illnesses happen more often in other countries. This may be true, but the occurrence of illnesses, hospitalizations, and deaths are still high. It is estimated by the Centers for Disease Control (CDC) that each year there are 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths linked to food-borne illness.<sup>[16]</sup>

Food suppliers are facing difficulties with regards to the safety and quality of their products as a result of the rising demand for ready-to-eat fresh food products. Artificial preservatives meet some of these challenges by preserving freshness for longer periods of time, but these preservatives can cause negative side-effects as well. Sodium nitrite is a preservative used in lunch meats, hams, sausages, hot dogs, and bacon to prevent botulism. It serves the important function of controlling the bacteria that cause botulism, but sodium nitrite can react with proteins, or during cooking at high heats, to form carcinogenic N-nitrosamines.<sup>[17]</sup> It has also been linked to cancer in lab animals.<sup>[18]</sup> The commonly used sodium benzoate has been found to extend the shelf life of bottled tomato paste to 40 weeks without loss of quality.<sup>[12]</sup> However, it can form the carcinogen benzene when combined with vitamin C.<sup>[1]</sup> Many food manufacturers have reformed their products to eliminate this combination, but a risk still exists.<sup>[18]</sup> Consumption of sodium benzoate may also cause hyperactivity. For over 30 years, there has been a debate about whether or not preservatives and other food additives can cause hyperactivity. Studies have found that there may be increases in hyperactivity amongst children who consume artificial colorings and benzoate preservatives and who are already genetically predisposed to hyperactivity, but these studies were not entirely conclusive. Hyperactivity only increased



moderately, and it was not determined if the preservatives, colorings, or a combination of the two were responsible for the increase.<sup>[19]</sup>

In foods, stabilizers prevent spoilage. Classes of food stabilizers include emulsifiers, thickeners and gelling agents, foam stabilizers, humectants, anticaking agents, and coating agents.<sup>[4]</sup>

Food additives can be divided into several groups, although there is some overlap because some additives exert more than one effect. For example, salt is both a preservative as well as a flavor.<sup>[5][1]</sup>

#### Acidulants

Acidulants confer sour or acid taste. Common acidulants include vinegar, citric acid, tartaric acid, malic acid, fumaric acid, and lactic acid.

#### Acidity regulators

Acidity regulators are used for controlling the pH of foods for stability or to affect activity of enzymes.

#### Anticaking agents

Anticaking agents keep powders such as milk powder from caking or sticking.

#### Antifoaming and foaming agents

Antifoaming agents reduce or prevent foaming in foods. Foaming agents do the reverse.

#### Antioxidants

Antioxidants such as vitamin C are preservatives by inhibiting the degradation of food by oxygen.

#### Bulking agents

Bulking agents such as starch are additives that increase the bulk of a food without affecting its taste.

#### Food coloring

Colorings are added to food to replace colors lost during preparation or to make food look more attractive.

#### Fortifying agents

Vitamins, minerals, and dietary supplements to increase the nutritional value

#### Color retention agents

In contrast to colorings, color retention agents are used to preserve a food's existing color.

#### Emulsifiers

Emulsifiers allow water and oils to remain mixed together in an emulsion, as in mayonnaise, ice cream, and homogenized milk.

#### Flavorings\*

Flavorings are additives that give food a particular taste or smell, and may be derived from natural ingredients or created artificially.

\*In EU, flavorings do not have an E-code and they are not considered as food additives.

#### Flavor enhancers

Flavor enhancers enhance a food's existing flavors. A popular example is monosodium glutamate. Some flavor enhancers have their own flavors that are independent of the food.

#### Flour treatment agents

Flour treatment agents are added to flour to improve its color or its use in baking.

#### Glazing agents

Glazing agents provide a shiny appearance or protective coating to foods.

#### Humectants

Humectants prevent foods from drying out.

#### Tracer gas

Tracer gas allows for package integrity testing to prevent foods from being exposed to atmosphere, thus guaranteeing shelf life.

#### Preservatives

Preservatives prevent or inhibit spoilage of food due to fungi, bacteria and other microorganisms.

#### Stabilizers

Stabilizers, thickeners and gelling agents, like agar or pectin (used in jam for example) give foods a firmer texture. While they are not true emulsifiers, they help to stabilize emulsions.

#### Sweeteners



Sweeteners are added to foods for flavoring. Sweeteners other than sugar are added to keep the food energy (calories) low, or because they have beneficial effects regarding diabetes mellitus, tooth decay, or diarrhea.

#### Thickeners

Thickening agents are substances which, when added to the mixture, increase its viscosity without substantially modifying its other properties.

#### Packaging

Bisphenols, phthalates, and perfluoroalkyl chemicals (PFCs) are indirect additives used in manufacturing or packaging. In July 2018 the American Academy of Pediatrics called for more careful study of those three substances, along with nitrates and food coloring, as they might harm children during development.<sup>[6]</sup>

### CHAPTER-2

With the increasing use of processed foods since the 19th century, food additives are more widely used. Many countries regulate their use. For example, boric acid was widely used as a food preservative from the 1870s to the 1920s,<sup>[7][8]</sup> but was banned after World War I due to its toxicity, as demonstrated in animal and human studies. During World War II, the urgent need for cheap, available food preservatives led to it being used again, but it was finally banned in the 1950s.<sup>[7]</sup> Such cases led to a general mistrust of food additives, and an application of the precautionary principle led to the conclusion that only additives that are known to be safe should be used in foods. In the United States, this led to the adoption of the Delaney clause, an amendment to the Federal Food, Drug, and Cosmetic Act of 1938, stating that no carcinogenic substances may be used as food additives.<sup>[9]</sup> However, after the banning of cyclamates in the United States and Britain in 1969, saccharin, the only remaining legal artificial sweetener at the time, was found to cause cancer in rats.<sup>[10]</sup> Widespread public outcry in the United States, partly communicated to Congress by postage-paid postcards supplied in the packaging of sweetened soft drinks, led to the retention of saccharin, despite its violation of the Delaney clause.<sup>[11]</sup> However, in 2000, saccharin was found to be carcinogenic in rats due only to their unique urine chemistry.<sup>[12][13]</sup>

In 2007, Food Standards Australia New Zealand published an official shoppers' guidance with which the concerns of food additives and their labeling are mediated.<sup>[14]</sup> In the EU it can take 10 years or more to obtain approval for a new food additive. This includes five years of safety testing, followed by two years for evaluation by the European Food Safety Authority (EFSA) and another three years before the additive receives an EU-wide approval for use in every country in the European Union.<sup>[15]</sup> Apart from testing and analyzing food products during the whole production process to ensure safety and compliance with regulatory standards, Trading Standards officers (in the UK) protect the public from any illegal use or potentially dangerous mis-use of food additives by performing random testing of food products.<sup>[16]</sup>

There has been significant controversy associated with the risks and benefits of food additives.<sup>[17]</sup> Natural additives may be similarly harmful or be the cause of allergic reactions in certain individuals. For example, safrole was used to flavor root beer until it was shown to be carcinogenic. Due to the application of the Delaney clause, it may not be added to foods, even though it occurs naturally in sassafras and sweet basil.<sup>[18]</sup>

#### Hyperactivity

Periodically, concerns have been expressed about a linkage between additives and hyperactivity,<sup>[19]</sup> however "no clear evidence of ADHD was provided".<sup>[20]</sup>

#### Toxicity

In 2012, the EFSA proposed the tier approach to evaluate the potential toxicity of food additives. It is based on four dimensions: toxicokinetics (absorption, distribution, metabolism and excretion); genotoxicity; subchronic (at least 90 data) and chronic toxicity and carcinogenicity; reproductive and developmental toxicity.<sup>[21]</sup> Recent work has demonstrated that certain food additives such as carboxymethylcellulose may cause encroachment of microbes from the gastrointestinal tract into the protective mucus layer that lines the intestines.<sup>[22]</sup> Additional preclinical work suggests that emulsifiers may disrupt the gut microbiome, cause or exacerbate inflammation, and increase intestinal permeability.<sup>[23]</sup> Other food additives in processed foods, such as xanthan gum, have also been shown to influence the ecology of human gut microbiomes and may play a role in the divergence of gut microbiomes in industrialized societies as compared to pre-industrialized societies.<sup>[24]</sup> Although still controversial, some scientists hypothesize that these changes to human gut microbiomes may be a contributing factor to the rise in chronic inflammatory diseases in industrialized populations.<sup>[25]</sup>



Micronutrients

A subset of food additives, micronutrients added in food fortification processes preserve nutrient value by providing vitamins and minerals to foods such as flour, cereal, margarine and milk which normally would not retain such high levels.<sup>[26]</sup> Added ingredients, such as air, bacteria, fungi, and yeast, also contribute manufacturing and flavor qualities, and reduce spoilage.<sup>[27]</sup>

Food Additive Approval in the United States

The United States Food and Drug Administration (FDA) defines a food additive as "any substance the intended use of which results or may reasonably be expected to result directly or indirectly in its becoming a component or otherwise affecting the characteristics of any food".<sup>[28]</sup> In order for a novel food additive to be approved in the U.S., a food additive approval petition (FAP) must be submitted to the FDA.<sup>[29]</sup> The identity of the ingredient, the proposed use in the food system, the technical effect of the ingredient, a method of analysis for the ingredient in foods, information on the manufacturing process, and full safety reports must be defined in a FAP.<sup>[30]</sup> For FDA approval of a FAP, the FDA evaluates the chemical composition of the ingredient, the quantities that would be typically consumed, acute and chronic health impacts, and other safety factors.<sup>[28]</sup> The FDA reviews the petition prior to market approval of the additive

Colour retention agents are food additives that are added to food to prevent the colour from changing. Many of them work by absorbing or binding to oxygen before it can damage food (antioxidants). For example, ascorbic acid (vitamin C) is often added to brightly coloured fruits such as peaches during canning.

List of colour retention agent

E number	Common name	Max permitted level	Sources	Application
E222	Sodium bisulfite		Sulfite food and beverage additives	Meat, hominy, bananas
E300	Ascorbic acid	GMP[1]	Standard 1.3.1 - Food Additives (Australian)[2]	Wine, sparkling wine and fortified wine
		0.03% (w/w), or 0.02% (w/w) depending on the matrix[3]	The Miscellaneous Food Additives Regulations 1995[4]	Fruit and vegetable-based drinks, juices and baby foods Fat-containing cereal-based foods including biscuits and rusks

A sugar substitute is a food additive that provides a sweetness like that of sugar while containing significantly less food energy than sugar-based sweeteners, making it a zero-calorie (non-nutritive)<sup>[2]</sup> or low-calorie sweetener. Artificial sweeteners may be derived through manufacturing of plant extracts or processed by chemical synthesis. Sugar substitute products are commercially available in various forms, such as small pills, powders, and packets.

Common sugar substitutes include aspartame, monk fruit extract, saccharin, sucralose, stevia, acesulfame potassium (ace-k), and cyclamate. These sweeteners are a fundamental ingredient in diet drinks to sweeten them without adding calories. Additionally, sugar alcohols such as erythritol, xylitol, and sorbitol are derived from sugars.

Approved artificial sweeteners have not been shown to cause cancer. Reviews and dietetic professionals have concluded that moderate use of non-nutritive sweeteners as a safe replacement for sugars can help limit energy intake and assist with managing blood glucose and weight.

Artificial sweeteners may be derived through manufacturing of plant extracts or processed by chemical synthesis.

High-intensity sweeteners – one type of sugar substitute – are compounds with many times the sweetness of sucrose (common table sugar). As a result, much less sweetener is required and energy contribution is often negligible. The sensation of sweetness caused by these compounds is sometimes notably different from sucrose, so they are often used in complex mixtures that achieve the most intense sweet sensation.





In North America, common sugar substitutes include aspartame, monk fruit extract, saccharin, sucralose, and stevia. Cyclamate is prohibited from being used as a sweetener within the United States, but is allowed in other parts of the world.<sup>[3]</sup>

Sorbitol, xylitol and lactitol are examples of sugar alcohols (also known as polyols). These are, in general, less sweet than sucrose but have similar bulk properties and can be used in a wide range of food products. Sometimes the sweetness profile is fine-tuned by mixing with high-intensity sweeteners.

#### Allulose

Allulose is a sweetener in the sugar family, with a chemical structure similar to fructose. It is naturally found in figs, maple syrup, and some fruit. While it comes from the same family as other sugars, it does not substantially metabolize as sugar in the body.<sup>[4]</sup> The FDA recognizes that allulose does not act like sugar, and as of 2019, no longer requires it to be listed with sugars on U.S. nutrition labels.<sup>[5]</sup> Allulose is about 70% as sweet as sugar, which is why it is sometimes combined with high-intensity sweeteners to make sugar substitutes.<sup>[6]</sup>

#### Acesulfame potassium

Acesulfame potassium (Ace-K) is 200 times sweeter than sucrose (common sugar), as sweet as aspartame, about two-thirds as sweet as saccharin, and one-third as sweet as sucralose. Like saccharin, it has a slightly bitter aftertaste, especially at high concentrations. Kraft Foods has patented the use of sodium ferulate to mask acesulfame's aftertaste. Acesulfame potassium is often blended with other sweeteners (usually aspartame or sucralose), which give a more sucrose-like taste, whereby each sweetener masks the other's aftertaste and also exhibits a synergistic effect in which the blend is sweeter than its components.

Unlike aspartame, acesulfame potassium is stable under heat, even under moderately acidic or basic conditions, allowing it to be used as a food additive in baking or in products that require a long shelf life. In carbonated drinks, it is almost always used in conjunction with another sweetener, such as aspartame or sucralose. It is also used as a sweetener in protein shakes and pharmaceutical products, especially chewable and liquid medications, where it can make the active ingredients more palatable.

#### Aspartame

Aspartame was discovered in 1965 by James M. Schlatter at the G.D. Searle company. He was working on an anti-ulcer drug and accidentally spilled some aspartame on his hand. When he licked his finger, he noticed that it had a sweet taste. Torunn Atteraa Garin oversaw the development of aspartame as an artificial sweetener. It is an odorless, white crystalline powder that is derived from the two amino acids aspartic acid and phenylalanine. It is about 180–200 times sweeter than sugar,<sup>[7][8]</sup> and can be used as a tabletop sweetener or in frozen desserts, gelatins, beverages, and chewing gum. When cooked or stored at high temperatures, aspartame breaks down into its constituent amino acids. This makes aspartame undesirable as a baking sweetener. It is more stable in somewhat acidic conditions, such as in soft drinks. Though it does not have a bitter aftertaste like saccharin, it may not taste exactly like sugar. When eaten, aspartame is metabolized into its original amino acids. Because it is so intensely sweet, relatively little of it is needed to sweeten a food product, and is thus useful for reducing the number of calories in a product.

The safety of aspartame has been studied extensively since its discovery with research that includes animal studies, clinical and epidemiological research, and postmarketing surveillance,<sup>[9]</sup> with aspartame being a rigorously tested food ingredient.<sup>[10]</sup> Although aspartame has been subject to claims against its safety,<sup>[11]</sup> multiple authoritative reviews have found it to be safe for consumption at typical levels used in food manufacturing.<sup>[9][11][12][13]</sup> Aspartame has been deemed safe for human consumption by over 100 regulatory agencies in their respective countries,<sup>[13]</sup> including the UK Food Standards Agency,<sup>[7]</sup> the European Food Safety Authority (EFSA)<sup>[8]</sup> and Health Canada.<sup>[14]</sup>

#### Cyclamate

Cyclamate-based sugar substitute sold in Canada (Sweet'N Low)

In the United States, the Food and Drug Administration banned the sale of cyclamate in 1969 after lab tests in rats involving a 10:1 mixture of cyclamate and saccharin (at levels comparable to humans ingesting 550 cans of diet soda per day) caused bladder cancer.<sup>[15]</sup> This information, however, is regarded as "weak" evidence of carcinogenic activity,<sup>[16]</sup> and cyclamate remains in common use in many parts of the world, including Canada, the European Union and Russia.<sup>[17][18]</sup>



#### Mogrosides (monk fruit)

Mogrosides, extracted from monk fruit and commonly called *luo han guo*, are recognized as safe for human consumption and are used in commercial products worldwide.<sup>[19][20]</sup> As of 2017, it is not a permitted sweetener in the European Union,<sup>[21]</sup> although it is allowed as a flavor at concentrations where it does not function as a sweetener.<sup>[20]</sup> In 2017, a Chinese company requested a scientific review of its mogroside product by the European Food Safety Authority.<sup>[22]</sup> It is the basis of McNeil Nutritionals's tabletop sweetener Nectresse in the United States and Norbu Sweetener in Australia.<sup>[23]</sup>

#### Saccharin

Apart from sugar of lead (used as a sweetener in ancient through medieval times before the toxicity of lead was known), saccharin was the first artificial sweetener and was originally synthesized in 1879 by Remsen and Fahlberg. Its sweet taste was discovered by accident. It had been created in an experiment with toluene derivatives. A process for the creation of saccharin from phthalic anhydride was developed in 1950, and, currently, saccharin is created by this process as well as the original process by which it was discovered. It is 300 to 500 times sweeter than sucrose and is often used to improve the taste of toothpastes, dietary foods, and dietary beverages. The bitter aftertaste of saccharin is often minimized by blending it with other sweeteners.

Fear about saccharin increased when a 1960 study showed that high levels of saccharin may cause bladder cancer in laboratory rats. In 1977, Canada banned saccharin due to the animal research. In the United States, the FDA considered banning saccharin in 1977, but Congress stepped in and placed a moratorium on such a ban. The moratorium required a warning label and also mandated further study of saccharin safety.

Subsequently, it was discovered that saccharin causes cancer in male rats by a mechanism not found in humans. At high doses, saccharin causes a precipitate to form in rat urine. This precipitate damages the cells lining the bladder (urinary bladder urothelial cytotoxicity) and a tumor forms when the cells regenerate (regenerative hyperplasia). According to the International Agency for Research on Cancer, part of the World Health Organization, "Saccharin and its salts was [sic] downgraded from Group 2B, possibly carcinogenic to humans, to Group 3, not classifiable as to carcinogenicity to humans, despite sufficient evidence of carcinogenicity to animals, because it is carcinogenic by a non-DNA-reactive mechanism that is not relevant to humans because of critical interspecies differences in urine composition."

In 2001, the United States repealed the warning label requirement, while the threat of an FDA ban had already been lifted in 1991. Most other countries also permit saccharin, but restrict the levels of use, while other countries have outright banned it.

The EPA has removed saccharin and its salts from their list of hazardous constituents and commercial chemical products. In a 14 December 2010 release, the EPA stated that saccharin is no longer considered a potential hazard to human health.

#### Steviol glycosides (stevia)

Stevia is a natural non-caloric sweetener derived from the *Stevia rebaudiana* plant, and is manufactured as a sweetener.<sup>[24]</sup> It is indigenous to South America, and has historically been used in Japanese food products, although it is now common internationally.<sup>[24]</sup> In 1987, the FDA issued a ban on stevia because it had not been approved as a food additive, although it continued to be available as a dietary supplement.<sup>[25]</sup> After being provided with sufficient scientific data demonstrating safety of using stevia as a manufactured sweetener, such as Cargill and Coca-Cola, the FDA gave a "no objection" status as generally recognized as safe (GRAS) in December 2008 to Cargill for its stevia product, Truvia, for use of the refined stevia extracts as a blend of rebaudioside A and erythritol.<sup>[26][27][28]</sup> In Australia, the brand Vitarium uses Natvia, a stevia sweetener, in a range of sugar-free children's milk mixes.<sup>[29]</sup>

In August 2019, the FDA placed an import alert on stevia leaves and crude extracts – which do not have GRAS status – and on foods or dietary supplements containing them due to concerns about safety and potential for toxicity.<sup>[30]</sup>

#### Sucralose

The world's most commonly used artificial sweetener,<sup>[17]</sup> sucralose is a chlorinated sugar that is about 600 times sweeter than sugar. It is produced from sucrose when three chlorine atoms replace three hydroxyl groups. It is used in beverages, frozen desserts, chewing gum, baked goods, and other foods. Unlike other artificial sweeteners, it is stable when heated and can therefore be used in baked and fried goods. Discovered in 1976, the FDA approved sucralose for use in 1998.<sup>[31]</sup>



Most of the controversy surrounding Splenda, a sucralose sweetener, is focused not on safety but on its marketing. It has been marketed with the slogan, "Splenda is made from sugar, so it tastes like sugar." Sucralose is prepared from either of two sugars, sucrose or raffinose. With either base sugar, processing replaces three oxygen-hydrogen groups in the sugar molecule with three chlorine atoms.<sup>[32]</sup> The "Truth About Splenda" website was created in 2005 by the Sugar Association, an organization representing sugar beet and sugar cane farmers in the United States,<sup>[33]</sup> to provide its view of sucralose. In December 2004, five separate false-advertising claims were filed by the Sugar Association against Splenda manufacturers Merisant and McNeil Nutritionals for claims made about Splenda related to the slogan, "Made from sugar, so it tastes like sugar". French courts ordered the slogan to no longer be used in France, while in the U.S. the case came to an undisclosed settlement during the trial.<sup>[32]</sup>

There are few safety concerns pertaining to sucralose<sup>[34]</sup> and the way sucralose is metabolized suggests a reduced risk of toxicity. For example, sucralose is extremely insoluble in fat and, thus, does not accumulate in fatty tissues; sucralose also does not break down and will dechlorinate only under conditions that are not found during regular digestion (i.e., high heat applied to the powder form of the molecule).<sup>[35]</sup> Only about 15% of sucralose is absorbed by the body and most of it passes out of the body unchanged.<sup>[35]</sup>

In 2017, sucralose was the most common sugar substitute used in the manufacture of foods and beverages; it had 30% of the global market, which was projected to be valued at \$2.8 billion by 2021.<sup>[17]</sup>

#### Sugar alcohol

Sugar alcohols, or polyols, are sweetening and bulking ingredients used in the manufacturing of foods and beverages, particularly sugar-free candies, cookies, and chewing gums.<sup>[36][37]</sup> As a sugar substitute, they typically are less-sweet and supply fewer calories (about a half to one-third fewer calories) than sugar. They are converted to glucose slowly, and do not spike increases in blood glucose.<sup>[36][37][38]</sup>

Sorbitol, xylitol, mannitol, erythritol, and lactitol are examples of sugar alcohols.<sup>[37]</sup> These are, in general, less sweet than sucrose, but have similar bulk properties and can be used in a wide range of food products.<sup>[37]</sup> The sweetness profile may be altered during manufacturing by mixing with high-intensity sweeteners.

Sugar alcohols are carbohydrates with a biochemical structure partially matching the structures of sugar and alcohol, although not containing ethanol.<sup>[37][39]</sup> They are not entirely metabolized by the human body.<sup>[39]</sup> The unabsorbed sugar alcohols may cause bloating and diarrhea due to their osmotic effect, if consumed in sufficient amounts.<sup>[40]</sup> They are found commonly in small quantities in some fruits and vegetables, and are commercially manufactured from different carbohydrates and starch.<sup>[37][39][41]</sup>

Acidity regulators, or pH control agents, are food additives used to change or maintain pH (acidity or basicity).<sup>[1]</sup> They can be organic or mineral acids, bases, neutralizing agents, or buffering agents. Typical agents include the following acids and their sodium salts: sorbic acid, acetic acid, benzoic acid, and propionic acid.<sup>[2]</sup> Acidity regulators are indicated by their E number, such as E260 (acetic acid), or simply listed as "food acid".

Acidity regulators differ from acidulants, which are often acidic but are added to confer sour flavors. They are not intended to stabilize the food, although that can be a collateral benefit.<sup>[2][3]</sup> Acidity regulators are also important for food safety, as incorrect pH can result in bacteria growth.<sup>[4]</sup>

E numbers, short for Europe numbers, are codes for substances used as food additives, including those found naturally in many foods such as vitamin C, for use within the European Union (EU)<sup>[1]:27</sup> and European Free Trade Association (EFTA).<sup>[2]</sup> Commonly found on food labels, their safety assessment and approval are the responsibility of the European Food Safety Authority (EFSA).<sup>[3]</sup> The fact that an additive has an E number implies that its use was at one time permitted in products for sale in the European Single Market; some of these additives are no longer allowed today.

Having a single unified list for food additives was first agreed upon in 1962 with food colouring. In 1964, the directives for preservatives were added, in 1970 antioxidants were added, in 1974 emulsifiers, stabilisers, thickeners and gelling agents were added as well.<sup>[4]</sup>

#### Numbering schemes

The numbering scheme follows that of the International Numbering System (INS) as determined by the *Codex Alimentarius* committee,<sup>[5]</sup> though only a subset of the INS additives are approved for use in the European Union as food additives. Outside the European continent plus Russia, E numbers are also encountered on food labelling in other jurisdictions, including the Cooperation Council for the Arab States of the Gulf, South Africa, Australia, New Zealand,<sup>[6]</sup> Malaysia, Hong Kong,<sup>[7]</sup> and India.





Colloquial use

In some European countries, the "E number" is used informally as a derogatory term for artificial food additives. For example, in the UK, food companies are required to include the 'E Number(s)' in the ingredients that are added as part of the manufacturing process. Many components of naturally occurring healthy foods and vitamins have assigned E numbers (and the number is a synonym for the chemical component), e.g. vitamin C (E300) and lycopene (E160d), found in carrots. At the same time, "E number" is sometimes misunderstood to imply approval for safe consumption. This is not necessarily the case, e.g. Avoparcin (E715) is an antibiotic once used in animal feed, but is no longer permitted in the EU, and has never been permitted for human consumption.

Classification by numeric range

E number range	Subranges	Description
100–199 (full list) Colours	100–107	yellows
	110–111	oranges
	120–129	reds
	130–139	blues and violets
	140–149	greens
	150–159	browns and blacks
	160–199	gold and others
200–299 (full list) Preservatives	200–209	sorbates
	210–219	benzoates
	220–229	sulfites
	230–239	phenols and formates (methanoates)
	240–259	nitrates



	260–269	acetates (ethanoates)
	270–279	lactates
	280–289	propionates (propanoates)
	290–299	others
300–399 (full list) Antioxidants and acidity regulators	300–305	ascorbates (vitamin C)
	306–309	Tocopherol (vitamin E)
	310–319	gallates and erythorbates
	320–329	lactates
	330–337	citrates and tartrates
	338–343	phosphates
	344–345	citrates
	349–359	malates and adipates
	360–369	succinates and fumarates
	370–399	others
400–499 (full list) Thickeners, stabilisers and emulsifiers	400–409	alginates
	410–419	natural gums



	420–429	other natural agents
	430–439	polyoxyethylene compounds
	440–449	natural emulsifiers
	450–459	phosphates
	460–469	cellulose compounds
	470–489	fatty acids and compounds
	490–499	others
500–599 (full list) pH regulators and anti-caking agents	500–509	mineral acids and bases
	510–519	chlorides and sulfates
	520–529	sulfates and hydroxides
	530–549	alkali metal compounds
	550–559	silicates
	570–579	stearates and gluconates
	580–599	others
600–699 (full list) Flavour enhancers	620–629	glutamates and guanylates
	630–639	inosinates



	640–649	others
700–799 (full list) Antibiotics	700–713	
900–999 (full list) Glazing agents, gases and sweeteners	900–909	waxes
	910–919	synthetic glazes
	920–929	improving agents
	930–949	packaging gases
	950–969	sweeteners
	990–999	foaming agents
1000–1599 (full list) Additional additives	1100–1599	New chemicals that do not fall into standard classification schemes

NB: Not all examples of a class fall into the given numeric range. Moreover, many chemicals, particularly in the E400–499 range, have a variety of purposes.

Full list

The list shows all components that have an E-number assigned, *even those no longer allowed in the EU*.

E100–E199 (colours)

Code	Name(s)	Colour	Status
E100	Curcumin (from turmeric)	Yellow-orange	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E101	Riboflavin (Vitamin B <sub>2</sub> ), formerly called lactoflavin	Yellow-orange	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>



Code	Name(s)	Colour	Status
E101a	Riboflavin-5'-Phosphate	Yellow-orange	Approved in the EU. <sup>[8]</sup>
E102	Tartrazine (FD&C Yellow 5)	Yellow	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E103	Alkannin <sup>[10]</sup>	Red-brown	
E104	Quinoline Yellow WS	Dull or greenish yellow	Restricted use approved in the EU. <sup>[8][11]</sup>
E105	Fast Yellow AB	Yellow	Forbidden in the EU and US. <sup>[12]</sup>
E106	Riboflavin-5-Sodium Phosphate	Yellow	
E107	Yellow 2G	Yellow	
E110	Sunset Yellow FCF (Orange Yellow S, FD&C Yellow 6)	Yellow-orange	Restricted use approved in the EU. <sup>[8][11]</sup> Banned in Norway. <sup>[13]</sup> Products in the EU require warnings and its use is being phased out. <sup>[11]</sup> Approved in the US. <sup>[9]</sup>
E111	Orange GGN	Orange	
E120	Cochineal, Carminic acid, Carmine (Natural Red 4)	Crimson	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E121	Citrus Red 2	Dark red	Approved in the United States only for use in colouring the skin of oranges. <sup>[14]</sup>
E122	Carmoisine (azorubine)	Red to maroon	Approved in the EU. <sup>[8]</sup> Undergoing a voluntary phase-out in the UK. Currently banned in Canada, Japan, Norway, USA. <sup>!</sup> EU currently





Code	Name(s)	Colour	Status
			evaluating health risks. <sup>1</sup>
E123	Amaranth (FD&C Red 2)	Red	Approved in the EU. <sup>[8]</sup> Banned in the United States. <sup>[15]</sup>
E124	Ponceau 4R (Cochineal Red A, Brilliant Scarlet 4R)	Red	Restricted use approved in the EU. <sup>[8][11]</sup>
E125	Ponceau SX, Scarlet GN	Red	Only permitted for externally applied drugs and cosmetics in the US. <sup>[16][17][18]</sup>
E126	Ponceau 6R	Red	
E127	Erythrosine (FD&C Red 3)	Red	Approved in the EU. <sup>[8]</sup> Approved in the US except for lake variant. <sup>[9]</sup>
E128	Red 2G	Red or pink	Not approved in the EU. <sup>[11]</sup>
E129	Allura Red AC (FD&C Red 40)	Red	Approved in the EU. <sup>[8]</sup> Banned in Switzerland. <sup>1</sup> Undergoing a voluntary phase out in the UK. Approved in the US. <sup>[9]</sup>
E130	Indanthrene blue RS	Blue	
E131	Patent Blue V	Dark blue	Approved in the EU. <sup>[8]</sup>
E132	Indigo carmine (indigotine, FD&C Blue 2)	Indigo	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E133	Brilliant blue FCF (FD&C Blue 1)	Reddish blue	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>



Code	Name(s)	Colour	Status
E140	Chlorophylls and Chlorophyllins: (i) Chlorophylls (ii) Chlorophyllins	Green	Approved in the EU. <sup>[8]</sup>
E141	Copper complexes of chlorophylls and chlorophyllins (i) Copper complexes of chlorophylls (ii) Copper complexes of chlorophyllins	Green	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E142	Green S	Green	Approved in the EU. <sup>[8]</sup>
E143	Fast Green FCF (FD&C Green 3)	Green	Approved in the US. Banned in the EU.
E150a	Plain caramel	Brown	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E150b	Caustic sulfite caramel	Brown	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E150c	Ammonia caramel	Brown	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E150d	Sulfite ammonia caramel	Brown	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E151	Black PN, Brilliant Black BN	Black	Approved in the EU. <sup>[8]</sup>
E152	Carbon black (hydrocarbon)	Black	
E153	Vegetable carbon	Black	Approved in the EU. <sup>[8]</sup>
E154	Brown FK (kipper brown)	Brown	Previously approved in the EU for dyeing kippers only: approval withdrawn November 2011. <sup>[11]</sup>



Code	Name(s)	Colour	Status
E155	Brown HT (chocolate brown HT)	Brown	Approved in the EU. <sup>[8]</sup>
E160a	Alpha-carotene, Beta-carotene, Gamma-carotene	Yellow-orange to brown	Approved in the EU. <sup>[8]</sup>
E160b	Annatto, bixin, norbixin	Orange	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E160c	Paprika oleoresin: (i) capsanthin, (ii) capsorubin	Red	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E160d	Lycopene	Bright to deep red	Restricted use approved in the EU. <sup>[8][11]</sup> Approved in the US. <sup>[9]</sup>
E160e	Beta-apo-8'-carotenal (C 30)	Orange-red to yellow	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E160f	Ethyl ester of beta-apo-8'-carotenic acid (C 30)	Orange-red to yellow	Not approved in the EU. <sup>[11]</sup>
E161a	Flavoxanthin	Golden-yellow and brownish	
E161b	Lutein	Orange-red to yellow	Approved in the EU. <sup>[8]</sup>
E161c	Cryptoxanthin	Orange-red	
E161d	Rubixanthin	Orange-red	
E161e	Violaxanthin	Orange	
E161f	Rhodoxanthin	Purple	



Code	Name(s)	Colour	Status
E161g	Canthaxanthin	Violet	Not approved in the EU. <sup>[11]</sup> Approved in the US. <sup>[9]</sup>
E161h	Zeaxanthin	Orange-red	
E161i	Citranaxanthin	Deep violet	
E161j	Astaxanthin	Red	
E162	Beetroot Red, Betanin	Red	Approved in the EU. <sup>[8]</sup> Approved in the US. <sup>[9]</sup>
E163	Anthocyanins	pH dependent (Red, green and purple ranges)	Approved in the EU. <sup>[8]</sup>
E164	Saffron	Orange-red <sup>[colour?]</sup>	Approved in the US. <sup>[9]</sup>
E170	Calcium carbonate, Chalk	White	Approved in the EU. <sup>[8]</sup>
E171	Titanium dioxide	White	No longer approved in the EU as of June 2022, <sup>[19]</sup> due to the identification of potential carcinogenic effects. <sup>[20]</sup> Approved in the US. <sup>[9]</sup>
E172	Iron oxides and iron hydroxides	Brown	Approved in the EU. <sup>[8]</sup> Approved in the US for sausage casings. <sup>[9]</sup>
E173	Aluminium	Silver to grey	Approved in the EU. <sup>[8]</sup>
E174	Silver	Silver	Approved in the EU. <sup>[8]</sup>



Code	Name(s)	Colour	Status
E175	Gold	Gold	Approved in the EU. <sup>[8]</sup>
E180	Pigment Rubine, Lithol Rubine BK	Red	Approved in the EU. <sup>[8]</sup>
E181	Tannin	Brown	
E182	Orcein, Orchil	Purple	

E200–E299 (preservatives)

Code	Name(s)	Purpose	Status
E200	Sorbic acid	preservative	Approved in the EU. <sup>[8]</sup>
E201	Sodium sorbate	preservative	
E202	Potassium sorbate	preservative	Approved in the EU. <sup>[8]</sup>
E203	Calcium sorbate	preservative	Approved in the EU. <sup>[8]</sup>
E209	Heptyl p-hydroxybenzoate	preservative	
E210	Benzoic acid	preservative	Approved in the EU. <sup>[8]</sup>
E211	Sodium benzoate	preservative	Approved in the EU. <sup>[8]</sup>
E212	Potassium benzoate	preservative	Approved in the EU. <sup>[8]</sup>
E213	Calcium benzoate	preservative	Approved in the EU. <sup>[8]</sup>





Code	Name(s)	Purpose	Status
E214	Ethylparaben (ethyl para-hydroxybenzoate)	preservative	Approved in the EU. <sup>[8]</sup>
E215	Sodium ethyl para-hydroxybenzoate	preservative	Approved in the EU. <sup>[8]</sup>
E216	Propylparaben (propyl para-hydroxybenzoate)	preservative	
E217	Sodium propyl para-hydroxybenzoate	preservative	
E218	Methylparaben (methyl para-hydroxybenzoate)	preservative	Approved in the EU. <sup>[8]</sup>
E219	Sodium methyl para-hydroxybenzoate	preservative	Approved in the EU. <sup>[8]</sup>
E220	Sulfur dioxide	preservative	Approved in the EU. <sup>[8]</sup>
E221	Sodium sulfite	preservative	Approved in the EU. <sup>[8]</sup>
E222	Sodium bisulfite (sodium hydrogen sulfite)	preservative	Approved in the EU. <sup>[8]</sup>
E223	Sodium metabisulfite	preservative	Approved in the EU. <sup>[8]</sup>
E224	Potassium metabisulfite	preservative	Approved in the EU. <sup>[8]</sup>
E225	Potassium sulfite	preservative	
E226	Calcium sulfite	preservative	Approved in the EU. <sup>[8]</sup>
E227	Calcium hydrogen sulfite (preservative)	firming agent	Approved in the EU. <sup>[8]</sup>
E228	Potassium hydrogen sulfite	preservative	Approved in the EU. <sup>[8]</sup>



Code	Name(s)	Purpose	Status
E230	Biphenyl, diphenyl	preservative	Not approved in the EU.
E231	Orthophenyl phenol	preservative	Not approved in the EU.
E232	Sodium orthophenyl phenol	preservative	Not approved in the EU.
E233	Thiabendazole	preservative	Not approved in the EU.
E234	Nisin	preservative	Approved in the EU. <sup>[8]</sup>
E235	Natamycin, Pimaracin	preservative	Approved in the EU. <sup>[8]</sup>
E236	Formic acid	preservative	
E237	Sodium formate	preservative	
E238	Calcium formate	preservative	
E239	Hexamine (hexamethylene tetramine)	preservative	Approved in the EU. <sup>[8]</sup>
E240	Formaldehyde	preservative	
E242	Dimethyl dicarbonate	preservative	Approved in the EU. <sup>[8]</sup>
E249	Potassium nitrite	preservative	Approved in the EU. <sup>[8]</sup> In April 2023 the French Court of Appeals of Limoges confirmed that food-watch NGO Yuka was legally legitimate in describing Potassium Nitrate E249 to E252 as a "cancer risk", and thus rejected an appeal by the French charcuterie industry against



Code	Name(s)	Purpose	Status
			the organisation. <sup>[21]</sup>
E250	Sodium nitrite	preservative	Approved in the EU. <sup>[8]</sup>
E251	Sodium nitrate (Chile saltpetre)	preservative	Approved in the EU. <sup>[8]</sup>
E252	Potassium nitrate (Saltpetre)	preservative	Approved in the EU. <sup>[8]</sup>
E260	Acetic acid (preservative)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E261	Potassium acetate (preservative)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E262	Sodium acetates (i) Sodium acetate (ii) Sodium diacetate (sodium hydrogen acetate)	preservative, acidity regulator	Approved in the EU. <sup>[22]</sup>
E263	Calcium acetate (preservative)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E264	Ammonium acetate	preservative	Approved in Australia and New Zealand <sup>[23]</sup>
E265	Dehydroacetic acid	preservative	
E266	Sodium dehydroacetate	preservative	
E270	Lactic acid (preservative)	antioxidant	Approved in the EU. <sup>[22]</sup>
E280	Propionic acid	preservative	Approved in the EU. <sup>[8]</sup>
E281	Sodium propionate	preservative	Approved in the EU. <sup>[8]</sup>



Code	Name(s)	Purpose	Status
E282	Calcium propionate	preservative	Approved in the EU. <sup>[8]</sup>
E283	Potassium propionate	preservative	Approved in the EU. <sup>[8]</sup>
E284	Boric acid	preservative	Approved in the EU. <sup>[8]</sup>
E285	Sodium tetraborate (borax)	preservative	Approved in the EU. <sup>[8]</sup>
E290	Carbon dioxide	acidity regulator	Approved in the EU. <sup>[22]</sup>
E296	Malic acid (acid)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E297	Fumaric acid	acidity regulator	Approved in the EU. <sup>[22]</sup>

E300–E399 (antioxidants, acidity regulators)

Code	Name(s)	Purpose	Status
E300	Ascorbic acid (Vitamin C)	antioxidant	Approved in the EU. <sup>[24]</sup>
E301	Sodium ascorbate	antioxidant	Approved in the EU. <sup>[24]</sup>
E302	Calcium ascorbate	antioxidant	Approved in the EU. <sup>[24]</sup>
E303	Potassium ascorbate	antioxidant	
E304	Fatty acid esters of ascorbic acid (Ascorbyl palmitate)	antioxidant	Approved in the EU. <sup>[24]</sup>
E305	Ascorbyl stearate	antioxidant	



Code	Name(s)	Purpose	Status
E306	Tocopherols (Vitamin E, natural)	antioxidant	Approved in the EU. <sup>[24]</sup>
E307	Alpha-Tocopherol (synthetic)	antioxidant	Approved in the EU. <sup>[24]</sup>
E308	Gamma-Tocopherol (synthetic)	antioxidant	Approved in the EU. <sup>[24]</sup>
E309	Delta-Tocopherol (synthetic)	antioxidant	Approved in the EU. <sup>[24]</sup>
E310	Propyl gallate	antioxidant	Approved in the EU. <sup>[24]</sup>
E311	Octyl gallate	antioxidant	Approved in the EU. <sup>[24]</sup>
E312	Dodecyl gallate	antioxidant	Approved in the EU. <sup>[24]</sup>
E313	Ethyl gallate	antioxidant	
E314	Guaiaic resin	antioxidant	
E315	Erythorbic acid	antioxidant	Approved in the EU. <sup>[24]</sup>
E316	Sodium erythorbate	antioxidant	Approved in the EU. <sup>[24]</sup>
E317	Erythorbin acid <sup>l</sup>	antioxidant	
E318	Sodium erythorbin <sup>l</sup>	antioxidant	
E319	tert-Butylhydroquinone (TBHQ)	antioxidant	Approved in the EU. <sup>[24]</sup>
E320	Butylated hydroxyanisole (BHA)	antioxidant	Approved in the EU. <sup>[24]</sup>





Code	Name(s)	Purpose	Status
E321	Butylated hydroxytoluene (BHT)	antioxidant	Approved in the EU. <sup>[24]</sup>
E322	Lecithin	emulsifier	Approved in the EU. <sup>[25]</sup>
E323	Anoxomer	antioxidant	
E324	Ethoxyquin	antioxidant	
E325	Sodium lactate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E326	Potassium lactate (antioxidant)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E327	Calcium lactate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E328	Ammonium lactate	acidity regulator	
E329	Magnesium lactate	acidity regulator	
E330	Citric acid	acid, acidity regulator	Approved in the EU. <sup>[22]</sup>
E331	Sodium citrates (i) Monosodium citrate (ii) Disodium citrate (iii) Sodium citrate (trisodium citrate)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E332	Potassium citrates (i) Monopotassium citrate (ii) Potassium citrate (tripotassium citrate)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E333	Calcium citrates (i) Monocalcium citrate (ii) Dicalcium citrate (iii) Calcium citrate (tricalcium citrate)	acidity regulator, firming agent, sequestrant	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E334	Tartaric acid (L(+)-)	(acid)	Approved in the EU. <sup>[22]</sup>
E335	Sodium tartrates (i) Monosodium tartrate (ii), Disodium tartrate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E336	Potassium tartrates (i) Monopotassium tartrate (cream of tartar) (ii) Dipotassium tartrate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E337	Sodium potassium tartrate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E338	Phosphoric acid	acid	Approved in the EU. <sup>[22]</sup>
E339	Sodium phosphates (i) Monosodium phosphate (ii) Disodium phosphate (iii) Trisodium phosphate	antioxidant	Approved in the EU. <sup>[22]</sup>
E340	Potassium phosphates (i) Monopotassium phosphate (ii) Dipotassium phosphate (iii) Tripotassium phosphate	antioxidant	Approved in the EU. <sup>[22]</sup>
E341	Calcium phosphates (i) Monocalcium phosphate (ii) Dicalcium phosphate (iii) Tricalcium phosphate	anti-caking agent, firming agent	Approved in the EU. <sup>[22]</sup>
E342	Ammonium phosphates: (i) monoammonium phosphate (ii) diammonium phosphate		
E343	Magnesium phosphates (i) monomagnesium phosphate (ii) Dimagnesium phosphate	anti-caking agent	Approved in the EU. <sup>[22]</sup> This additive is under discussion and may be included in a future amendment to the Directive on miscellaneous additives.
E344	Lecithin citrate	acidity regulator	Not approved in the UK <sup>[26]</sup>



Code	Name(s)	Purpose	Status
E345	Magnesium citrate	acidity regulator	
E349	Ammonium malate	acidity regulator	
E350	Sodium malates (i) Sodium malate (ii) Sodium hydrogen malate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E351	Potassium malate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E352	Calcium malates (i) Calcium malate (ii) Calcium hydrogen malate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E353	Metatartaric acid	emulsifier	Approved in the EU. <sup>[22]</sup>
E354	Calcium tartrate	emulsifier	Approved in the EU. <sup>[22]</sup>
E355	Adipic acid	acidity regulator	Approved in the EU. <sup>[22]</sup>
E356	Sodium adipate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E357	Potassium adipate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E359	Ammonium adipate	acidity regulator	
E363	Succinic acid	acidity regulator	Approved in the EU. <sup>[22]</sup>
E365	Monosodium fumarate	acidity regulator	
E366	Potassium fumarate	acidity regulator	



Code	Name(s)	Purpose	Status
E367	Calcium fumarate	acidity regulator	
E368	Ammonium fumarate	acidity regulator	
E370	1,4-Heptonolactone	acidity regulator	
E375	Niacin	acidity regulator	
E380	Triammonium citrate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E381	Ammonium ferric citrate	acidity regulator	
E383	Calcium glycerylphosphate	acidity regulator	
E384	Isopropyl citrate	acidity regulator	
E385	Calcium disodium ethylene diamine tetraacetate, (Calcium disodium EDTA)	sequestrant	Approved in the EU. <sup>[22]</sup>
E386	Disodium ethylene diamine tetraacetate (Disodium EDTA)	sequestrant	
E387	Oxystearin	stabiliser	
E388	Thiodipropionic acid		
E389	Dilauryl thiodipropionate		
E390	Distearyl thiodipropionate		



Code	Name(s)	Purpose	Status
E391	Phytic acid		
E392	Extracts of rosemary		Approved in 2010 <sup>[27]</sup>
E399	Calcium lactobionate		

E400–E499 (thickeners, stabilisers, emulsifiers)

Code	Name(s)	Purpose	Status
E400	Alginic acid (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E401	Sodium alginate (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E402	Potassium alginate (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E403	Ammonium alginate (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E404	Calcium alginate (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E405	Propane-1,2-diol alginate (Propylene glycol alginate) (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E406	Agar (thickener) (gelling agent)	stabiliser	Approved in the EU. <sup>[25]</sup>
E407	Carrageenan (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E407a	Processed eucheuma seaweed (thickener)	emulsifier	Approved in the EU. <sup>[25]</sup>



Code	Name(s)	Purpose	Status
	(stabiliser) (gelling agent)		
E408	Bakers yeast glycan		
E409	Arabinogalactan		
E410	Locust bean gum (Carob gum) (thickener) (stabiliser) (gelling agent)	emulsifier	Approved in the EU. <sup>[25]</sup>
E411	Oat gum (thickener)	stabiliser	
E412	Guar gum (thickener)	stabiliser	Approved in the EU. <sup>[25]</sup>
E413	Tragacanth (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E414	Acacia gum (gum arabic) (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E415	Xanthan gum (thickener)	stabiliser	Approved in the EU. <sup>[25]</sup>
E416	Karaya gum (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E417	Tara gum (thickener)	stabiliser	Approved in the EU. <sup>[25]</sup>
E418	Gellan gum (thickener) (stabiliser)	emulsifier	Approved in the EU. <sup>[25]</sup>
E419	Gum ghatti (thickener) (stabiliser)	emulsifier	
E420	Sorbitol (i) Sorbitol (ii) Sorbitol syrup (emulsifier) (sweetener)	humectant	Approved in the EU. <sup>[28]</sup>



Code	Name(s)	Purpose	Status
E421	Mannitol (anti-caking agent)	sweetener	Approved in the EU. <sup>[28]</sup>
E422	Glycerol (emulsifier)	sweetener	Approved in the EU. <sup>[22]</sup>
E424	Curdlan	gelling agent	
E425	Konjac (i) Konjac gum (ii) Konjac glucomannane	emulsifier	Approved in the EU. <sup>[25]</sup> May not be used in confectionery owing to choking risk. <sup>[needed]</sup>
E426	Soybean hemicellulose		Approved in the EU. <sup>[25]</sup>
E427	Cassia gum		Approved in 2010 <sup>[27]</sup>
E429	Peptones		
E430	Polyoxyethene (8) stearate (emulsifier)	stabiliser	
E431	Polyoxyethene (40) stearate	emulsifier	Approved in the EU. <sup>[22]</sup>
E432	Polyoxyethene (20) sorbitan monolaurate (polysorbate 20)	emulsifier	Approved in the EU. <sup>[25]</sup>
E433	Polyoxyethene (20) sorbitan monooleate (polysorbate 80)	emulsifier	Approved in the EU. <sup>[25]</sup>
E434	Polyoxyethene (20) sorbitan monopalmitate (polysorbate 40)	emulsifier	Approved in the EU. <sup>[25]</sup>
E435	Polyoxyethene (20) sorbitan monostearate (polysorbate 60)	emulsifier	Approved in the EU. <sup>[25]</sup>



Code	Name(s)	Purpose	Status
E436	Polyoxyethene (20) sorbitan tristearate (polysorbate 65)	emulsifier	Approved in the EU. <sup>[25]</sup>
E440	Pectins (i) pectin (ii) amidated pectin	emulsifier	Approved in the EU. <sup>[25]</sup>
E441	Gelatine (emulsifier)	gelling agent	
E442	Ammonium phosphatides	emulsifier	Approved in the EU. <sup>[25]</sup>
E443	Brominated vegetable oil	emulsifier	
E444	Sucrose acetate isobutyrate	emulsifier	
E445	Glycerol esters of wood rosins	emulsifier	Approved in the EU. <sup>[25]</sup>
E446	Succistearin		
E450	Diphosphates (i) Disodium diphosphate (ii) Trisodium diphosphate (iii) Tetrasodium diphosphate (iv) Dipotassium diphosphate (v) Tetrapotassium diphosphate (vi) Dicalcium diphosphate (vii) Calcium dihydrogen diphosphate	emulsifier	Approved in the EU. <sup>[22]</sup>
E451	Triphosphates (i) Sodium triphosphate (pentasodium triphosphate) (ii) Pentapotassium triphosphate	emulsifier	Approved in the EU. <sup>[22]</sup>
E452	Polyphosphates (i) Sodium polyphosphates (ii) Potassium polyphosphates (iii) Sodium calcium polyphosphate (iv) Calcium polyphosphates (v) Ammonium polyphosphate	emulsifier	Approved in the EU. <sup>[22]</sup>





Code	Name(s)	Purpose	Status
E459	Beta-cyclodextrin	emulsifier	Approved in the EU. <sup>[22]</sup>
E460	Cellulose (i) Microcrystalline cellulose (ii) Powdered cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E461	Methyl cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E462	Ethyl cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E463	Hydroxypropyl cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E464	Hypromellose (hydroxypropyl methylcellulose)	emulsifier	Approved in the EU. <sup>[25]</sup>
E465	Ethyl methyl cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E466	Carboxymethyl cellulose, Sodium carboxymethyl cellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E467	Ethyl hydroxyethyl cellulose		
E468	Crosslinked sodium carboxymethyl cellulose (Croscarmellose)	emulsifier	Approved in the EU. <sup>[25]</sup> This additive is under discussion and may be included in a future amendment to the Directive on miscellaneous additives
E469	Enzymically hydrolysed carboxymethylcellulose	emulsifier	Approved in the EU. <sup>[25]</sup>
E470a	Sodium, potassium and calcium salts of fatty acids (emulsifier)	anti-caking agent	Approved in the EU. <sup>[25]</sup>
E470b	Magnesium salts of fatty acids (emulsifier)	anti-caking agent	Approved in the EU. <sup>[25]</sup>



Code	Name(s)	Purpose	Status
E471	Mono- and diglycerides of fatty acids (glyceryl monostearate, glyceryl distearate)	emulsifier	Approved in the EU. <sup>[25]</sup>
E472a	Acetic acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472b	Lactic acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472c	Citric acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472d	Tartaric acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472e	Mono- and diacetyl tartaric acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472f	Mixed acetic and tartaric acid esters of mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E472g	Succinylated monoglycerides	emulsifier	
E473	Sucrose esters of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E474	Sucroglycerides	emulsifier	Approved in the EU. <sup>[25]</sup>
E475	Polyglycerol esters of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E476	Polyglycerol polyricinoleate	emulsifier	Approved in the EU. <sup>[25]</sup>
E477	Propane-1,2-diol esters of fatty acids, propylene	emulsifier	Approved in the EU. <sup>[25]</sup>



Code	Name(s)	Purpose	Status
	glycol esters of fatty acids		
E478	Lactylated fatty acid esters of glycerol and propane-1	emulsifier	
E479b	Thermally oxidized soya bean oil interacted with mono- and diglycerides of fatty acids	emulsifier	Approved in the EU. <sup>[25]</sup>
E480	Diocetyl sodium sulfosuccinate	emulsifier	
E481	Sodium stearyl-2-lactylate	emulsifier	Approved in the EU. <sup>[25]</sup>
E482	Calcium stearyl-2-lactylate	emulsifier	Approved in the EU. <sup>[25]</sup>
E483	Stearyl tartrate	emulsifier	Approved in the EU. <sup>[25]</sup>
E484	Stearyl citrate	emulsifier	
E485	Sodium stearyl fumarate	emulsifier	
E486	Calcium stearyl fumarate	emulsifier	
E487	Sodium laurylsulfate	emulsifier	
E488	Ethoxylated Mono- and Di-Glycerides	emulsifier	
E489	Methyl glucoside-coconut oil ester	emulsifier	
E490	Propane-1,2-diol		



Code	Name(s)	Purpose	Status
E491	Sorbitan monostearate	emulsifier	Approved in the EU. <sup>[25]</sup>
E492	Sorbitan tristearate	emulsifier	Approved in the EU. <sup>[25]</sup>
E493	Sorbitan monolaurate	emulsifier	Approved in the EU. <sup>[25]</sup>
E494	Sorbitan monooleate	emulsifier	Approved in the EU. <sup>[25]</sup>
E495	Sorbitan monopalmitate	emulsifier	Approved in the EU. <sup>[25]</sup>
E496	Sorbitan trioleate	emulsifier	
E497	Polyoxypropylene-polyoxyethylene polymers		
E498	Partial polyglycerol esters of polycondensed fatty acids of castor oil		
E499	Stigmasterol-rich plant sterols		Approved in the EU. <sup>[25]</sup>

E500–E599 (acidity regulators, anti-caking agents)

Code	Name(s)	Purpose	Status
E500	Sodium carbonates: (i) Sodium carbonate (ii) Sodium bicarbonate (Sodium hydrogen carbonate) (iii) Sodium sesquicarbonate (acidity regulator)	raising agent	Approved in the EU. <sup>[22]</sup>
E501	Potassium carbonates: (i) Potassium carbonate (ii) Potassium bicarbonate (Potassium hydrogen carbonate)	acidity regulator	Approved in the EU. <sup>[22]</sup>
E503	Ammonium carbonates: (i) Ammonium carbonate (ii) Ammonium	acidity regulator	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
	bicarbonate (Ammonium hydrogen carbonate)		
E504	Magnesium carbonates: (i) Magnesium carbonate (ii) Magnesium bicarbonate Magnesium hydrogen carbonate	acidity regulator, anti-caking agent	Approved in the EU. <sup>[22]</sup>
E505	Ferrous carbonate	acidity regulator	
E507	Hydrochloric acid	acid	Approved in the EU. <sup>[22]</sup>
E508	Potassium chloride (gelling agent)	seasoning	Approved in the EU. <sup>[22]</sup>
E509	Calcium chloride (sequestrant)	firming agent	Approved in the EU. <sup>[22]</sup>
E510	Ammonium chloride, ammonia solution (acidity regulator)	improving agent	
E511	Magnesium chloride	firming agent	Approved in the EU. <sup>[22]</sup>
E512	Stannous chloride	antioxidant	Approved in the EU. <sup>[22]</sup>
E513	Sulfuric acid	acid	Approved in the EU. <sup>[22]</sup>
E514	Sodium sulfates (i) Sodium sulfate (ii) sodium bisulfate	acid	Approved in the EU. <sup>[22]</sup>
E515	Potassium sulfates (i) potassium sulfate (ii) potassium bisulfate		Approved in the EU. <sup>[22]</sup>
E516	Calcium sulfate		Approved in the EU. <sup>[22]</sup>
E517	Ammonium sulfate	acidity regulator	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E518	Magnesium sulfate (Epsom salts), (acidity regulator)	firming agent	
E519	Copper(II) sulfate	preservative	
E520	Aluminium sulfate	firming agent	Approved in the EU. <sup>[22]</sup>
E521	Aluminium sodium sulfate	firming agent	Approved in the EU. <sup>[22]</sup>
E522	Aluminium potassium sulfate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E523	Aluminium ammonium sulfate	acidity regulator	Approved in the EU. <sup>[22]</sup>
E524	Sodium hydroxide	acidity regulator	Approved in the EU. <sup>[22]</sup>
E525	Potassium hydroxide	acidity regulator	Approved in the EU. <sup>[22]</sup>
E526	Calcium hydroxide (acidity regulator)	firming agent	Approved in the EU. <sup>[22]</sup>
E527	Ammonium hydroxide	acidity regulator	Approved in the EU. <sup>[22]</sup>
E528	Magnesium hydroxide	acidity regulator	Approved in the EU. <sup>[22]</sup>
E529	Calcium oxide (acidity regulator)	improving agent	Approved in the EU. <sup>[22]</sup>
E530	Magnesium oxide (acidity regulator)	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E535	Sodium ferrocyanide (acidity regulator)	anti-caking agent	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E536	Potassium ferrocyanide	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E537	Ferrous hexacyanomanganate	anti-caking agent	
E538	Calcium ferrocyanide	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E539	Sodium thiosulfate	antioxidant	
E540	Dicalcium diphosphate (acidity regulator)	emulsifier	
E541	Sodium aluminium phosphate (i) Acidic (ii) Basic	emulsifier	Approved in the EU. <sup>[22]</sup>
E542	Bone phosphate (Essential Calcium Phosphate, Tribasic)	anti-caking agent	
E543	Calcium sodium polyphosphate	emulsifier	
E544	Calcium polyphosphate	emulsifier	
E545	Ammonium polyphosphate	emulsifier	
E550	Sodium Silicates (i) Sodium silicate (ii) Sodium metasilicate	anti-caking agent	
E551	Silicon dioxide (Silica)	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E552	Calcium silicate	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E553a	(i) Magnesium silicate (ii) Magnesium trisilicate	anti-caking agent	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E553b	Talc	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E554	Sodium aluminosilicate (sodium aluminium silicate)	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E555	Potassium aluminium silicate	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E556	Calcium aluminosilicate (calcium aluminium silicate)	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E557	Zinc silicate	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E558	Bentonite	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E559	Aluminium silicate (Kaolin)	anti-caking agent	removed from list per Commission Regulation (EU) No 380/2012 of 3 May 2012
E560	Potassium silicate	anti-caking agent	
E561	Vermiculite		
E562	Sepiolite		
E563	Sepiolitic clay		





Code	Name(s)	Purpose	Status
E565	Lignosulfonates		
E566	Natrolite-phonolite		
E570	Fatty acids	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E572	Magnesium stearate, calcium stearate (emulsifier)	anti-caking agent	
E574	Gluconic acid	acidity regulator	Approved in the EU. <sup>[22]</sup>
E575	Glucono delta-lactone (acidity regulator)	sequestrant	Approved in the EU. <sup>[22]</sup>
E576	Sodium gluconate	sequestrant	Approved in the EU. <sup>[22]</sup>
E577	Potassium gluconate	sequestrant	Approved in the EU. <sup>[22]</sup>
E578	Calcium gluconate	firming agent	Approved in the EU. <sup>[22]</sup>
E579	Ferrous gluconate	food colouring	Approved in the EU. <sup>[22]</sup>
E580	Magnesium gluconate		
E585	Ferrous lactate	food colouring	Approved in the EU. <sup>[22]</sup>
E586	4-Hexylresorcinol	antioxidant	Approved in the EU. <sup>[24]</sup>
E598	Synthetic calcium aluminates		



Code	Name(s)	Purpose	Status
E599	Perlite		

E600–E699 (flavour enhancer)

Code	Name(s)	Purpose	Status
E620	Glutamic acid	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E621	Monosodium glutamate (MSG)	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E622	Monopotassium glutamate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E623	Calcium diglutamate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E624	Monoammonium glutamate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E625	Magnesium diglutamate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E626	Guanylic acid	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E627	Disodium guanylate, sodium guanylate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E628	Dipotassium guanylate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E629	Calcium guanylate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E630	Inosinic acid	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E631	Disodium inosinate	flavour enhancer	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E632	Dipotassium inosinate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E633	Calcium inosinate	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E634	Calcium 5'-ribonucleotides	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E635	Disodium 5'-ribonucleotides	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E636	Maltol	flavour enhancer	
E637	Ethyl maltol	flavour enhancer	
E640	Glycine and its sodium salt	flavour enhancer	Approved in the EU. <sup>[22]</sup>
E650	Zinc acetate	flavour enhancer	Approved in the EU. <sup>[22]</sup>

E700–E799 (antibiotics)

[29]

Code	Name(s)	Purpose	Status
E701	Tetracyclines	antibiotic	
E702	Chlortetracycline	antibiotic	
E703	Oxytetracycline	antibiotic	
E704	Oleandomycin	antibiotic	
E705	Penicillin G potassium	antibiotic	



Code	Name(s)	Purpose	Status
E706	Penicillin G sodium	antibiotic	
E707	Penicillin G procaine	antibiotic	
E708	Penicillin G benzathine	antibiotic	
E710	Spiramycins	antibiotic	
E711	Virginiamycins	antibiotic	
E712	Flavomycin	antibiotic	
E713	Tylosin	antibiotic	
E714	Monensin A	antibiotic	
E715	Avoparcin	antibiotic	
E716	Salinomycin	antibiotic	
E717	Avilamycin	antibiotic	

E900–E999 (glazing agents, gases and sweeteners)

Code	Name(s)	Purpose	Status
E900	Dimethyl polysiloxane (anti-foaming agent)	anti-caking agent	Approved in the EU. <sup>[22]</sup>
E901	Beeswax, white and yellow	glazing agent	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E902	Candelilla wax	glazing agent	Approved in the EU. <sup>[22]</sup>
E903	Carnauba wax	glazing agent	Approved in the EU. <sup>[22]</sup>
E904	Shellac	glazing agent	Approved in the EU. <sup>[22]</sup>
E905	Paraffins		Approved in the EU. <sup>[22]</sup>
E905a	Mineral oil	anti-foaming agent	
E905b	Petrolatum		
E905c	Petroleum wax (i) Microcrystalline wax (ii) Paraffin wax	glazing agent	
E906	Gum benzoic	flavour enhancer	
E907	Crystalline wax	glazing agent	
E908	Rice bran wax	glazing agent	
E909	Spermaceti wax	glazing agent	
E910	Wax esters	glazing agent	
E911	Methyl esters of fatty acids	glazing agent	
E912	Montanic acid esters, Montan acid esters	glazing agent	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E913	Lanolin, sheep wool grease	glazing agent	
E914	Oxidized polyethylene wax, oxidized polyethylene	glazing agent	Approved in the EU. <sup>[22]</sup>
E915	Esters of colophony	glazing agent	
E916	Calcium iodate		
E917	Potassium iodate		
E918	Nitrogen oxides		
E919	Nitrosyl chloride		
E920	L-cysteine	improving agent	Approved in the EU <sup>[30]</sup>
E921	L-cystine	improving agent	
E922	Potassium persulfate	improving agent	
E923	Ammonium persulfate	improving agent	
E924	Potassium bromate	improving agent	Banned in the EU; <sup>[31]</sup> genotoxic carcinogen <sup>[32]</sup>
E924b	Calcium bromate	improving agent	
E925	Chlorine	preservative, bleach, improving agent	



Code	Name(s)	Purpose	Status
E926	Chlorine dioxide (preservative)	bleach	
E927a	Azodicarbonamide	improving agent	identified as a Substance of Very High Concern in EU. <sup>[33]</sup>
E927b	Carbamide (urea)	improving agent	Approved in the EU. <sup>[22]</sup>
E928	Benzoyl peroxide (improving agent)	bleach	
E929	Acetone peroxide		
E930	Calcium peroxide (improving agent)	bleach	
E938	Argon	packaging gas	Approved in the EU. <sup>[22]</sup>
E939	Helium	packaging gas	Approved in the EU. <sup>[22]</sup>
E940	Dichlorodifluoromethane	packaging gas	Banned in all countries, in compliance with the Montreal Protocol.
E941	Nitrogen (packaging gas)	propellant	Approved in the EU. <sup>[22]</sup>
E942	Nitrous oxide	propellant	Approved in the EU. <sup>[22]</sup>
E943a	Butane	propellant	Approved in the EU. <sup>[22]</sup>
E943b	Isobutane	propellant	Approved in the EU. <sup>[22]</sup>
E944	Propane	propellant	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E945	Chloropentafluoroethane	propellant	
E946	Octafluorocyclobutane	propellant	
E948	Oxygen	packaging gas	Approved in the EU. <sup>[22]</sup>
E949	Hydrogen	packaging gas	Approved in the EU. <sup>[22]</sup>
E950	Acesulfame potassium	sweetener	Approved in the EU. <sup>[28]</sup>
E951	Aspartame	sweetener	Approved in the EU. <sup>[28]</sup>
E952	Cyclamic acid and its sodium and calcium salts, also known as Cyclamate	sweetener	Approved in the EU. <sup>[28]</sup>
E953	Isomalt, Isomaltitol	sweetener	Approved in the EU. <sup>[28]</sup>
E954	Saccharin and its sodium, potassium and calcium salts	sweetener	Approved in the EU. <sup>[28]</sup>
E955	Sucralose (Trichlorogalactosucrose)	sweetener	Approved in the EU. <sup>[28]</sup>
E956	Alitame	sweetener	
E957	Thaumatococcus (sweetener)	flavour enhancer	Approved in the EU. <sup>[28]</sup>
E958	Glycyrrhizin (sweetener)	flavour enhancer	
E959	Neohesperidine dihydrochalcone (sweetener)	flavour enhancer	Approved in the EU. <sup>[28]</sup>





Code	Name(s)	Purpose	Status
E960	Steviol glycosides	sweetener	Approved in the EU. <sup>[34]</sup>
E961	Neotame	sweetener	Approved in 2010 <sup>[27]</sup>
E962	Aspartame-acesulfame salt (sweetener)	stabiliser	Approved in the EU. <sup>[28]</sup>
E965	Maltitol (i) Maltitol (ii) Maltitol syrup (sweetener) (stabiliser)	humectant	Approved in the EU. <sup>[28]</sup>
E966	Lactitol	sweetener	Approved in the EU. <sup>[28]</sup>
E967	Xylitol	sweetener	Approved in the EU. <sup>[28]</sup>
E968	Erythritol	sweetener	Approved in the EU. <sup>[28]</sup>
E969	Advantame	sweetener	Approved in the EU. <sup>[28]</sup>
E999	Quillaia extract	foaming agent	Approved in the EU. <sup>[22]</sup>

E1000–E1599 (additional additives)

Code	Name(s)	Purpose	Status
E1000	Cholic acid	emulsifier	
E1001	Choline salts	emulsifier	
E1100	Amylase	stabiliser, flavour enhancer	
E1101	Proteases ((i)Protease, (ii)Papain,	stabiliser, flavour	



Code	Name(s)	Purpose	Status
	(iii)Bromelain, (iv)Ficin)	enhancer	
E1102	Glucose oxidase	antioxidant	
E1103	Invertase	stabiliser	Approved in the EU. <sup>[25]</sup>
E1104	Lipases		
E1105	Lysozyme	preservative	
E1200	Polydextrose	stabiliser, thickening agent, humectant, carrier	Approved in the EU. <sup>[22]</sup>
E1201	Polyvinylpyrrolidone	stabiliser	Approved in the EU. <sup>[22]</sup>
E1202	Polyvinylpolypyrrolidone (carrier)	stabiliser	Approved in the EU. <sup>[22]</sup>
E1203	Polyvinyl alcohol		Approved in 2010 <sup>[27]</sup>
E1204	Pullulan		Approved in the EU. <sup>[22]</sup>
E1400	Dextrin (Dextrins, roasted starch white and yellow) (stabiliser)	thickening agent	
E1401	Modified starch ((Acid-treated starch) stabiliser)	thickening agent	
E1402	Alkaline modified starch (stabiliser)	thickening agent	
E1403	Bleached starch (stabiliser)	thickening agent	



Code	Name(s)	Purpose	Status
E1404	Oxidized starch (emulsifier)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1405	Enzyme treated starch		
E1410	Monostarch phosphate (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1411	Distarch glycerol (thickening agent)	emulsifier	
E1412	Distarch phosphate esterified with sodium trimetaphosphate; esterified with phosphorus oxychloride (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1413	Phosphated distarch phosphate (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1414	Acetylated distarch phosphate (emulsifier)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1420	Starch acetate esterified with acetic anhydride (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1421	Starch acetate esterified with vinyl acetate (stabiliser)	thickening agent	
E1422	Acetylated distarch adipate (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1423	Acetylated distarch glycerol	thickening agent	
E1430	Distarch glycerine (stabiliser)	thickening agent	
E1440	Hydroxy propyl starch (emulsifier)	thickening agent	Approved in the EU. <sup>[22]</sup>



Code	Name(s)	Purpose	Status
E1441	Hydroxy propyl distarch glycerine (stabiliser)	thickening agent	
E1442	Hydroxy propyl distarch phosphate (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1443	Hydroxy propyl distarch glycerol		
E1450	Starch sodium octenyl succinate (emulsifier) (stabiliser)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1451	Acetylated oxidised starch (emulsifier)	thickening agent	Approved in the EU. <sup>[22]</sup>
E1452	Starch aluminium octenyl succinate		Approved in the EU. <sup>[22]</sup>
E1501	Benzylated hydrocarbons		
E1502	Butane-1, 3-diol		
E1503	Castor oil	resolving agent	
E1504	Ethyl acetate	flavour solvent	
E1505	Triethyl citrate	foam stabiliser	Approved in the EU. <sup>[22]</sup>
E1510	Ethanol		
E1516	Glyceryl monoacetate	flavour solvent	
E1517	Glyceryl diacetate or diacetin	flavour solvent	



Code	Name(s)	Purpose	Status
E1518	Glyceryl triacetate or triacetin	humectant and flavour solvent	Approved in the EU. <sup>[22]</sup>
E1519	Benzyl alcohol		
E1520	Propylene glycol	humectant and flavour solvent	Approved in the EU. <sup>[22]</sup>
E1521	Polyethylene glycol 8000 <sup>[35]</sup>		Approved in 2010 <sup>[27]</sup>
E1525	Hydroxyethyl cellulose	thickening agent	

### CHAPTER-3

Food coloring, or color additive, is any dye, pigment, or substance that imparts color when it is added to food or drink. They can be supplied as liquids, powders, gels, or pastes. Food coloring is used in both commercial food production and domestic cooking. Food colorants are also used in a variety of non-food applications, including cosmetics, pharmaceuticals, home craft projects, and medical devices.<sup>[1]</sup> Colorings may be natural (e.g. anthocyanins, cochineal) or artificial/synthetic (e.g. tartrazine yellow).

#### Purpose of food coloring

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People associate certain colors with certain flavors, and the color of food can influence the perceived flavor in anything from candy to wine.<sup>[3]</sup> Sometimes, the aim is to simulate a color that is perceived by the consumer as natural, such as adding red coloring to glacé cherries (which would otherwise be beige), but sometimes it is for effect, like the green ketchup that Heinz launched in 2000. Color additives are used in foods for many reasons including:<sup>[4][5]</sup>

- To make food more attractive, appealing, appetizing, and informative
- Offsetting color loss over time due to exposure to light, air, temperature extremes, moisture and storage conditions
- Correcting natural variations in color
- Enhancing colors that occur naturally
- Providing color to colorless and "fun" foods
- Allowing products to be identified on sight, like candy flavors or medicine dosages

#### Natural food dyes

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##### History

The addition of colorants to foods is thought to have occurred in Egyptian cities as early as 1500 BC, when candy makers added natural extracts and wine to improve the products' appearance.<sup>[6]</sup> During the Middle Ages, the economy in the European countries was based on agriculture, and the peasants were accustomed to producing their own food locally or trading within the village communities. Under feudalism, aesthetic aspects were not considered, at least not by the vast majority of the generally very poor population.<sup>[7]</sup> This situation changed with urbanization at the beginning of the Modern Age, when trade emerged—especially the import of precious spices and colors. One of the first food laws, created in Augsburg, Germany, in 1531, concerned spices or colorants and required saffron counterfeiters to be burned to death.<sup>[8]</sup>



#### Natural colorants

Carotenoids (E160, E161, E164), chlorophyllin (E140, E141), anthocyanins (E163), and betanin (E162) comprise four main categories of plant pigments grown to color food products.<sup>[9]</sup> Other colorants or specialized derivatives of these core groups include:

- Annatto (E160b), a reddish-orange dye made from the seed of the achiote
- Caramel coloring (E150a-d), made from caramelized sugar
- Carmine (E120), a red dye derived from the cochineal insect, *Dactylopius coccus*
- Elderberry juice (E163)
- Lycopene (E160d)
- Paprika (E160c)
- Turmeric/curcumin (E100)

Blue colors are rare.<sup>[10]</sup> One feasible blue dye in use is derived from spirulina. The pigment genipin, present in the fruit of *Gardenia jasminoides*, can be treated with amino acids to produce the blue pigment gardenia blue, which is approved for use in Japan but not the EU or the US.<sup>[11]</sup>

To ensure reproducibility, the colored components of these substances are often provided in highly purified form. For stability and convenience, they can be formulated in suitable carrier materials (solid and liquids). Hexane, acetone, and other solvents break down cell walls in the fruit and vegetables and allow for maximum extraction of the coloring. Traces of these may still remain in the finished colorant, but they do not need to be declared on the product label. These solvents are known as carry-over ingredients.

#### Chemical structures of representative natural colorants

#### Artificial food colorants

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##### History

With the onset of the industrial revolution, people became dependent on foods produced by others.<sup>[7]</sup> These new urban dwellers demanded food at low cost. Analytical chemistry was still primitive and regulations few. The adulteration of foods flourished.<sup>[7]</sup> Heavy metal and other inorganic element-containing compounds turned out to be cheap and suitable to "restore" the color of watered-down milk and other foodstuffs, some more lurid examples being:<sup>[12]</sup>

- Red lead ( $Pb_3O_4$ ) and vermilion ( $HgS$ ) were routinely used to color cheese and confectionery.
- Copper arsenite ( $CuHASO_3$ ) was used to recolor used tea leaves for resale. It also caused two deaths when used to color a dessert in 1860.

Sellers at the time offered more than 80 artificial coloring agents, some invented for dyeing textiles, not foods.<sup>[12]</sup>

Thus, with potted meat, fish and sauces taken at breakfast he would consume more or less Armenian bole, red lead, or even bisulphuret of mercury [vermillion,  $HgS$ ]. At dinner with his curry or cayenne he would run the chance of a second dose of lead or mercury; with pickles, bottled fruit and vegetables he would be nearly sure to have copper administered to him; and while he partook of bon-bons at dessert, there was no telling of the number of poisonous pigments he might consume. Again his tea if mixed or green, he would certainly not escape without the administration of a little Prussian blue...<sup>[13]</sup>

Many color additives had never been tested for toxicity or other adverse effects. Historical records show that injuries, even deaths, resulted from tainted colorants. In 1851, about 200 people were poisoned in England, 17 of them fatally, directly as a result of eating adulterated lozenges.<sup>[7]</sup> In 1856, mauveine, the first synthetic color, was developed by Sir William Henry Perkin and by the turn of the century, unmonitored color additives had spread through Europe and the United States in all sorts of popular foods, including ketchup, mustard, jellies, and wine.<sup>[14][15]</sup> Originally, these were dubbed 'coal-tar' colors because the starting materials were obtained from bituminous coal.<sup>[16][5]</sup>

Synthetic dyes are often less costly and technically superior to natural dyes.<sup>[12][17][18]</sup>

#### Chemical structures of representative artificial colorants



## Regulation

While naturally derived colors, most of which have been used traditionally for centuries, are not required to be certified by a number of regulatory bodies throughout the world (including the U.S. FDA), they may require approval in some countries. Food colorings are tested for safety by various bodies around the world, and sometimes different bodies have different views on food color safety. Artificial food additives usually require certification everywhere.

### History of regulation

Concerns over food safety led to numerous regulations throughout the world. German food regulations released in 1882 stipulated the exclusion of dangerous "minerals" such as arsenic, copper, chromium, lead, mercury, and zinc, which were frequently used as ingredients in colorants.<sup>[19]</sup> In contrast to today's regulatory guidelines, these first laws followed the principle of a negative listing (substances not allowed for use); they were already driven by the main principles of today's food regulations all over the world, since all of these regulations follow the same goal: the protection of consumers from toxic substances and from fraud.<sup>[7]</sup> In the United States, the Pure Food and Drug Act of 1906 reduced the permitted list of synthetic colors from 700 down to seven.<sup>[20]</sup> The seven dyes initially approved were Ponceau 3R (FD&C Red No. 1), amaranth (FD&C Red No. 2), erythrosine (FD&C Red No. 3), indigotine (FD&C Blue No. 2), light green SF (FD&C Green No. 2), naphthol yellow 1 (FD&C Yellow No. 1), and orange 1 (FD&C Orange No. 1). Even with updated food laws, adulteration continued for many years.

In the 20th century, improved chemical analysis and testing led to the replacement of the negative lists by positive listings. Positive lists consist of substances allowed to be used for the production and the improvement of foods. Most prevailing legislations are based on positive listing.<sup>[7]</sup> Positive listing implies that substances meant for human consumption have been tested for their safety, and that they have to meet specified purity criteria prior to their approval by the corresponding authorities. In 1962, the first EU directive (62/2645/EEC) approved 36 colorants, of which 20 were naturally derived and 16 were synthetic.<sup>[21][22]</sup> This directive did not list which food products the colorants could or could not be used in. At that time, each member state could designate where certain colors could and could not be used. In Germany, for example, quinoline yellow was allowed in puddings and desserts, but tartrazine was not. The reverse was true in France.<sup>[8]</sup> This was updated in 1989 with 89/107/EEC, which concerned food additives authorized for use in foodstuffs.<sup>[23][24]</sup>

### National regulations

A comparison of food color regulations in the EU and the US was published in 2017.<sup>[25]</sup>

#### Canada

Canada has published food and drug regulations covering food colorants.<sup>[26]</sup>

Food in Canada cannot be sold with more than:<sup>[26]:</sup>

- 100 ppm of fast green FCF or brilliant blue FCF. or any combination
- 300 ppm of allura red, amaranth, erythrosine, indigotine, sunset yellow FCF or tartrazine and fast green FCF or brilliant blue FCF combined
- 150 ppm of ponceau SX dye.

#### European Union

In the European Union E numbers are used for all additives, both synthetic and natural, that are approved in food applications. E numbers beginning with 1, such as E100 (turmeric) or E161b (lutein), are allocated to colorants.<sup>[27]</sup> The safety of food colors and other food additives in the EU is evaluated by the European Food Safety Authority. Color Directive 94/36/EC, enacted by the European Commission in 1994, outlines permitted natural and artificial colors with their approved applications and limits in different foodstuffs.<sup>[8][28]</sup> This is binding on all member countries of the EU; any changes have to be implemented into national laws by a specified deadline. In non-EU member states, food additives are regulated by national authorities, which usually, but not always, try to harmonize with EU regulations. Most other countries have their own regulations and list of food colors which can be used in various applications, including maximum daily intake limits.

#### Permitted synthetic colorants (EU)

E numbers 102–143 cover the range of artificial colors. The EU maintains a list of currently allowed additives.<sup>[29]</sup> Some artificial dyes approved for food use in the EU include:



- E104: Quinoline yellow
- E122: Carmoisine
- E124: Ponceau 4R
- E131: Patent blue V
- E142: Green S

The three synthetic colors Orange B, Citrus Red No. 2 and FD&C Green No. 3 are permitted in the US but not the EU, as is the natural toasted partially defatted cooked cottonseed flour.<sup>[25]:338</sup>

*India*

The Food Safety and Standard Act, 2006 in India generally permits eight artificial colorings in food:<sup>[30]</sup>

SL No.	Color	Common name	INS No.	Chemical class
1	Red	Ponceu 4R	124	Azo
		Carmoisine	122	Azo
		Erythrosine	127	Xanthene
2	Yellow	Tartrazine	102	Pyrazolone
		Sunset yellow FCF	110	Azo
3	Blue	Indigo carmine	132	Indigoid
		Brilliant blue FCF	133	Triarylmethane
4	Green	Fast green FCF	143	Triarylmethane

*United States*

The U.S. FDA's permitted colors are classified as subject to certification or exempt from certification in Code of Federal Regulations – Title 21 Part 73 & 74,<sup>[33]</sup> both of which are subject to rigorous safety standards prior to their approval and listing for use in foods.<sup>[34]</sup>

- Certified colors are synthetically produced and are used widely because they impart an intense, uniform color, are less expensive, and blend more easily to create a variety of hues. There are nine certified color additives approved for use in the United States. Certified food colors generally do not add undesirable flavors to foods.
- Colors that are exempt from certification include pigments derived from natural sources such as vegetables, minerals, or animals. Nature-derived color additives are typically more expensive than certified colors, and may add unintended flavors to foods. Examples of exempt colors include annatto, beet extract, caramel, beta-carotene,





turmeric and grape skin extract. This list contains substances which may have synthetic origins, such as nature-identical beta-carotene.

In the United States, FD&C numbers (which indicate that the FDA has approved the colorant for use in foods, drugs and cosmetics) are given to approved synthetic food dyes that do not exist in nature.

Permitted synthetic colorants (US)

In the US, the following seven artificial colorings are generally permitted in food (the most common in bold) as of 2016. The lakes of these colorings are also permitted except the lake of Red No. 3.<sup>[35]</sup>

- FD&C Blue No. 1 – Brilliant blue FCF, E133 (blue shade)
- FD&C Blue No. 2 – Indigotine, E132 (indigo shade)
- FD&C Green No. 3 – Fast green FCF, E143 (turquoise shade)
- FD&C Red No. 3 – Erythrosine, E127 (pink shade, commonly used in glacé cherries)<sup>[36]</sup>
- FD&C Red No. 40 – Allura red AC, E129 (red shade)
- FD&C Yellow No. 5 – Tartrazine, E102 (yellow shade)
- FD&C Yellow No. 6 – Sunset yellow FCF, E110 (orange shade)

Two dyes are allowed by the FDA for limited applications:

- Citrus red 2 (orange shade) – allowed only to color orange peels.
- Orange B (red shade) – allowed only for use in hot dog and sausage casings (not produced after 1978, but not delisted)

(Orange B, Citrus Red No. 2 and FD&C Green No. 3 are not permitted in the EU.<sup>[25]:338</sup>)

Many dyes have been delisted for a variety of reasons, ranging from poor coloring properties to regulatory restrictions.<sup>[37]</sup> Some of these delisted food colorants are:

- FD&C Red No. 2 – Amaranth, E123
- FD&C Red No. 4 – Scarlet GN, E125<sup>[38][39]</sup>
- FD&C Red No. 32 was used to color Florida oranges.<sup>[37][38][40]</sup>
- FD&C Orange Number 1 was one of the first water-soluble dyes to be commercialized, and one of seven original food dyes allowed under the Pure Food and Drug Act of June 30, 1906.<sup>[37][38]</sup>
- FD&C Orange No. 2 was used to color Florida oranges.<sup>[37]</sup>
- FD&C Yellow No. 1, 2, 3, and 4<sup>[38]</sup>
- FD&C Violet No. 1<sup>[38]</sup>

Global harmonization

Since the beginning of the 1960s, JECFA has promoted the development of international standards for food additives, not only by its toxicological assessments, which are continuously published by the WHO in a "Technical Report Series",<sup>[41]</sup> but furthermore by elaborating appropriate purity criteria, which are laid down in the two volumes of the "Compendium of Food Additive Specifications" and their supplements.<sup>[42]</sup> These specifications are not legally binding but very often serve as a guiding principle, especially in countries where no scientific expert committees have been established.<sup>[7]</sup>

In order to further regulate the use of these evaluated additives, in 1962 the WHO and FAO created an international commission, the Codex Alimentarius, which is composed of authorities, food industry associations and consumer groups from all over the world. Within the Codex organization, the Codex Committee for Food Additives and Contaminants is responsible for working out recommendations for the application of food additives: the General Standard for Food Additives.<sup>[43]</sup> In the light of the World Trade Organizations General Agreement on Tariffs and Trade (GATT), the Codex Standard, although not legally binding, influences food color regulations all over the world.<sup>[7]</sup>

Criticism and health implications

Widespread public belief that artificial food coloring causes ADHD-like hyperactivity in children originated from Benjamin Feingold, a pediatric allergist from California, who proposed in 1973 that salicylates, artificial colors,



and artificial flavors cause hyperactivity in children;<sup>[44]</sup> however, there is no evidence to support broad claims that food coloring causes food intolerance and ADHD-like behavior in children.<sup>[45]:452[46]</sup> It is possible that certain food colorings may act as a trigger in those who are genetically predisposed, but the evidence is weak.<sup>[47][48]</sup>

Despite concerns expressed that food colorings may cause ADHD-like behavior in children,<sup>[47]</sup> the collective evidence does not support this assertion.<sup>[49]</sup> UK Food Standards Agency (FSA) examined the effects of tartrazine, allura red, ponceau 4R, quinoline yellow, sunset yellow and carmoisine on children. These colorants are found in beverages.<sup>[47][50]</sup> The study found "a possible link between the consumption of these artificial colours and a sodium benzoate preservative and increased hyperactivity" in the children;<sup>[47][50]</sup> the advisory committee to the FSA that evaluated the study also determined that because of study limitations, the results could not be extrapolated to the general population, and further testing was recommended.<sup>[51][47]</sup> The U.S. FDA did not make changes following the publication of the Southampton study. Following a citizen petition filed by the Center for Science in the Public Interest in 2008, requesting the FDA ban several food additives, the FDA reviewed the available evidence, and still made no changes.<sup>[47]</sup>

The European regulatory community, with an emphasis on the precautionary principle, required labelling and temporarily reduced the acceptable daily intake (ADI) for the food colorings; the UK FSA called for voluntary withdrawal of the colorings by food manufacturers.<sup>[47][50]</sup> However, in 2009 the EFSA re-evaluated the data at hand and determined that "the available scientific evidence does not substantiate a link between the color additives and behavioral effects" for any of the dyes

#### CHAPTER-4

Sodium benzoate also known as benzoate of soda is the sodium salt of benzoic acid, widely used as a food preservative (with an E number of E211) and a pickling agent. It appears as a white crystalline chemical with the formula  $C_6H_5COONa$ .

##### Production

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Sodium benzoate is commonly produced by the neutralization of sodium hydroxide (NaOH) with benzoic acid ( $C_6H_5COOH$ ),<sup>[3]</sup> which is itself produced commercially by partial oxidation of toluene with oxygen.

##### Reactions

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Sodium benzoate can be decarboxylated with strong base and heat, yielding benzene:<sup>[4]</sup>

##### Natural occurrence

Many foods are natural sources of benzoic acid, its salts, and its esters.<sup>[5]</sup> Fruits and vegetables can be rich sources, particularly berries such as cranberry and bilberry. Other sources include seafood, such as prawns, and dairy products.

##### Uses

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###### As a preservative

Sodium benzoate can act as a food preservative. It is most widely used in acidic foods such as salad dressings (for example acetic acid in vinegar), carbonated drinks (carbonic acid), jams and fruit juices (citric acid), pickles (acetic acid), condiments, and frozen yogurt toppings. It is also used as a preservative in medicines and cosmetics.<sup>[6][7]</sup> Under these conditions it is converted into benzoic acid (E210), which is bacteriostatic and fungistatic. Benzoic acid is generally not used directly due to its poor water solubility. Concentration as a food preservative is limited by the FDA in the U.S. to 0.1% by weight.<sup>[8]</sup> Sodium benzoate is also allowed as an animal food additive at up to 0.1%, per the Association of American Feed Control Officials.<sup>[9]</sup> Sodium benzoate has been replaced by potassium sorbate in the majority of soft drinks in the United Kingdom.<sup>[10]</sup>

In the 19th century, sodium benzoate as a food ingredient was investigated by Harvey W. Wiley with his 'Poison Squad' as part of the US Department of Agriculture. This led to the 1906 Pure Food and Drug Act, a key event in the early history of food regulation in the United States.

###### In pharmaceuticals

Sodium benzoate is used as a treatment for urea cycle disorders due to its ability to bind amino acids.<sup>[11][12]</sup> This leads to excretion of these amino acids and a decrease in ammonia levels. Recent research shows that sodium benzoate may be



beneficial as an add-on therapy (1 gram/day) in schizophrenia.<sup>[13][14][15]</sup> Total Positive and Negative Syndrome Scale scores dropped by 21% compared to placebo.

Sodium benzoate, along with phenylbutyrate, is used to treat hyperammonemia.<sup>[16][17]</sup>

Sodium benzoate, along with caffeine, is used to treat postdural puncture headache, respiratory depression associated with overdosage of narcotics,<sup>[18][19]</sup> and with ergotamine to treat vascular headache.<sup>[20]</sup>

Other uses

Sodium benzoate is also used in fireworks as a fuel in whistle mix, a powder that emits a whistling noise when compressed into a tube and ignited.

#### Mechanism of food preservation

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The mechanism starts with the absorption of benzoic acid into the cell. If the intracellular pH falls to 5 or lower, the anaerobic fermentation of glucose through phosphofructokinase decreases sharply,<sup>[21]</sup> which inhibits the growth and survival of microorganisms that cause food spoilage.

#### Health and safety

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In the United States, sodium benzoate is designated as generally recognized as safe (GRAS) by the Food and Drug Administration.<sup>[22]</sup> The International Programme on Chemical Safety found no adverse effects in humans at doses of 647–825 mg/kg of body weight per day.<sup>[23][24]</sup>

Cats have a significantly lower tolerance against benzoic acid and its salts than rats and mice.<sup>[25]</sup>

The human body rapidly clears sodium benzoate by combining it with glycine to form hippuric acid which is then excreted.<sup>[24]</sup> The metabolic pathway for this begins with the conversion of benzoate by butyrate-CoA ligase into an intermediate product, benzoyl-CoA,<sup>[26]</sup> which is then metabolized by glycine *N*-acyltransferase into hippuric acid.<sup>[27]</sup>

Association with benzene in soft drinks & pepper sauces

In combination with ascorbic acid (vitamin C, E300), sodium benzoate and potassium benzoate may form benzene. In 2006, the Food and Drug Administration tested 100 beverages available in the United States that contained both ascorbic acid and benzoate. Four had benzene levels that were above the 5 ppb Maximum Contaminant Level set by the Environmental Protection Agency for drinking water.<sup>[28]</sup> Most of the beverages that tested above the limit have been reformulated and subsequently tested below the safety limit.<sup>[28]</sup> Heat, light and shelf life can increase the rate at which benzene is formed. Hot peppers naturally contain vitamin C ("nearly as much as in one orange"<sup>[29]</sup>) so the observation about beverages applies to pepper sauces containing sodium benzoate, like Texas Pete.

ADHD and Hyperactivity

Research published, including in 2007 for the UK's Food Standards Agency (FSA) suggests that certain artificial colors, when paired with sodium benzoate, may be linked to hyperactive behavior and other ADHD symptoms. The results were inconsistent regarding sodium benzoate, so the FSA recommended further study.<sup>[30][31][32]</sup> The Food Standards Agency concluded that the observed increases in hyperactive behavior, if real, were more likely to be linked to the artificial colors than to sodium benzoate.<sup>[32]</sup> The report's author, Jim Stevenson from Southampton University, said: "The results suggest that consumption of certain mixtures of artificial food colours and sodium benzoate preservative are associated with increases in hyperactive behaviour in children. . . . Many other influences are at work but this at least is one a child can avoid."<sup>[32]</sup>

Potassium benzoate (E212), the potassium salt of benzoic acid, is a food preservative that inhibits the growth of mold, yeast and some bacteria. It works best in low-pH products, below 4.5, where it exists as benzoic acid.

Acidic foods and beverages such as fruit juice (citric acid), sparkling drinks (carbonic acid), soft drinks (phosphoric acid), and pickles (vinegar) may be preserved with potassium benzoate. It is approved for use in most countries including Canada, the United States and the European Union, where it is designated by the E number E212.

Potassium benzoate is also used in the whistle in many fireworks.<sup>[4]</sup>



## Synthesis

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One very common way to make potassium benzoate is by oxidizing toluene to benzoic acid followed by a neutralization with potassium hydroxide:<sup>[5]</sup>

Another way to synthesize potassium benzoate in the lab setting is by hydrolyzing methyl benzoate with potassium hydroxide:

### Reactions

Potassium benzoate, like sodium benzoate, can be decarboxylated with a strong base and heat:

### Mechanism of food preservation

The mechanism of food preservation begins with the absorption of benzoic acid into the cell. If the intracellular pH changes to 5 or lower, the anaerobic fermentation of glucose through phosphofructokinase is decreased by 95%.

## Safety and health

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Potassium benzoate has low acute toxicity upon oral and dermal exposure.<sup>[6]</sup> The Food Commission, which campaigns for safer, healthier food in the UK, describes potassium benzoate as "mildly irritant to the skin, eyes and mucous membranes".<sup>[7]</sup>

Cats have a significantly lower tolerance to benzoic acid and its salts than rats and mice.<sup>[8]</sup>

Under certain circumstances, such as in the presence of ascorbic acid, benzoate salts can produce benzene in soft drinks. The US Food and Drug Administration states the levels of benzene measured do not pose a safety concern for consumers.<sup>[9]</sup>

## Spectra

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### Carbon-13 NMR

The carbon-13 NMR shows 5 unique peaks. There are four peaks between 130-140 ppm from the carbon atoms in the benzene ring. There is an additional carbon peak around 178 ppm representing the carbon atom from the carbonyl group.<sup>[10]</sup>

### Infrared spectrum

The following are the main peaks in the IR spectrum.<sup>[10]</sup>

- 1610: C=O from carbonyl
- 1580: C=C from benzene ring

## CHAPTER-5

Canning is a method of food preservation in which food is processed and sealed in an airtight container (jars like Mason jars, and steel and tin cans). Canning provides a shelf life that typically ranges from one to five years, although under specific circumstances, it can be much longer.<sup>[1]</sup> A freeze-dried canned product, such as canned dried lentils, could last as long as 30 years in an edible state.

In 1974, samples of canned food from the wreck of the *Bertrand*, a steamboat that sank in the Missouri River in 1865, were tested by the National Food Processors Association. Although appearance, smell, and vitamin content had deteriorated, there was no trace of microbial growth and the 109-year-old food was determined to be still safe to eat.<sup>[2]</sup>

In the beginning of the 19th century the process of canning foods was mainly done by small canneries. These canneries were full of overlooked sanitation problems, such as poor hygiene and unsanitary work environments. Since the refrigerator did not exist and industrial canning standards were not set in place it was very common for contaminated cans to slip onto the grocery store shelves.<sup>[16]</sup>

According to *The Fruits of Empire: Art, Food and the Politics of Race in the Age of American Expansion* by Shana Klein, "Workers also suffered injuries, specifically bruised knuckles and open sores, from trimming and packaging pineapples. Gloves were one preventative measure to protect a canner's hands from the acidity of the pineapple, but gloves did not always help."



In canning toxicology, *migration* is the movement of substances from the can itself into the contents.<sup>[18]</sup> Potential toxic substances that can migrate are lead, causing lead poisoning, or bisphenol A (BPA), a potential endocrine disruptor that is an ingredient in the epoxy commonly used to coat the inner surface of cans. Some cans are manufactured with a BPA-free enamel lining produced from plant oils and resins.<sup>[19]</sup> In February 2018, the Can Manufacturers Institute, a trade association in the United States, surveyed the industry and reported that at least 90% of food cans no longer contained BPA.<sup>[20]</sup>

#### Salt content

Salt (sodium chloride), dissolved in water, is used in the canning process.<sup>[21]</sup> As a result, canned food can be a major source of dietary salt.<sup>[22]</sup> Too much salt increases the risk of health problems, including high blood pressure. Therefore, health authorities have recommended limitations of dietary sodium.<sup>[23][24][25][26][27]</sup> Many canned products are available in low-salt and no-salt alternatives.

Rinsing thoroughly after opening may reduce the amount of salt in canned vegetables, since much of the salt content is thought to be in the liquid, rather than the food itself.<sup>[28]</sup>

#### Botulism

Foodborne botulism results from contaminated foodstuffs in which *C. botulinum* spores have been allowed to germinate and produce botulism toxin,<sup>[29]</sup> and this typically occurs in canned non-acidic food substances that have not received a strong enough thermal heat treatment. *C. botulinum* prefers low oxygen environments and is a poor competitor to other bacteria, but its spores are resistant to thermal treatments. When a canned food is sterilized insufficiently, most other bacteria besides the *C. botulinum* spores are killed, and the spores can germinate and produce botulism toxin.<sup>[29]</sup> Botulism is a rare but serious paralytic illness, leading to paralysis that typically starts with the muscles of the face and then spreads towards the limbs.<sup>[30]</sup> The botulinum toxin is extremely dangerous because it cannot be detected by sight or smell, and ingestion of even a small amount of the toxin can be deadly.<sup>[31]</sup> In severe forms, it leads to paralysis of the breathing muscles and causes respiratory failure. In view of this life-threatening complication, all suspected cases of botulism are treated as medical emergencies, and public health officials are usually involved to prevent further cases from the same source.<sup>[30]</sup>

Nisin is a polycyclic antibacterial peptide produced by the bacterium *Lactococcus lactis* that is used as a food preservative. It has 34 amino acid residues, including the uncommon amino acids lanthionine (Lan), methyllanthionine (MeLan), didehydroalanine (Dha), and didehydroaminobutyric acid (Dhb). These unusual amino acids are introduced by posttranslational modification of the precursor peptide. In these reactions a ribosomally synthesized 57-mer is converted to the final peptide. The unsaturated amino acids originate from serine and threonine, and the enzyme-catalysed addition of cysteine residues to the didehydro amino acids result in the multiple (5) thioether bridges.

Subtilin and epidermin are related to nisin. All are members of a class of molecules known as lantibiotics.

In the food industry, nisin is obtained from the culturing of *L. lactis* on natural substrates, such as milk or dextrose, and it is not chemically synthesized.

It was originally isolated in the late 1930s, and produced since the 1950s as Nisaplin from naturally occurring sources by Aplin and Barrett in laboratories in Beaminster in Dorset (now owned by International\_Flavors\_&\_Fragrances), and approved as an additive for food use in the US in the late 1960s.<sup>[1]</sup>

#### Properties

While in general most bacteriocins inhibit only closely related species, nisin is a rare example of a "broad-spectrum" bacteriocin effective against many Gram-positive organisms, including lactic acid bacteria (commonly associated to avoid food spoilage), *Listeria monocytogenes* (a known pathogen), *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium botulinum*, etc.<sup>[2]</sup> It is also particularly effective against spores. Gram-negative bacteria are protected by their outer membrane but may become susceptible to nisin action after a heat shock or when this is coupled with the chelator EDTA. When used in combination with EDTA, nisin has the ability to inhibit *E. coli* O157:H7 and *Salmonella enterica*.<sup>[2]</sup> Nisin, as a class I bacteriocin, is very stable at acidic pHs and is more heat stable at lower pHs.<sup>[2]</sup> The mode of action of Nisin against pathogens such as *L. monocytogenes* is to dissipate the membrane potential and pH gradient.<sup>[2]</sup>

Nisin is soluble in water and can be effective at levels nearing the parts-per-billion range. Nisin concentration can be measured using various techniques such as chromatography or by a simple agar diffusion bioassay.<sup>[3]</sup>





## Applications

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### Food production

Nisin is used in processed cheese, meats, beverages, etc. during production to extend shelf life by suppressing Gram-positive spoilage and pathogenic bacteria. In foods, it is common to use nisin at levels ranging from ~1-25 ppm, depending on the food type and regulatory approval. As a food additive, nisin has an E number of E234.

### Other

Due to its naturally selective spectrum of activity, it is also employed as a selective agent in microbiological media for the isolation of gram-negative bacteria, yeast, and moulds.

Nisin has also been used in food packaging applications and can serve as a preservative by controlled release onto the food surface from the polymer packaging.<sup>[4]</sup>

In combination with miconazole it has been studied as a possible treatment for infections of *Clostridium difficile*.

## CHAPTER-6

Wine preservatives are used to preserve the quality and shelf life of bottled wine without affecting its taste. Specifically, they are used to prevent oxidation and bacterial spoilage by inhibiting microbial activity.<sup>[1]</sup>

Wine contains natural preservatives such as tannin, sugar and alcohol,<sup>[2]</sup> and can be preserved through physical preservation methods, such as storage at an appropriate temperature.<sup>[3]</sup> However, bacterial growth is still possible, so chemical preservatives are added to most wines.<sup>[1][4]</sup> Typical chemical preservatives include sulfur dioxide and its related chemicals, such as sulfites.<sup>[2]</sup>

The use of preservatives in wine has been shown to cause health problems in some consumers.

## Deterioration

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Despite the alcohol in wine, growth of bacteria is possible, even when completely fermented.<sup>[2]</sup> Wine is made from the fermentation of grape juice, which contains sugar.<sup>[4]</sup> During the fermentation process, yeast will convert sugar into alcohol.<sup>[5]</sup> If the fermentation is not complete, the wine will contain residual sugar content. The sugar acts as nutrient needed for the growth of bacteria, which can deteriorate the wine or even turn it into grape vinegar.<sup>[5]</sup> Because the alcohol content of wine is relatively low, the alcohol cannot completely inhibit the proliferation of bacteria. Long-term improper storage may accelerate deterioration.<sup>[4]</sup>

During the brewing process, microbial spoilage can lead to the deterioration of wine quality and taste, making it unhygienic and unacceptable to consumers.<sup>[5]</sup> The main bacterial groups are yeast, candida and *Hanseniaspora*.<sup>[5]</sup> In addition, microbial diseases of wine are mainly caused by yeast, lactobacillus and acetic acid bacteria.<sup>[6]</sup> This is because yeast may re-ferment a wine with high sugar content, making it cloudy and impure.<sup>[1]</sup> Lactic acid bacteria can cause acid spoilage in dry wine with low acidity and lactic acid bacteria disease in sweet wine with low acidity.<sup>[2]</sup> Acetic acid bacteria may cause the increase of volatile acid in wine, resulting in an undesirable sour vinegar taste.<sup>[2]</sup> These fungi are all bad for the safety and flavor of wine.<sup>[2]</sup>

## Preservatives

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Anything that extends the shelf life of red wine is considered a preservative. Preservatives are mainly divided into natural preservatives and chemical preservatives.<sup>[3]</sup>

### Natural preservatives

#### Tannins

Tannins, also known as polyphenols, are found in the xylem, bark, leaves, fruits and roots of plants.<sup>[3]</sup> Tannin molecules undergo polymerization to join into longer molecules<sup>[7]</sup> and turn it into a "protective colloids" that prevents or limits aggregation, flocculation and step haze formation and precipitation.<sup>[6]</sup> At the same time, tannins are also one of the main sources of bitterness and astringency in wines.<sup>[1]</sup> Its content and quality are one of the important factors in evaluating the quality of red wine.



### *Sugar*

Just as people use sugar or salt when making preserved foods, sugar is also a preservative for wine.<sup>[4]</sup> The sugar lowers the water activity of the food, meaning that less water is available for the bacteria, stunting its growth.<sup>[2]</sup> Salt is used as a preservative in the same way.<sup>[8]</sup>

### *Alcohol*

Alcohol is used as a preservative especially in spirits such as sherry.<sup>[3]</sup> Because common alcohol can have the same problems as acid when used as preservatives, the lack of acidity does not play a role of maintaining quality.<sup>[4]</sup>

### *Chemical preservatives*

Acid is widely used as a preservative. In red wine, Sulfurous anhydride or sulfur dioxide (SO<sub>2</sub>), in particular, is the most frequently used source.<sup>[4]</sup> Acid protects wine from bacteria by regulating the pH value, which affects the growth and vitality of yeast during fermentation.<sup>[2]</sup> Acidity also directly affects color, balance and taste.<sup>[2]</sup>

For example, sulfur dioxide, the most widely used preservative by wine merchants, has been used as a cleaning agent for centuries.<sup>[9]</sup> Sulphur dioxide has a pungent taste that people dislike, and its use has been controversial because of its disease-causing properties<sup>[10]</sup> (see section on the controversy).

Sorbic acid, which acts like sulfites, has recently been approved for use in European Community countries, but only under very limited conditions.<sup>[10]</sup> It must be effective in wines with an alcohol concentration of 12%.<sup>[11]</sup>

Apart from sulfur dioxide, which is used most frequently, other chemicals such as benzoic acid, diethyl pyrocarbonate, parabens, pimaricin and sorbic acid are also used as preservatives in wine, but the potential threat or side effects of these chemicals are still to be investigated, so they are not permitted to be used in large quantities for the time being.<sup>[10]</sup>

### *Weak acid*

Compared with other preservatives, weak acids are characterized by their antiseptic effect by slowing down the growth and reproduction cycle of microorganisms rather than killing them.<sup>[12]</sup> Weak acids inhibit microbial growth by dissociating protons from cells.<sup>[12]</sup> Although the chemical formula of different weak acids is different, they all play a more obvious inhibitory effect in the environment with a low pH value; that is, the more acidic the environment, the greater the inhibitory effect.<sup>[12]</sup> This practice was first discovered by John Evelyn in 1670, who used sulfur dioxide from burning sulfur to preserve cider.<sup>[12]</sup>

### *Tartaric acid*

In hot climates, tartaric acid is added when grapes become too ripe for natural acidity.<sup>[7]</sup> Most people agree that grapes should be picked when there is a balance between optimum ripeness and acidity, and there are many factors that can reduce the acidity of the wine-making process.<sup>[9]</sup> Acidification is widespread in Argentina, Australia, California, Washington, Italy and South Africa.<sup>[9]</sup> It is not common in northern France, Germany, Austria, Oregon and New Zealand.<sup>[4]</sup>

### *Calcium carbonate*

In contrast to tartaric acid, if the grapes are too acidic, calcium carbonate is used to bring them down to the level needed to make wine.<sup>[10]</sup>

In addition, many also use oak, oak slices, fermentation agents, tutu, and more, according to the quality of grapes and the different styles of wine. The need for additives and the amount used depends on the winemaker, as different winemakers make different choices.<sup>[7]</sup>

### The basic principle of preservatives against oxidation

Wine has different preservatives from other drinks such as milk, juice and beer. Its preservatives work primarily by inhibiting the growth of microorganisms through oxidation.<sup>[3]</sup> However, because different kinds of wine have different aromas, colors and flavors, they should not use the same preservatives.<sup>[3]</sup> For example, the preservatives added to white wine are mainly ascorbic acid (vitamin C) and sorbic acid.<sup>[13]</sup> Ascorbic acid is used as an antioxidant, while sorbic acid is used to inhibit the growth of yeast in white wine.<sup>[3]</sup> Sorbic acid cannot be used in red wine because it can cause pollution. Sulfites, or small molecules of sulfur dioxide (SO<sub>2</sub>) and hydrogen disulfide (H<sub>2</sub>O<sub>2</sub>), are commonly used as preservatives in wine and even other fruit drinks.<sup>[7]</sup> Their principle is basically to make microbial protein coagulation or denaturation, thereby interfering with their growth and reproduction.<sup>[7]</sup> Sulfites are mainly in the form of sulfur dioxide at different pH concentrations.<sup>[10]</sup> Experiments show that only the sulfur dioxide molecule has an antibacterial



effect.<sup>[14]</sup> That's the active ingredient in preservatives. Sulfur dioxide inactivates by combining with compounds derived from wine.<sup>[14]</sup> Because of the nature of sulfur dioxide, it is more effective at lower pH concentrations and at higher ethanol concentrations,<sup>[15]</sup> finally achieving the function of anti-corrosion.

#### Preservatives controversy

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Allergy to preservatives has aroused people's concern.<sup>[4]</sup> Studies have shown that a possible cause of allergy in wine ingredients is an adverse reaction to sulfur dioxide by asthma patients. Sulfur dioxide allergy was the cause of 1.7% of asthma patients.<sup>[4]</sup> It is not precisely a true statement that a person is allergic to preservatives, but rather, the person may be allergic to preservatives that contain sulfur dioxide.<sup>[13]</sup> The controversy over preservatives has not entirely disappeared,<sup>[4]</sup> but sulfur dioxide is still the most widely used preservative in wine at this stage because it is effective and no alternative chemical additive has been found.<sup>[10]</sup>

People are concerned about their health and have higher requirements for food quality.<sup>[16]</sup> Because of the controversy, disease-causing preservatives have been used as sparingly as possible<sup>[16]</sup> or clearly labeled on wine bottles to make it easier for people with the disease to stay informed.<sup>[4]</sup> Meanwhile, people are increasingly looking for safe and healthy wine preservatives.<sup>[4]</sup>

In addition to traditional preservation methods that do not require preservatives, such as cryopreservation,<sup>[17]</sup> it is evident that there are many new technologies, such as high hydrostatic pressure (HHP) and pulsed electric fields (PEF) that can also play a beneficial role in food preservation.<sup>[13]</sup> Whether these new technologies can replace chemical preservatives is worth considering.<sup>[13]</sup> In addition, researchers have targeted potential biological preservatives, such as antimicrobial peptides and bacteriolytic enzymes.<sup>[5]</sup> There is still a lot of research space for biological preservatives, which is relatively safe and has certain benefits.<sup>[5]</sup>

#### Known health effects due to preservatives

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It has been reported that many food preservatives, including sorbitan, hydrogen peroxide, benzoic acid and sodium benzoate, can cause health problems, especially in high doses.<sup>[16]</sup> In addition, as mentioned in the controversy section, the adverse effects of sulfites on asthma patients also confirmed the health threat of preservatives containing this substance.<sup>[18]</sup> In the meantime, sulfite accumulates can decompose sulfur dioxide and also have certain stimulation to lungs.<sup>[19]</sup> Therefore, some people are urging that sulfur dioxide be banned as a preservative and food additive, in wine and other food and beverages.<sup>[10]</sup>

Propionic acid, which is also used as a preservative, has also been shown to be carcinogenic in rodents.<sup>[8]</sup> However, there are currently only two ways to minimize the health threat of sulfur dioxide.<sup>[10]</sup> One is to try to reduce the dose of sulfur dioxide, which is already happening.<sup>[10]</sup> The second is to study the chemical structure and characteristics of sulfur dioxide, looking for alternative chemical preservatives.<sup>[10]</sup> This requires a lot of scientific research efforts and has not seen effective results in a short time.<sup>[10]</sup>

Experts studying wine preservatives have discovered that a specific type of wine yeast can be made<sup>[17]</sup> using the substances secreted by yeast during fermentation as new biological preservatives may reduce the threat of wine preservatives to life and health.<sup>[17]</sup> But the possibility of adding antibacterial compounds to the manufacturing process may prevent the risk from being completely avoided, so the study is ongoing.<sup>[20]</sup>

Monosodium glutamate (MSG) is a flavor enhancer often added to restaurant foods, canned vegetables, soups, deli meats and other foods. The U.S. Food and Drug Administration (FDA) has classified MSG as a food ingredient that's generally recognized as safe. But its use is still debated. For this reason, when MSG is added to food, the FDA requires it to be listed on the label.

MSG has been used as a food additive for many years. During this time, the FDA has received many reports of concerning reactions that people have attributed to foods that had MSG in them. These reactions — called MSG symptom complex — include:

- Headache
- Flushing
- Sweating
- Face pressure or tightness
- Lack of feeling (numbness), tingling or burning in the face, neck and other areas
- Quick, fluttering heartbeats





- Chest pain
- Feeling sick (nausea)
- Weakness

But researchers have found no clear proof of a link between MSG and these symptoms. Researchers admit, though, that a small number of people may have short-term reactions to MSG. Symptoms are often mild and don't need to be treated. The only way to prevent a reaction is to not eat foods that have MSG in them.

The topic of sulfite food and beverage additives covers the application of sulfites in food chemistry. "Sulfite" is jargon that encompasses a variety of materials that are commonly used as preservatives or food additive in the production of diverse foods and beverages. Although sulfite salts are relatively nontoxic, their use has led to controversy, resulting in extensive regulations. Sulfites are a source of sulfur dioxide (SO<sub>2</sub>), a bactericide.

### Chemical principles

#### Inventory

- sodium bisulfite, NaHSO<sub>3</sub>: ill-defined, widely used source of bisulfite, which predominates below pH 7
- sodium metabisulfite, Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>: well-defined, widely used source of bisulfite, which predominates below pH 7
- potassium bisulfite, KHSO<sub>3</sub>: ill-defined, widely used source of bisulfite, which predominates below pH 7
- potassium metabisulfite, K<sub>2</sub>S<sub>2</sub>O<sub>5</sub>: well-defined, widely used source of bisulfite, which predominates below pH 7
- sodium sulfite, Na<sub>2</sub>SO<sub>3</sub>: well-defined, widely used source of sulfite, which predominates above pH 7
- potassium sulfite, K<sub>2</sub>SO<sub>3</sub>: well-defined, widely used source of sulfite, which predominates above pH 7

#### Descriptive chemistry

Sulfite is SO<sub>3</sub><sup>2-</sup>, available as its sodium and potassium salts, Na<sub>2</sub>SO<sub>3</sub> and K<sub>2</sub>SO<sub>3</sub>, respectively. When dissolved in water, these salts react with oxygen to give the corresponding sulfate salts, which are innocuous. Sodium sulfite used industrial as a corrosion inhibitor/oxygen scavenger.

Monoprotonation of sulfite gives HSO<sub>3</sub><sup>-</sup>, which is called bisulfite. The sodium and potassium salts of bisulfite are not available, but solid and solutions of the approximate formula NaHSO<sub>3</sub> and KHSO<sub>3</sub> are widely marketed as sodium bisulfite and potassium bisulfite. Closely related are the metabisulfite salts with formula Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, respectively sodium metabisulfite and potassium metabisulfite. These salts dissolve to give solutions containing the bisulfite ion.

### E numbers

E numbers for sulfites as food additives are:

E150b	Caustic sulfite caramel
E150d	Sulfite ammonia caramel
E220	Sulfur dioxide
E221	Sodium sulfite
E222	Sodium bisulfite (sodium hydrogen sulfite)
E223	Sodium metabisulfite
E224	Potassium metabisulfite
E225	Potassium sulfite
E226	Calcium sulfite
E227	Calcium hydrogen sulfite (preservative)
E228	Potassium hydrogen sulfite

#### Use in wine and beer industry

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Sulfites occur naturally in wines to some extent.<sup>[1][2][3]</sup> Sulfites are commonly introduced to arrest fermentation at a desired time, and may also be added to wine as preservatives to prevent spoilage and oxidation at several stages of the winemaking. Sulfur dioxide (SO<sub>2</sub>) protects wine from not only oxidation, but also from bacteria. Without sulfites, grape juice would quickly turn to vinegar.<sup>[4]</sup>

Organic wines are not necessarily sulfite-free, but generally have lower amounts and regulations stipulate lower maximum sulfite contents for these wines. In general, white wines contain more sulfites than red wines and sweeter wines contain more sulfites than drier ones.<sup>[5]</sup>

The compound sodium metabisulfite is used in almost all commercial wines to prevent oxidation and preserve flavor, sodium bisulfite is sold by some home winemaking suppliers for the same purpose.<sup>[6]</sup> In fruit canning, sodium bisulfite is used to prevent browning (caused by oxidation) and to kill microbes. The sulfur dioxide released by these salts kills yeasts, fungi, and bacteria in the grape juice before fermentation. Once the levels of sulfur dioxide have subsided (about 24 hours), fresh yeast is added for fermentation.

It is later added to bottled wine to prevent the formation of vinegar if bacteria are present, and to protect the color, aroma and flavor of the wine from oxidation, which causes browning and other chemical changes.

Sodium metabisulfite and potassium metabisulfite are the primary ingredients in Campden tablets, used for wine and beer making.<sup>[7]</sup> Most beers no longer contain sulfites, although some alcoholic ciders contain them.

#### Other foods

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Shrimp are sometimes treated with sulfites on fishing vessels, the chemical may not appear on the label.

#### Vegetables and fruit

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Sulfites are often used as preservatives in dried fruits, preserved radish, and dried potato products. Sodium bisulfite is also added to leafy green vegetables in salad bars and elsewhere, to preserve freshness, under names like LeafGreen. It can be used to preserve color of some fruits, such as bananas.<sup>[8]</sup>

#### Regulation and safety

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##### Australia and New Zealand

It is approved for use in Australia and New Zealand<sup>[9]</sup>

In Australia and New Zealand, sulfites must be declared in the statement of ingredients when present in packaged foods in concentrations of 10 mg/kg (ppm) or more as an ingredient; or as an ingredient of a compound ingredient; or as a food additive or component of a food additive; or as a processing aid or component of a processing aid.<sup>[10]</sup>

##### Canada

Sulfites that can be added to foods in Canada are potassium bisulfite, potassium metabisulfite, sodium bisulfite, sodium dithionite, sodium metabisulfite, sodium sulfite, sulfur dioxide and sulfurous acid. These can also be declared using the common names sulfites, sulfates, sulfiting agents.<sup>[11]</sup>

##### EU

In the European Union, "EU law requires food labels to indicate "contains sulfites" (when exceeding 10 milligrams per kilogram or per litre) without specifying the amount".<sup>[12]</sup>

In the European Union an equivalent regulation came into force in November 2005.<sup>[13]</sup> In 2012, a new regulation for organic wines came into force.<sup>[14]</sup>

##### UK

In the United Kingdom, similar laws to the EU apply. Bottles of wine that contain over 10 mg/L (ppm) of sulfites are required to bear "contains sulphites" on the label.<sup>[15]</sup> This does not differ whether sulfites are naturally occurring or added in the winemaking process.<sup>[16]</sup>



US

In 1986, the U.S. Food and Drug Administration banned the addition of sulfites to all fresh fruit and vegetables that are eaten raw.<sup>[17]</sup>

In 1986, the U.S. Food and Drug Administration banned the use of sulfites as preservatives on foods intended to be eaten fresh (such as salad ingredients).<sup>[17]</sup> This has contributed to the increased use of erythorbic acid and its salts as preservatives.<sup>[18]</sup>

Generally, U.S. labeling regulations do not require products to indicate the presence of sulfites in foods unless it is added specifically as a preservative;<sup>[17]</sup> still, many companies voluntarily label sulfite-containing foods.<sup>[19]</sup> Sulfites used in food processing (but not as a preservative) are required to be listed if they are not incidental additives (21 CFR 101.100(a)(3)), and if there are more than 10 ppm in the finished product (21 CFR 101.100(a)(4)) On July 8, 1986, sodium bisulfite (and other sulfites : "The chemicals affected by the order are sulfur dioxide, sodium sulfite, sodium bisulfite, potassium bisulfite, sodium metabisulfite and potassium metabisulfite.") was banned from use by the U.S. FDA on fresh fruits and vegetables following the deaths of 13 people and many illnesses, mainly among asthmatics.<sup>[20]</sup>

In the United States, wines bottled after mid-1987 must have a label stating that they contain sulfites if they contain more than 10 parts per million (ppm).<sup>[21]</sup>

## Safety

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### Toxicity

Sodium bisulfite has low toxicity, 130 mg/kg (mice, intravenous).<sup>[22]</sup> According to another source<sup>[who?]</sup>, the acceptable daily intake is up to 0.7 milligrams per kilogram of body weight.<sup>[23]</sup> Sodium metabisulfite oxidizes in the liver to harmless sulfate which is excreted in the urine.<sup>[23]</sup>

### Other health effects

It may cause adverse reactions in those who are sensitive to sulfites, including respiratory reactions in asthmatics, anaphylaxis, and other allergic reactions in sensitive individuals.<sup>[24][25]</sup>

Adverse reactions to sulfites appear to be very rare in the general population.<sup>[26]</sup> An adverse reaction to sulfite is not a true allergy.<sup>[27]</sup> Chronic skin conditions in the hands, perineum, and face have been reported in individuals that regularly use cosmetics or medications containing sulfites. Occupational exposure to sulfites has been reported to cause persistent skin symptoms.<sup>[28]</sup>

Breathing difficulty can commence within minutes after eating a food containing sulfites.<sup>[29]</sup> Asthmatics<sup>[30][31]</sup> may experience asthma attacks from sulfite fumes as well. Other potential symptoms include sneezing, swelling of the throat, hives, and migraine.<sup>[32][33][34]</sup>

A 2017 study has shown negative impacts from sulfites on bacteria found in the human microbiome.<sup>[35]</sup>

## CHAPTER-7

A wine fault is a sensory-associated (organoleptic<sup>[1]</sup>) characteristic of a wine that is unpleasant, and may include elements of taste, smell, or appearance, elements that may arise from a "chemical or a microbial origin", where particular sensory experiences (e.g., an off-odor) might arise from more than one wine fault.<sup>[2]</sup> Wine faults may result from poor winemaking practices or storage conditions that lead to *wine spoilage*.<sup>[1]</sup>

In the case of a chemical origin, many compounds causing wine faults are already naturally present in wine, but at insufficient concentrations to be of issue, and in fact may impart positive characters to the wine; however, when the concentration of such compounds exceed a sensory threshold, they replace or obscure desirable flavors and aromas that the winemaker wants the wine to express. The ultimate result is that the quality of the wine is reduced (less appealing, sometimes undrinkable), with consequent impact on its value.<sup>[3]</sup>

There are many underlying causes of wine faults, including poor hygiene at the winery, excessive or insufficient exposure of the wine to oxygen, excessive or insufficient exposure of the wine to sulphur, overextended maceration of the wine either pre- or post-fermentation, faulty fining, filtering and stabilization of the wine, the use of dirty oak barrels, over-extended barrel aging and the use of poor quality corks. Outside of the winery, other factors within the control of the retailer or end user of the wine can contribute to the perception of flaws in the wine. These include poor storage of the wine that exposes it to excessive heat and temperature fluctuations as well as the use of



dirty stemware during wine tasting that can introduce materials or aromas to what was previously a clean and fault-free wine.<sup>[3]</sup>

Differences between flaws and faults

In wine tasting, there is a big distinction made between what is considered a *flaw* and a *fault*. Wine flaws are minor attributes that depart from what are perceived as normal wine characteristics. These include excessive sulfur dioxide, volatile acidity, *Brettanomyces* or "Brett aromas" and diacetyl or buttery aromas. The amount to which these aromas or attributes become excessive is dependent on the particular tastes and recognition threshold of the wine taster. Generally, a wine exhibiting these qualities is still considered drinkable by most people. However, some flaws such as volatile acidity and *Brettanomyces* can be considered a fault when they are in such an excess that they overwhelm other components of the wine. Wine faults are generally major attributes that make a wine undrinkable to most wine tasters. Examples of wine faults include acetaldehyde (except when purposely induced in wines like Sherry and Rancio), ethyl acetate and cork taint.<sup>[3]</sup>

Detecting faults in wine tasting

The vast majority of wine faults are detected by the nose and the distinctive aromas that they give off. However, the presence of some wine faults can be detected by visual and taste perceptions. For example, premature oxidation can be noticed by the yellowing and browning of the wine's color. The sign of gas bubbles in wines that are not meant to be sparkling can be a sign of refermentation or malolactic fermentation happening in the bottle. Unusual breaks in the color of the wine could be a sign of excessive copper, iron or proteins that were not removed during fining or filtering. A wine with an unusual color for its variety or wine region could be a sign of excessive or insufficient maceration as well as poor temperature controls during fermentation. Tactile clues of potential wine faults include the burning, acidic taste associated with volatile acidity that can make a wine seem out of balance.<sup>[3][4]</sup>

Wine fault	Characteristics
Acetaldehyde	Smell of roasted nuts or dried out straw. Often described as green apples and emulsion paint. Commonly associated with Sherries where these aromas are considered acceptable
Amyl-acetate	Smell of "fake" candy banana flavoring
Brettanomyces	Smell of barnyards, fecal and gamey horse aromas
Cork taint	Smell of a damp basement, wet cardboard or newspapers and mushrooms
Butyric acid	Smell of rancid butter
Ethyl acetate	Smell of vinegar, paint thinner and nail polish remover
Hydrogen sulfide	Smell of rotten eggs or garlic that has gone bad
Iodine	Smell of moldy grapes
Lactic acid bacteria	Smell of sauerkraut
Mercaptans	Smell of burnt garlic or onion
Oxidation	Smell of cooked fruit and walnuts. Also detectable visually by premature browning or yellowing of the wine
Sorbic acid plus lactic acid bacteria	Smell of crushed geranium leaves

Sulfur dioxide                      Smell of burnt matches. Can also come across as a pricking sensation in the nose.

#### Oxidation

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The oxidation of wine is perhaps the most common of wine faults, as the presence of oxygen and a catalyst are the only requirements for the process to occur. Oxidation can occur throughout the winemaking process, and even after the wine has been bottled. Anthocyanins, catechins, epicatechins and other phenols present in wine are those most easily oxidised,<sup>[5]</sup> which leads to a loss of colour, flavour and aroma - sometimes referred to as *flattening*. In most cases compounds such as sulfur dioxide or erythorbic acid are added to wine by winemakers, which protect the wine from oxidation and also bind with some of the oxidation products to reduce their organoleptic effect.<sup>[6]</sup> Apart from phenolic oxidation, the ethanol present within wine can also be oxidised into other compounds responsible for flavour and aroma taints. Some wine styles can be oxidised intentionally, as in certain Sherry wines and Vin jaune from the Jura region of France.

#### Acetaldehyde

Acetaldehyde is an intermediate product of yeast fermentation; however, it is more commonly associated with ethanol oxidation catalysed by the enzyme ethanol dehydrogenase. Acetaldehyde production is also associated with the presence of surface film forming yeasts and bacteria, such as acetic acid bacteria, which form the compound by the decarboxylation of pyruvate. The sensory threshold for acetaldehyde is 100-125 mg/L. Beyond this level it imparts a *sherry* type character to the wine which can also be described as *green apple*, *sour* and *metallic*. Acetaldehyde intoxication is also implicated in hangovers.

#### Acetic acid

Acetic acid in wine, often referred to as volatile acidity (VA) or *vinegar taint*, can be contributed by many wine spoilage yeasts and bacteria. This can be from either a by-product of fermentation, or due to the spoilage of finished wine. Acetic acid bacteria, such as those from the genera *Acetobacter* and *Gluconobacter* produce high levels of acetic acid. The sensory threshold for acetic acid in wine is >700 mg/L, with concentrations greater than 1.2-1.3 g/L becoming unpleasant.

There are different opinions as to what level of volatile acidity is appropriate for higher quality wine. Although too high a concentration is sure to leave an undesirable, 'vinegar' tasting wine, some wine's acetic acid levels are developed to create a more 'complex', desirable taste.<sup>[7]</sup> The renowned 1947 Cheval Blanc is widely recognized to contain high levels of volatile acidity.

Ethyl acetate is formed in wine by the esterification of ethanol and acetic acid. Therefore, wines with high acetic acid levels are more likely to see ethyl acetate formation, but the compound does not contribute to the volatile acidity. It is a common microbial fault produced by wine spoilage yeasts, particularly *Pichia anomala* or *Kloeckera apiculata*. High levels of ethyl acetate are also produced by lactic acid bacteria and acetic acid bacteria.

#### Sulfur compounds

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Sulfur is used as an additive throughout the winemaking process, primarily to stop oxidation as mentioned above but also as antimicrobial agent. When managed properly in wine, its presence there is often undetected, however when used recklessly it can contribute to flavour and aroma taints which are very volatile and potent. Sulfur compounds typically have low sensory thresholds.

#### Sulfur dioxide

Sulfur dioxide is a common wine additive, used for its antioxidant and preservative properties. When its use is not managed well it can be overadded, with its perception in wine reminiscent of *matchsticks*, *burnt rubber*, or *mothballs*. Wines such as these are often termed *sulfitic*.

#### Hydrogen sulfide

Hydrogen sulfide (H<sub>2</sub>S) is generally thought to be a metabolic by-product of yeast fermentation in nitrogen limited environments. It is formed when yeast ferments via the sulfate reduction pathway. Fermenting wine is often supplemented with diammonium phosphate (DAP) as a nitrogen source to prevent H<sub>2</sub>S formation. The sensory



threshold for hydrogen sulfide is 8-10 µg/L, with levels above this imparting a distinct *rotten egg* aroma to the wine. Hydrogen sulfide can further react with wine compounds to form mercaptans and disulfides.

#### Mercaptans

Mercaptans (thiols) are produced in wine by the reaction of hydrogen sulfide with other wine components such as ethanol. They can be formed if finished wine is allowed prolonged contact with the lees. This can be prevented by racking the wine. Mercaptans have a very low sensory threshold, around 1.5 µg/L,<sup>[8]</sup> with levels above causing *onion*, *rubber*, and *skunk* type odours. Note that dimethyl disulfide is formed from the oxidation of methyl mercaptan.

#### Dimethyl sulfide

Dimethyl sulfide (DMS) is naturally present in most wines, probably from the breakdown of sulfur containing amino acids. Like ethyl acetate, levels of DMS below the sensory threshold can have a positive effect on flavour, contributing to *fruitiness*, *fullness*, and *complexity*. Levels above the sensory threshold of >30 µg/L in white wines and >50 µg/L for red wines, give the wine characteristics of *cooked cabbage*, *canned corn*, *asparagus* or *truffles*.

#### Environmental

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##### Cork taint

Cork taint is a wine fault mostly attributed to the compound 2,4,6-trichloroanisole (TCA), although other compounds such as guaiacol, geosmin, 2-methylisoborneol, 1-octen-3-ol, 1-octen-3-one, 2,3,4,6-tetrachloroanisole, pentachloroanisole, and 2,4,6-tribromoanisole are also thought to be involved.<sup>[9]</sup> TCA most likely originates as a metabolite of mould growth on chlorine-bleached wine corks and barrels. It causes *earthy*, *mouldy*, and *musty* aromas in wine that easily mask the natural fruit aromas, making the wine very unappealing. Wines in this state are often described as "*corked*". As cork taint has gained a wide reputation as a wine fault, other faults are often mistakenly attributed to it.

##### Heat damage

Heat damaged wines are often casually referred to as *cooked*, which suggests how heat can affect a wine. They are also known as maderized wine, from Madeira wine, which is intentionally exposed to heat. The ideal storage temperature for wine is generally accepted to be 13 °C (55 °F). Wines that are stored at temperatures greatly higher than this will experience an increased aging rate. Wines exposed to extreme temperatures will thermally expand, and may even push up between the cork and bottle and leak from the top. When opening a bottle of wine, if a trace of wine is visible along the length of the cork, the cork is partially pushed out of the bottle, or wine is visible on the top of the cork while it is still in the bottle, it has most likely been heat damaged. Heat damaged wines often become oxidized, and red wines may take on a brick color.

Even if the temperatures do not reach extremes, temperature variation alone can also damage bottled wine through oxidation. All corks allow some leakage of air (hence old wines become increasingly oxidized), and temperature fluctuations will vary the pressure differential between the inside and outside of the bottle and will act to "pump" air into the bottle at a faster rate than will occur at any temperature strictly maintained.

Reputedly, heat damage is the most widespread and common problem found in wines. It often goes unnoticed because of the prevalence of the problem, consumers don't know it's possible, and most often would just chalk the problem up to poor quality, or other factors.

##### Lightstrike

Lightstruck wines are those that have had excessive exposure to ultraviolet light, particularly in the range 325 to 450 nm.<sup>[10]</sup> Very delicate wines, such as Champagnes, are generally worst affected, with the fault causing a *wet cardboard* or *wet wool* type flavour and aroma. Red wines rarely become lightstruck because of the phenolic compounds present within the wine that protect it. Lightstrike is thought to be caused by sulfur compounds such as dimethyl sulfide. In France lightstrike is known as "*goût de lumière*", which translates to *a taste of light*. The fault explains why wines are generally bottled in coloured glass, which blocks the ultraviolet light, and why wine should be stored in dark environments.

##### Ladybird (pyrazine) taint

Some insects present in the grapes at harvest inevitably end up in the press and for the most part are inoffensive. Others, notably the Asian lady beetle, release unpleasant smelling nitrogen heterocycles as a defensive mechanism





when disturbed. In sufficient quantities these can affect the wine's odor and taste. With an olfactory detection threshold of a few ppb, the principal active compound is isopropyl methoxy pyrazine - this molecule is perceived as rancid peanut butter, green bell pepper, urine, or simply bitter. This is also a naturally occurring compound in Sauvignon grapes and so pyrazine taint has been known to make Rieslings taste like Sauvignon blanc.

### Microbiological

#### *Brettanomyces (Dekkera)*

The yeast *Brettanomyces* produces an array of metabolites when growing in wine, some of which are volatile phenolic compounds. Together these compounds are often referred to as *phenolic taint*, "*Brettanomyces character*", or simply "Brett". The main constituents are listed below, with their sensory threshold and common sensory descriptors:

- 4-ethylphenol (>140 µg/L): Band-aids, barnyard, horse stable, antiseptic
- 4-ethylguaiacol (>600 µg/L): Bacon, spice, cloves, smoky
- isovaleric acid: Sweaty, cheese, rancidity

#### Geosmin

Geosmin is a compound with a very distinct *earthy, musty, beetroot, even turnip* flavour and aroma and has an extremely low sensory threshold of down to 10 parts per trillion. Its presence in wine is usually derived as metabolite from the growth of filamentous actinomycetes such as *Streptomyces*, and moulds such as *Botrytis cinerea* and *Penicillium expansum*, on grapes. Wines affected by but not attributed to geosmins are often thought to have earthy properties due to terroir.<sup>[11]</sup> The geosmin fault occurs worldwide and has been found in recent vintages of red wines from Beaujolais, Bordeaux, Burgundy and the Loire in France. Geosmin is also thought to be a contributing factor in cork taint.

#### Lactic acid bacteria

Lactic acid bacteria have a useful role in winemaking converting malic acid to lactic acid in malolactic fermentation. However, after this function has completed, the bacteria may still be present within the wine, where they can metabolise other compounds and produce wine faults. Wines that have not undergone malolactic fermentation may be contaminated with lactic acid bacteria, leading to refermentation of the wine with it becoming turbid, *swampy*, and slightly effervescent or *spritz*. This can be avoided by sterile filtering wine directly before bottling. Lactic acid bacteria can also be responsible for other wine faults such as those below.

#### *Bitterness taint*

Bitterness taint or *amertume* is rather uncommon and is produced by certain strains of bacteria from the genera *Pediococcus*, *Lactobacillus*, and *Oenococcus*. It begins by the degradation of glycerol, a compound naturally found in wine at levels of 5-8 g/L, via a dehydratase enzyme to *3-hydroxypropionaldehyde*. During ageing this is further dehydrated to acrolein which reacts with the anthocyanins and other phenols present within the wine to form the taint.<sup>[12]</sup> As red wines contain high levels of anthocyanins they are generally more susceptible.

#### *Diacetyl*

Diacetyl in wine is produced by lactic acid bacteria, mainly *Oenococcus oeni*. In low levels it can impart positive *nutty* or *caramel* characters, however at levels above 5 mg/L it creates an intense *buttery* or *butterscotch* flavour, where it is perceived as a flaw. The sensory threshold for the compound can vary depending on the levels of certain wine components, such as sulfur dioxide. It can be produced as a metabolite of citric acid when all of the malic acid has been consumed. Diacetyl rarely taints wine to levels where it becomes undrinkable.<sup>[13]</sup>

#### *Geranium taint*

Geranium taint, as the name suggests, is a flavour and aroma taint in wine reminiscent of geranium leaves. The compound responsible is *2-ethoxyhexa-3,5-diene*, which has a low sensory threshold concentration of 1 ng/L.<sup>[14]</sup> In wine it is formed during the metabolism of potassium sorbate by lactic acid bacteria. Potassium sorbate is sometimes added to wine as a preservative against yeast, however its use is generally kept to a minimum due to the possibility of the taint developing. The production of the taint begins with the conversion of sorbic acid to the alcohol *sorbinol*. The



alcohol is then isomerised in the presence of acid to 3,5-hexadiene-2-ol, which is then esterified with ethanol to form 2-ethoxy-3,5-hexadiene. As ethanol is necessary for the conversion, the geranium taint is not usually found in must.

#### Mannitol

Mannitol is a sugar alcohol, and in wine it is produced by heterofermentative lactic acid bacteria, such as *Lactobacillus brevis*, by the reduction of fructose. Its perception is often complicated as it generally exists in wine alongside other faults, but it is usually described as viscous, ester-like combined with a sweet and irritating finish.<sup>[12]</sup> Mannitol is usually produced in wines that undergo malolactic fermentation with a high level of residual sugars still present. Expert winemakers oftentimes add small amounts of sulfur dioxide during the crushing step to reduce early bacterial growth.

#### Ropiness

Ropiness is manifested as an increase in viscosity and a *slimey* or *fatty* mouthfeel of a wine. In France the fault is known as "*graisse*", which translates to *fat*. The problem stems from the production of dextrans and polysaccharides by certain lactic acid bacteria, particularly of the genera *Leuconostoc* and *Pediococcus*.

#### Mousiness

Mousiness is a wine fault most often attributed to *Brettanomyces* but can also originate from the lactic acid bacteria *Lactobacillus brevis*, *Lactobacillus fermentum*, and *Lactobacillus hilgardii*,<sup>[12]</sup> and hence can occur in malolactic fermentation. The compounds responsible are lysine derivatives, mainly;

- 2-acetyl-3,4,5,6-tetrahydropyridine
- 2-acetyl-1,4,5,6-tetrahydropyridine
- 2-ethyltetrahydropyridine<sup>[15]</sup>
- 2-acetyl-1-pyrrolone

The taints are not volatile at the pH of wine, and therefore not obvious as an aroma. However, when mixed with the slightly basic pH of saliva they can become very apparent on the palate,<sup>[16]</sup> especially at the back of the mouth, as *mouse cage* or *mouse urine*.

#### Refermentation

Refermentation, sometimes called secondary fermentation, is caused by yeasts refermenting the residual sugar present within bottled wine. It occurs when sweet wines are bottled in non-sterile conditions, allowing the presence of microorganisms. The most common yeast to referment wine is the standard wine fermentation yeast *Saccharomyces cerevisiae*, but has also been attributed to *Schizosaccharomyces pombe* and *Zygosaccharomyces bailii*.<sup>[12]</sup> The main issues associated with the fault include turbidity (from yeast biomass production), excess ethanol production (may violate labelling laws), slight carbonation, and some coarse odours. Refermentation can be prevented by bottling wines dry (with residual sugar levels <1.0g/L), sterile filtering wine prior to bottling, or adding preservative chemicals such as dimethyl dicarbonate. The Portuguese wine style known as "vinhos verdes" used to rely on this secondary fermentation in bottle to impart a slight spritziness to the wine, but now usually uses artificial carbonation.

#### Bunch rots

Organisms responsible for bunch rot of grape berries are filamentous fungi, the most common of these being *Botrytis cinerea* (gray mold) However, there are a range of other fungi responsible for the rotting of grapes such as *Aspergillus* spp., *Penicillium* spp., and fungi found in subtropical climates (e.g., *Colletotrichum* spp. (ripe rot) and *Greeneria uvicola* (bitter rot)). A further group more commonly associated with diseases of the vegetative tissues of the vine can also infect grape berries (e.g., Botryosphaeriaceae, *Phomopsis viticola*). Compounds found in bunch rot affected grapes and wine are typically described as having mushroom, earthy odors and include geosmin, 2-methylisoborneol, 1-octen-3-ol, 2-octen-1-ol, fenchol and fenchone.<sup>[17]</sup>

### CHAPTER-8

Pasteurization or pasteurisation is a process of food preservation in which packaged and non-packaged foods (such as milk and fruit juices) are treated with mild heat, usually to less than 100 °C (212 °F), to eliminate pathogens and extend shelf life. The process is intended to destroy or deactivate microorganisms and enzymes that contribute to food spoilage or risk of disease, including vegetative bacteria, but most bacterial spores survive the process.<sup>[1][2]</sup>





The process is named after the French microbiologist Louis Pasteur whose research in the 1860s demonstrated that thermal processing would deactivate unwanted microorganisms in wine.<sup>[2][3]</sup> Spoilage enzymes are also inactivated during pasteurization. Today, pasteurization is used widely in the dairy industry and other food processing industries to achieve food preservation and food safety.<sup>[3]</sup>

By the year 1999, most liquid products were heat treated in a continuous system where heat can be applied using a heat exchanger or the direct or indirect use of hot water and steam. Due to the mild heat, there are minor changes to the nutritional quality and sensory characteristics of the treated foods.<sup>[4]</sup> Pascalization or high pressure processing (HPP) and pulsed electric field (PEF) are non-thermal processes that are also used to pasteurize foods.<sup>[1]</sup>

During the early 20th century, there was no robust knowledge of what time and temperature combinations would inactivate pathogenic bacteria in milk, and so a number of different pasteurization standards were in use. By 1943, both HTST pasteurization conditions of 72 °C (162 °F) for 15 seconds, as well as batch pasteurization conditions of 63 °C (145 °F) for 30 minutes, were confirmed by studies of the complete thermal death (as best as could be measured at that time) for a range of pathogenic bacteria in milk.<sup>[42]</sup> Complete inactivation of *Coxiella burnetii* (which was thought at the time to cause Q fever by oral ingestion of infected milk)<sup>[43][44]</sup> as well as of *Mycobacterium tuberculosis* (which causes tuberculosis)<sup>[45]</sup> were later demonstrated. For all practical purposes, these conditions were adequate for destroying almost all yeasts, molds, and common spoilage bacteria and also for ensuring adequate destruction of common pathogenic, heat-resistant organisms. However, the microbiological techniques used until the 1960s did not allow for the actual reduction of bacteria to be enumerated. Demonstration of the extent of inactivation of pathogenic bacteria by milk pasteurization came from a study of surviving bacteria in milk that was heat-treated after being deliberately spiked with high levels of the most heat-resistant strains of the most significant milk-borne pathogens.<sup>[46]</sup>

The mean log<sub>10</sub> reductions and temperatures of inactivation of the major milk-borne pathogens during a 15-second treatment are:

- *Staphylococcus aureus* > 6.7 at 66.5 °C (151.7 °F)
- *Yersinia enterocolitica* > 6.8 at 62.5 °C (144.5 °F)
- Pathogenic *Escherichia coli* > 6.8 at 65 °C (149 °F)
- *Cronobacter sakazakii* > 6.7 at 67.5 °C (153.5 °F)
- *Listeria monocytogenes* > 6.9 at 65.5 °C (149.9 °F)
- Salmonella ser. Typhimurium > 6.9 at 61.5 °C (142.7 °F)<sup>[46]</sup>

(A log<sub>10</sub> reduction between 6 and 7 means that 1 bacterium out of 1 million (10<sup>6</sup>) to 10 million (10<sup>7</sup>) bacteria survive the treatment.)

The Codex Alimentarius *Code of Hygienic Practice for Milk* notes that milk pasteurization is designed to achieve at least a 5 log<sub>10</sub> reduction of *Coxiella burnetii*.<sup>[47]</sup> The Code also notes that: "The minimum pasteurization conditions are those having bactericidal effects equivalent to heating every particle of the milk to 72 °C for 15 seconds (continuous flow pasteurization) or 63 °C for 30 minutes (batch pasteurization)" and that "To ensure that each particle is sufficiently heated, the milk flow in heat exchangers should be turbulent, *i.e.* the Reynolds number should be sufficiently high". The point about turbulent flow is important because simplistic laboratory studies of heat inactivation that use test tubes, without flow, will have less bacterial inactivation than larger-scale experiments that seek to replicate conditions of commercial pasteurization.<sup>[48]</sup>

As a precaution, modern HTST pasteurization processes must be designed with flow-rate restriction as well as divert valves which ensure that the milk is heated evenly and that no part of the milk is subject to a shorter time or a lower temperature. It is common for the temperatures to exceed 72 °C by 1.5 °C or 2 °C.<sup>[48]</sup>

#### Double pasteurization

Pasteurization is not sterilization and does not kill spores. "Double" pasteurization, which involves a secondary heating process, can extend shelf life by killing spores that have germinated.<sup>[49]</sup>

The acceptance of double pasteurization varies by jurisdiction. In places where it is allowed, milk is initially pasteurized when it is collected from the farm so it does not spoil before processing. Many countries prohibit the labelling of such milk as "pasteurized" but allow it to be marked "thermized", which refers to a lower-temperature process.<sup>[50]</sup>

Dairy products may upset the digestive system in individuals with lactose intolerance or a milk allergy.<sup>[7][8][9]</sup> People who experience lactose intolerance usually avoid milk and other lactose-containing dairy products, which may cause



mild side effects, such as abdominal pain, bloating, diarrhea, gas, and nausea.<sup>[7][8]</sup> Such individuals may use non-dairy milk substitutes.

#### Cancer

The American Institute for Cancer Research (AICR), World Cancer Research Fund International (WCRF), Cancer Council Australia (CCA) and Cancer Research UK have stated that there is strong evidence that consumption of dairy products decreases risk of colorectal cancer.<sup>[10][11][12][13]</sup> The AICR, WCRF, CCA and Prostate Cancer UK have stated that there is limited but suggestive evidence that dairy products increase risk of prostate cancer.<sup>[10][11][12][14][15]</sup> The American Cancer Society (ACS) have stated that because dairy products "may lower the risk of some cancers and possibly increase the risk of others, the ACS does not make specific recommendations on dairy food consumption for cancer prevention."<sup>[16]</sup>

It has been suggested that consumption of insulin-like growth factor 1 (IGF-1) in dairy products could increase cancer risk, particularly prostate cancer.<sup>[17][18]</sup> However, a 2018 review by the Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) concluded that there is "insufficient evidence to draw any firm conclusions as to whether exposure to dietary IGF-1 is associated with an increased incidence of cancer in consumers".<sup>[18]</sup> The COC also stated it is unlikely that there would be absorption of intact IGF-1 from food by most consumers.<sup>[19]</sup>

A 2019 review concluded that higher-quality research was needed to characterise valid associations between dairy consumption and risk of and/or cancer-related mortality.<sup>[20]</sup> A 2021 umbrella review found strong evidence that consumption of dairy products decreases risk of colorectal cancer.<sup>[21]</sup> Fermented dairy is associated with significantly decreased bladder cancer and colorectal cancer risk.<sup>[22]</sup>

A 2023 review found no association between consumption of dairy products and breast cancer.<sup>[23]</sup>

#### Other

Consumption of dairy products such as low-fat and whole milk have been associated with an increased acne risk, however, as of 2022 there is no conclusive evidence.<sup>[24][25][26]</sup> Fermented and low-fat dairy products are associated with a decreased risk of diabetes.<sup>[27][28]</sup> Consumption of dairy products are also associated with a decreased risk of gout.<sup>[29]</sup>

#### Avoidance on principle

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Some groups avoid dairy products for non-health-related reasons. Some religions restrict or do not allow the consumption of dairy products. For example, some scholars of Jainism advocate not consuming any dairy products because dairy is perceived to involve violence against cows.<sup>[30]</sup> Orthodox Judaism requires that meat and dairy products not be served at the same meal, served or cooked in the same utensils, or stored together, as prescribed in Deuteronomy 14:21.<sup>[31]</sup>

Veganism is the avoidance of all animal products, including dairy products, most often due to the ethics regarding how dairy products are produced. The ethical reasons for avoiding meat and dairy products include how dairy is produced, how the animals are handled, and the environmental effect of dairy production.<sup>[32][33]</sup> According to a report of the United Nations' Food and Agriculture Organization in 2010 the dairy sector accounted for 4 percent of global human-made greenhouse gas emissions.<sup>[34][35]</sup>

### CHAPTER-9

Pasteurized eggs are eggs that have been pasteurized in order to reduce the risk of foodborne illness in dishes that are not cooked or are only lightly cooked. They may be sold as liquid egg products or pasteurized in the shell.

#### Rationale

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The 2013 United States Food and Drug Administration Food Code defines regular shell eggs as a potentially hazardous food, i.e., "a food that requires time/temperature control for safety (TCS) to limit pathogenic microorganism growth or toxin formation."<sup>[1]</sup>

All egg products sold in the U.S that are pasteurized due to the risk of foodborne illnesses are done per U.S. Department of Agriculture rules. They also do not allow any egg products to be sold without going through the process of pasteurization. They also do not recommend eating shell eggs that are raw or undercooked due to the possibility that *Salmonella* bacteria may be present.<sup>[2]</sup>

Because of the risk of foodborne illness caused by *Salmonella* bacteria that may be present in raw eggs, the U.S. Department of Agriculture requires a safe-handling advisory statement on all packages of raw shell eggs that are not treated to destroy *Salmonella* as follows: "Safe Handling Instructions: To prevent illness from bacteria: Keep eggs refrigerated, cook eggs until yolks are firm, and cook foods containing eggs thoroughly."<sup>[2]</sup>

#### Salmonellosis

The primary risk associated with eggs is foodborne illness caused by *Salmonella enteritidis* bacteria. *Salmonella enteritidis* is a dangerous bacterium that can be transferred to humans through ingestion of raw or undercooked eggs.<sup>[3]</sup> Nearly four out of five *Salmonella*-related foodborne illness cases share a common vehicle: raw or undercooked shell eggs.<sup>[3]</sup>

Salmonellosis, the illness that a *Salmonella* infection causes, is characterized by nausea, vomiting, abdominal cramps, diarrhea, fever, and headache. The onset of its symptoms begins between six hours and 72 hours after the consumption of food contaminated with *Salmonella* bacteria.<sup>[4]</sup> As few as 15 bacterial cells can cause foodborne illness.<sup>[2]</sup>

While the Centers for Disease Control and Prevention estimate there are one million cases of salmonellosis per year in the US leading to 19,000 hospitalizations and 380 deaths,<sup>[5]</sup> the U.S. Food and Drug Administration (FDA) estimates that only 79,000 cases each year are the result of consuming eggs contaminated with *Salmonella*, of which only 30 result in death.<sup>[6]</sup>

In Europe, all hens are required to be vaccinated against salmonellosis. Eggs are not washed (and, in some countries, not refrigerated) since condensation could lead to salmonellosis contamination.<sup>[7]</sup> In the US, it is important to keep eggs refrigerated since not all hens are vaccinated.

#### Avian flu virus

The process of pasteurizing eggs also destroys avian flu virus.<sup>[8]</sup>

#### Food code compliance

The 2013 FDA Food Code states that in serving highly susceptible populations (preschool age children; older adults; individuals with compromised immune systems; and individuals who receive meals through custodial care-giving environments such as child or adult day care centers, kidney dialysis centers, hospitals, or nursing homes<sup>[5]</sup>),<sup>[3]</sup>

Pasteurized eggs or egg products shall be substituted for raw eggs in the preparation of Foods such as Caesar salad, hollandaise or Béarnaise sauce, mayonnaise, meringue, eggnog, ice cream, egg-fortified beverages and recipes in which more than one egg is broken and the eggs are combined.

The FDA Food Code has gained adoption by health jurisdictions throughout the U.S.<sup>[9]</sup>

#### Products

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As distinct from whole shell eggs, "egg products" are defined by the U.S. Department of Agriculture (USDA) as "eggs that are removed from their shells for processing." The processing of egg products includes breaking eggs, filtering, mixing, stabilizing, blending, pasteurizing, cooling, freezing or drying, and packaging. This is done at USDA-inspected plants.

Egg products include whole eggs, whites, yolks and various blends with or without non-egg ingredients that are processed and pasteurized and may be available in liquid, frozen, and dried forms.<sup>[10]</sup> This is achieved by heating the products to a specified temperature for a specified period.

Pre-separated egg and whole egg products may be used in commercial cooking and baking for saving time or for reducing food waste. In addition, the "potentially hazardous" designation for shell eggs does not apply.

#### Pasteurized shell eggs

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According to the U.S. Department of Agriculture, in-shell pasteurized eggs may be used safely without cooking. For example, they may safely be consumed raw (as in raw cookie dough or eggnog) or in undercooked forms (such as a sunny-side up egg).<sup>[2]</sup> Many food service and health care providers use these eggs to prevent cross-contamination in their kitchens.



## History

By traditional pasteurization methods, heating a raw shell egg to a high enough temperature to achieve pasteurization would also cook the egg. However, beginning in the early 1980s, Dr. James P. Cox and R.W. Duffy Cox of Lynden, Washington, began developing methods to pasteurize shell eggs.

In the early 1990s, the Coxes were introduced to L. John Davidson. Davidson recognized the market need and opportunity for a safer egg option for consumers and food operations around the country. Davidson acquired a license agreement on the technology from the Cox Family and formed Pasteurized Egg Corporation to introduce safe egg technology to the consumer marketplace.

The process for pasteurizing shell eggs has been patented.<sup>[1][12]</sup> Currently, National Pasteurized Eggs Inc. of Lansing, Illinois, owns Dr. Cox's patent to the pasteurization process. Only National Pasteurized Eggs Inc. can provide pasteurized shell eggs produced through these patented processes. The eggs can be found in all U.S. states under the brand Davidson's Safest Choice, introduced in 2003.<sup>[13]</sup>

## Process

Pasteurizing eggs in their shells is achieved through a technique that uses precise time and temperature zones within water baths.<sup>[14][15]</sup> Pasteurizing eggs in their shells can also be achieved through a process that involves treatment with ozone and reactive oxygen species under high and low pressures, followed by replacement with an inert gas, such as nitrogen.

Currently, shell eggs pasteurized using the heating technique are the only commercially available pasteurized eggs.<sup>[16]</sup> According to the U.S. Department of Agriculture,<sup>[2]</sup>

Shell eggs can be pasteurized by a processor if FDA accepted the process for the destruction of Salmonella. Pasteurized shell eggs are now available at some grocery stores and must be kept refrigerated to retain quality. The equipment to pasteurize shell eggs isn't available for home use, and it is very difficult to pasteurize shell eggs at home without cooking the contents of the egg.

After pasteurization, the eggs are coated with food-grade wax to maintain freshness and prevent environmental contamination and stamped with a blue or red "P" in a circle to distinguish them from unpasteurized eggs.

## Quality

Opinion on the quality of pasteurized shell eggs is mixed, and sometimes depends on whether comparisons involve experimental processes or products that are actually on the market. Taste tests noted deficiencies in pasteurized shell eggs experimentally produced via a microwaved pasteurization process (not for commercially available pasteurized shell eggs).<sup>[17]</sup> Using commercially available pasteurized shell eggs, a *San Francisco Chronicle* reporter noted a "slight chemical taste" for pasteurized shell eggs,<sup>[18]</sup> and a Lifescript blogger noted a "barely detectable" flavor and aroma difference and stated the eggs were "worth" their price.<sup>[19]</sup> *Relish* magazine states that pasteurized shell eggs "look like real eggs, act like real eggs and taste like real eggs."<sup>[20]</sup> "Independent taste tests conducted in Good Housekeeping kitchens have not been able to tell any differences between raw and pasteurized eggs," according to *Food Safety News*,<sup>[21]</sup> and in two out of three tastings a *Chicago Tribune* reporter preferred pasteurized eggs flavor over farmers market eggs.<sup>[22]</sup> According to *International Business Times*, demand for pasteurized shell eggs within the food service industry is strong because, as of 2008, "states such as California, Iowa, Michigan, Wisconsin and Illinois have adopted the most recent FDA Food Code, in which pasteurized shell eggs shall be substituted for raw eggs to at-risk groups."<sup>[23]</sup>

## Exemption

The FDA Food Code exempts pasteurized shell eggs from the definition of "time/temperature control for safe food."<sup>[1][3]</sup> requirement to carry a safe handling advisory statement.<sup>[2]</sup>

The U.S. Department of Agriculture also states, "In-shell pasteurized eggs may be used safely without cooking."<sup>[2]</sup>

Candied fruit, also known as glacé fruit, is whole fruit, smaller pieces of fruit, or pieces of peel, placed in heated sugar syrup, which absorbs the moisture from within the fruit and eventually preserves it. Depending on the size and type of fruit, this process of preservation can take from several days to several months.<sup>[1]</sup> This process allows the fruit to remain edible for up to a year.<sup>[2]</sup> It has existed since the 14th century.<sup>[1]</sup>

The continual process of drenching the fruit in syrup causes the fruit to become saturated with sugar, preventing the growth of spoilage microorganisms due to the resulting unfavourable osmotic pressure.<sup>[3]</sup>



Fruits which are commonly candied include cherries, pineapple, greengages, pears, peaches and melon, as well as ginger root.<sup>[4]</sup> The principal candied peels are orange and citron; these, together with candied lemon peel, are the usual ingredients of mixed chopped peel. Candied vegetables are also made, from vegetables such as pumpkin, turnip and carrot.<sup>[5]</sup>

Recipes vary from region to region, but the general principle is to boil the fruit, steep it in increasingly stronger sugar solutions for a number of weeks, and then dry off any remaining water.<sup>[6]</sup>

#### Uses

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As well as being eaten as snacks, candied fruits such as cherries and candied peels are commonly used in fruitcakes or pancakes.

### CHAPTER-10

Pickling is the process of preserving or extending the shelf life of food by either anaerobic fermentation in brine or immersion in vinegar. The pickling procedure typically affects the food's texture and flavor. The resulting food is called a *pickle*, or, to prevent ambiguity, prefaced with *pickled*. Foods that are pickled include vegetables, fruits, mushrooms, meats, fish, dairy and eggs.

Pickling solutions are typically highly acidic, with a pH of 4.6 or lower,<sup>[1]</sup> and high in salt, preventing enzymes from working and micro-organisms from multiplying.<sup>[2]</sup> Pickling can preserve perishable foods for months. Antimicrobial herbs and spices, such as mustard seed, garlic, cinnamon or cloves, are often added.<sup>[3]</sup> If the food contains sufficient moisture, a pickling brine may be produced simply by adding dry salt. For example, sauerkraut and Korean kimchi are produced by salting the vegetables to draw out excess water. Natural fermentation at room temperature, by lactic acid bacteria, produces the required acidity. Other pickles are made by placing vegetables in vinegar. Like the canning process, pickling (which includes fermentation) does not require that the food be completely sterile before it is sealed. The acidity or salinity of the solution, the temperature of fermentation, and the exclusion of oxygen determine which microorganisms dominate, and determine the flavor of the end product.<sup>[4]</sup>

When both salt concentration and temperature are low, *Leuconostoc mesenteroides* dominates, producing a mix of acids, alcohol, and aroma compounds. At higher temperatures *Lactobacillus plantarum* dominates, which produces primarily lactic acid. Many pickles start with *Leuconostoc*, and change to *Lactobacillus* with higher acidity.<sup>[4]</sup>

#### History

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Pickling with vinegar likely originated in ancient Mesopotamia around 2400 BCE.<sup>[5][6]</sup> There is archaeological evidence of cucumbers being pickled in the Tigris Valley in 2030 BCE.<sup>[7]</sup> Pickling vegetables in vinegar continued to develop in the Middle East region before spreading to the Maghreb, to Sicily and to Spain. From Spain it spread to the Americas.<sup>[8]</sup> On the other hand, fermented salt pickling reportedly has its origins in China.<sup>[5]</sup>

Pickling was used as a way to preserve food for out-of-season use and for long journeys, especially by sea. Salt pork and salt beef were common staples for sailors before the days of steam engines. Although the process was invented to preserve foods, pickles are also made and eaten because people enjoy the resulting flavors. Pickling may also improve the nutritional value of food by introducing B vitamins produced by bacteria.<sup>[9]</sup>

#### Etymology

The English term "pickle" first appears around 1400 CE. It is from Middle English *pikel*, a spicy sauce served with meat or fish, borrowed from Middle Dutch or Middle Low German *pekel* ("brine") but later referred to preserving brine or vinegar.<sup>[8][10]</sup>

#### In world cuisines

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##### Asia

##### South Asia

Historic Indosphere cultural influence zone of Greater India for transmission of elements of Indian culture including food, e.g. pickle / atchaar / atchara / acar,

South Asia has a large variety of pickles (known as *achar* (अचार, اچار) in Nepali, Assamese, Bengali, Hindi (अचार), Punjabi, Gujarati, Urdu (اچار) *uppinakaayi* in Kannada, *lonacha* (लोनचं) in



Marathi, *uppilittathu* or *achar* in Malayalam, *oorukai* in Tamil, *pacchadi* or *ooragaya* in Telugu, which are mainly made from varieties of mango, lemon, lime, gongura (a sour leafy shrub), tamarind, Indian gooseberry (amla), and chilli. Vegetables such as eggplant, carrots, cauliflower, tomato, bitter gourd, green tamarind, ginger, garlic, onion, and citron are also occasionally used. These fruits and vegetables are mixed with ingredients like salt, spices, and vegetable oils. The pickling process is completed by placing filled jars in the sun where they mature in the sun. The sun's heat destroys moulds and microbes which could spoil the pickles.<sup>[2][8]</sup>

In Pakistan, pickles are known locally as *achaar* (in Urdu اچار) and *si meti* (in Punjabi ਸੀ ਮੇਟੀ). A traditional mixed Hyderabadi pickle, a common delicacy prepared from an assortment of fruits (most notably mangoes) and vegetables blended with selected spices. Although the origin of the word is ambiguous, the word *āchār* is widely considered to be of Persian origin. *Āchār* in Persian is defined as 'powdered or salted meats, pickles, or fruits, preserved in salt, vinegar, honey, sugar or syrup.'<sup>[11]</sup>

In Sri Lanka, a date and shallot pickle *achcharu* is traditionally prepared from carrots, chilli powder, shallots and ground dates mixed with garlic, crushed fresh ginger, green chilis, mustard seeds and vinegar, and left to sit in a clay pot.<sup>[12]</sup>

Indian pickles are mostly prepared in three ways: salt/brine, oil, and vinegar, with mango pickle being most popular among all.<sup>[13][14]</sup>

#### Southeast Asia

*Singapore, Indonesian and Malaysian pickles, called acar are typically made out of cucumber, carrot, bird's eye chilies, and shallots, these items being seasoned with vinegar, sugar and salt. Fruits, such as papaya and pineapple, are also sometimes pickled.*

In the Philippines, *pickling* is a common method of preserving food, with many commonly eaten foods pickled, traditionally done using large earthen jars. The process is known as *buro* or *binuro*. Pickling was a common method of preserving a large variety of foods like fish throughout the archipelago before the advent of refrigeration, but its popularity is now confined to vegetables and fruits. *Atchara* is primarily made out of julienned green papaya, carrots, and shallots, seasoned with cloves of garlic and vinegar; but could include ginger, bell peppers, white radishes, cucumbers or bamboo shoots. Pickled unripe mangoes or *burong mangga*, unripe tomatoes, guavas, jicama, bitter gourd and other fruit and vegetables still retain their appeal. *Siling labuyo*, sometimes with garlic and red onions, is also pickled in bottled vinegar and is a staple condiment in Filipino cuisine.

In Vietnamese cuisine, vegetable pickles are called *dưa muối* ("salted vegetables") or *dưa chua* ("sour vegetables"). *Dưa chua* or *dưa góp* is made from a variety of fruits and vegetables, including *cà pháo*, eggplant, Napa cabbage, kohlrabi, carrots, radishes, papaya, cauliflower, and *sung*. *Dưa chua* made from carrots and radishes are commonly added to *bánh mì* sandwiches. *Dưa cải muối* is made by pressing and sun-drying vegetables such as *cải xắt* and *gai choy*. *Nhút mít* is a specialty of Nghệ An and Hà Tĩnh provinces made from jackfruit.

In Burma, tea leaves are pickled to produce *lahpet*, which has strong social and cultural importance.

#### East Asia

A wide variety of foods are pickled throughout East Asia. The pickles are often sweet, salty, and/or spicy and preserved in sweetened solutions or oil.<sup>[15]</sup>

China is home to a huge variety of pickled vegetables, including radish, *baicai* (Chinese cabbage, notably *suan cai*, *pao cai*, and Tianjin preserved vegetable), *zha cai*, chili pepper (e.g. *duo jiao*), and cucumbers, among many others.

Japanese *tsukemono* (pickled foods) include *takuan* (daikon), *umeboshi* (ume plum), *tataki gobo* (burdock root), *gari* & *beni shōga* (ginger), turnip, cucumber, and Chinese cabbage.

The Korean staple kimchi is usually made from pickled napa cabbage and radish, but is also made from green onions, garlic stems, chives and a host of other vegetables. *Jangajji* is another banchan consisting of pickled vegetables.

#### Western Asia

In Iran, Turkey, Arab countries, the Balkans, and the South Caucasus, pickles (called *torshi* in Persian, *turşu* in Turkish language and *mekhallel* in Arabic) are commonly made from turnips, peppers, carrots, green olives, cucumbers, eggplants, cabbage, green tomatoes, lemons, and cauliflower.



Sauerkraut, as well as cabbage pickled in vinegar, with carrot and other vegetables is commonly consumed as a kosher dish in Israel and is considered pareve, meaning that it contains no meat or dairy so it can be consumed with either.<sup>[16]</sup>

#### Europe

##### Central and Eastern Europe

In Hungary, the main meal (*lunch*) usually includes some kind of pickles (*savanyúság*), but pickles are also commonly consumed at other times of the day. The most commonly consumed pickles are sauerkraut (*savanyú káposzta*), pickled cucumbers and peppers, and *csalamádé*, but tomatoes, carrots, beetroot, baby corn, onions, garlic, certain squashes and melons, and a few fruits like plums and apples are used to make pickles too. Stuffed pickles are specialties, usually made of peppers or melons pickled after being stuffed with a cabbage filling. Pickled plum stuffed with garlic is a unique Hungarian type of pickle just like *csalamádé* and leavened cucumber (*kovászos uborka*). *Csalamádé* is a type of mixed pickle made of cabbage, cucumber, paprika, onion, carrot, tomatoes, and bay leaf mixed up with vinegar as the fermenting agent. Leavened cucumber, unlike other types of pickled cucumbers that are around all year long, is rather a seasonal pickle produced in the summer. Cucumbers, spices, herbs, and slices of bread are put in a glass jar with salt water and kept in direct sunlight for a few days. The yeast from the bread, along with other pickling agents and spices fermented under the hot sun, give the cucumbers a unique flavor, texture, and slight carbonation. Its juice can be used instead of carbonated water to make a special type of spritzer (*Újházy fröccs*). It is common for Hungarian households to produce their own pickles. Different regions or towns have their special recipes unique to them. Among them all, the Vecsési sauerkraut (*Vecsési savanyú káposzta*) is the most famous.

Romanian pickles (*murături*) are made out of beetroot, cucumbers, green tomatoes (*gogonele*), carrots, cabbage, garlic, sauerkraut, bell peppers, melons, mushrooms, turnips, celery and cauliflower. Meat, like pork, can also be preserved in salt and lard.

Polish, Czech and Slovak traditional pickles are cucumbers, sauerkraut, peppers, beetroot, tomatoes, but other pickled fruits and vegetables, including plums, pumpkins and mushrooms are also common.

North Caucasian, Russian, Ukrainian and Belarusian pickled items include beets, mushrooms, tomatoes, sauerkraut, cucumbers, ramsons, garlic, eggplant (which is typically stuffed with julienned carrots), custard squash, and watermelon. Garden produce is commonly pickled using salt, dill, blackcurrant leaves, bay leaves and garlic and is stored in a cool, dark place. The leftover brine (called *rassol* (рассол) in Russian) has a number of culinary uses in these countries, especially for cooking traditional soups, such as *shchi*, *rassolnik*, and *solyanka*. *Rassol*, especially cucumber or sauerkraut *rassol*, is also a favorite traditional remedy against morning hangover.<sup>[17]</sup>

##### Southern Europe

An Italian pickled vegetable dish is *giardiniera*, which includes onions, carrots, celery and cauliflower. Many places in southern Italy, particularly in Sicily, pickle eggplants and hot peppers.

In Albania, Bulgaria, Serbia, North Macedonia and Turkey, mixed pickles, known as *turshi*, *tursija* or *turshu* form popular appetizers, which are typically eaten with *rakia*. Pickled green tomatoes, cucumbers, carrots, bell peppers, peppers, eggplants, and sauerkraut are also popular.

Turkish pickles, called *turşu*, are made out of vegetables, roots, and fruits such as peppers, cucumber, Armenian cucumber, cabbage, tomato, eggplant (aubergine), carrot, turnip, beetroot, green almond, baby watermelon, baby cantaloupe, garlic, cauliflower, bean and green plum. A mixture of spices flavor the pickles.

In Greece, pickles, called *τρυψί(α)*, are made out of carrots, celery, eggplants stuffed with diced carrots, cauliflower, tomatoes, and peppers.

In Spain, pickles, known as "encurtidos", are mainly made with olives, cucumbers, onions and green peppers ("guindillas" or "piparras"). "Banderillas" are small pieces of pickled cucumber and green pepper, along with olives and anchovies, mounted into toothpicks, and are very popular as Tapas.

##### Northern Europe

In Britain, pickled onions and pickled eggs are often sold in pubs and fish and chip shops. Pickled beetroot, walnuts, and gherkins, and condiments such as Branston Pickle and piccalilli are typically eaten as an accompaniment to pork pies and cold meats, sandwiches or a ploughman's lunch. Other popular pickles in the UK are pickled mussels, cockles, red cabbage, mango chutney, sauerkraut, and olives. Rollmops are also quite widely available under a range of names from various producers both within and out of the UK.



Pickled herring, rollmops, and salmon are popular in Scandinavia. Pickled cucumbers and red garden beets are important as condiments for several traditional dishes. Pickled capers are also common in Scandinavian cuisine.

#### North America

In the United States and Canada, pickled cucumbers (most often referred to simply as "pickles"), olives, and sauerkraut are most commonly seen, although pickles common in other nations are also very widely available. In Canada and the US, there may be a distinction made between gherkins (usually smaller), and pickles (larger pickled cucumbers).

Sweet pickles made with fruit are more common in the cuisine of the American South. The pickling "syrup" is made with vinegar, brown sugar, and whole spices such as cinnamon sticks, allspice and cloves. Fruit pickles can be made with an assortment of fruits including watermelon, cantaloupe, Concord grapes and peaches.<sup>[18]</sup>

Canadian pickling is similar to that of Britain. Through the winter, pickling is an important method of food preservation. Pickled cucumbers, onions, and eggs are common. Pickled egg and pickled sausage make popular pub snacks in much of English Canada. Chow-chow is a tart vegetable mix popular in the Maritime Provinces and the Southern United States, similar to piccalilli. Pickled fish is commonly seen, as in Scotland, and kippers may be seen for breakfast, as well as plentiful smoked salmon. Meat is often also pickled or preserved in different brines throughout the winter, most prominently in the harsh climate of Newfoundland.

Pickled eggs are common in many regions of the United States. Pickled herring is available in the Upper Midwest. Giardiniera, a mixture of pickled peppers, celery and olives, is a popular condiment in Chicago and other Midwestern cities with large Italian-American populations, and is often consumed with Italian beef sandwiches.

Pennsylvania Dutch Country has a strong tradition of pickled foods, including chow-chow and red beet eggs. In the Southern United States, pickled okra and watermelon rind are popular, as are deep-fried pickles and pickled pig's feet, pickled chicken eggs, pickled quail eggs, pickled garden vegetables and pickled sausage.<sup>[19][20]</sup>

Various pickled vegetables, fish, or eggs may make a side dish to a Canadian lunch or dinner. Popular pickles in the Pacific Northwest include pickled asparagus and green beans. Pickled fruits like blueberries and early green strawberries are paired with meat dishes in restaurants.

#### Thanksgiving

Pickles were part of Thanksgiving dinner traditions as early as 1827. The first mention of pickles at Thanksgiving comes from Sarah Josepha Hale's novel *Northwood*. (Hale is best known for her successful campaign to have Thanksgiving recognized as a national holiday in the United States.) Pickled peaches, coleslaw and other mixed pickles continue to be served alongside cranberry sauce at Thanksgiving dinner in present times.<sup>[21]</sup>

#### Mexico, Central America, and South America

In Mexico, chili peppers, particularly of the Jalapeño and serrano varieties, pickled with onions, carrots and herbs form common condiments.<sup>[1]</sup>

In the Mesoamerican region, pickling is known as encurtido or "curtido" for short. The pickles or "curtidos" as known in Latin America are served cold, as an appetizer, as a side dish or as a tapas dish in Spain. In several Central American countries it is prepared with cabbage, onions, carrots, lemon, vinegar, oregano, and salt. In Mexico, "curtido" consists of carrots, onions, and jalapeño peppers and used to accompany meals common in taquerías and restaurants

Another example of a type of pickling which involves the pickling of meats or seafood is the "escabeche" or "ceviches" popular in Peru, Ecuador, and throughout Latin America and the Caribbean. These dishes include the pickling of pig's feet, pig's ears, and gizzards prepared as an "escabeche" with spices and seasonings to flavor it. The ceviches consist of shrimp, octopus, and various fishes seasoned and served cold.

#### Process

In traditional pickling, fruit or vegetables are submerged in brine (20–40 grams/L of salt (3.2–6.4 oz/imp gal or 2.7–5.3 oz/US gal)), or shredded and salted as in sauerkraut preparation, and held underwater by flat stones layered on top.<sup>[22]</sup> Alternatively, a lid with an airtrap or a tight lid may be used if the lid is able to release pressure which may result from carbon dioxide buildup.<sup>[23]</sup> Mold or (white) kahm yeast may form on the surface; kahm yeast is mostly harmless but can impart an off taste and may be removed without affecting the pickling process.<sup>[24]</sup>





In chemical pickling, the fruits or vegetables to be pickled are placed in a sterilized jar along with brine, vinegar, or both, as well as spices, and are then allowed to mature until the desired taste is obtained.

The food can be pre-soaked in brine before transferring to vinegar. This reduces the water content of the food, which would otherwise dilute the vinegar. This method is particularly useful for fruit and vegetables with a high natural water content.

In commercial pickling, a preservative such as sodium benzoate or EDTA may also be added to enhance shelf life. In fermentation pickling, the food itself produces the preservation agent, typically by a process involving *Lactobacillus* bacteria that produce lactic acid as the preservative agent.

Alum, short for aluminum sulfate, is used in pickling to promote crisp texture and is approved, though not recommended, as a food additive by the United States Food and Drug Administration.<sup>[25][26]</sup> Another common crisping agent is calcium chloride, which evolved from the practice of using pickling lime.<sup>[27]</sup> See also firming agent.

"Refrigerator pickles" are unfermented pickles made by marinating fruit or vegetables in a seasoned vinegar solution. They must be stored under refrigeration or undergo canning to achieve long-term storage.<sup>[28]</sup>

Japanese Tsukemono use a variety of pickling ingredients depending on their type, and are produced by combining these ingredients with the vegetables to be preserved and putting the mixture under pressure.

#### Possible health hazards of pickled vegetables

The World Health Organization has listed pickled vegetables as a possible carcinogen, and the *British Journal of Cancer* released an online 2009 meta-analysis of research on pickles as increasing the risks of esophageal cancer. The report, citing limited data in a statistical meta analysis, indicates a potential two-fold increased risk of oesophageal cancer associated with Asian pickled vegetable consumption. Results from the research are described as having "high heterogeneity" and the study said that further well-designed prospective studies were warranted.<sup>[29]</sup> However, their results stated "The majority of subgroup analyses showed a statistically significant association between consuming pickled vegetables and Oesophageal Squamous Cell Carcinoma".<sup>[29]</sup>

The 2009 meta-analysis reported heavy infestation of pickled vegetables with fungi. Some common fungi can facilitate the formation of N-nitroso compounds, which are strong oesophageal carcinogens in several animal models.<sup>[30]</sup> Roussin red methyl ester,<sup>[31]</sup> a non-alkylating nitroso compound with tumour-promoting effect in vitro, was identified in pickles from Linzhou, Henan (formerly Linxian) in much higher concentrations than in samples from low-incidence areas. Fumonisin mycotoxins have been shown to cause liver and kidney tumours in rodents.<sup>[29]</sup>

A 2017 study in *Chinese Journal of Cancer*<sup>[32]</sup> has linked salted vegetables (pickled mustard green [zh] common among Chinese cuisine) to a fourfold increase in nasopharynx cancer. The researchers believe possible mechanisms include production of nitrosamines (a type of N-nitroso compound) by fermentation and activation of Epstein-Barr virus by fermentation products.<sup>[33][34]</sup>

Historically, pickling caused health concerns for reasons associated with copper salts, as explained in the mid-19th century *The English and Australian Cookery Book*: "The evidence of the Lancet commissioner (Dr. Hassall) and Mr. Blackwell (of the eminent firm of Crosse and Blackwell) went to prove that the pickles sold in the shops are nearly always artificially coloured, and are thus rendered highly unwholesome, if not actually poisonous."

#### Risk reduction

Reduction of suspected carcinogens from pickled products is a subject of active research.

- Fungi are of interest both for spoilage prevention and reduction of mycotoxins. Some pickle cultures are said to contain bacteria producing natural antifungals.<sup>[35]</sup>
- Nitrites, responsible for the creation of N-nitroso compounds, is reduced by low pH and/or high temperature.<sup>[36]</sup> Inclusion of a porcini enzyme (or the whole mushroom) also reduces nitrite content.<sup>[37]</sup>

#### REFERENCES

1. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction, In brief. Rome: FAO. 2021. p. 8. doi:10.4060/ca9825fr. ISBN 978-92-5-134306-7.
2. <sup>a b</sup> "Good food for a better future". Sustainable Development Goals Fund. 11 March 2016. Retrieved 3 November 2020.



3. ^ Fields of Farmers by Joel Salatin | Chelsea Green Publishing. Retrieved 3 November 2020.
4. ^ Stacy Simon (26 October 2015). "World Health Organization Says Processed Meat Causes Cancer". Cancer.org. Archived from the original on 7 January 2017. Retrieved 14 January 2016.
5. ^ James Gallagher (26 October 2015). "Processed meats do cause cancer – WHO". BBC.
6. ^ "IARC Monographs evaluate consumption of red meat and processed meat" (PDF). International Agency for Research on Cancer. 26 October 2015.
7. ^ Nicolas Appert inventeur et humaniste by Jean-Paul Barbier, Paris, 1994 and <http://www.appert-aina.com>
8. ^ <sup>a b c</sup> Nummer, B. (2002). "Historical Origins of Food Preservation" [http://nchfp.uga.edu/publications/nchfp/factsheets/food\\_pres\\_hist.html](http://nchfp.uga.edu/publications/nchfp/factsheets/food_pres_hist.html). (Accessed on 5 May 2014)
9. ^ Bruce Aidells (2012): The Great Meat Cookbook, page 429. Houghton Mifflin Harcourt; 632 pages. ISBN 9780547241418
10. ^ Susan Jung (2012): "Truc: confit, a fat-fabulous way to preserve meat". Post Magazine, online article, posted on 2012-11-03, accessed 2019-02-21.
11. ^ <sup>a b</sup> Msagati, T. (2012). "The Chemistry of Food Additives and Preservatives"
12. ^ Nummer, Brian; Andress, Elizabeth (June 2015). "Curing and Smoking Meats for Home Food Preservation". National Center for Home Food Preservation.
13. ^ <sup>a b c</sup> Ratti, Cristina (21 November 2008). Advances in Food Dehydration. CRC Press. pp. 209–235. ISBN 9781420052534.
14. ^ Fellows, P. (Peter) (2017). "Freeze drying and freeze concentration". Food processing technology : principles and practice (4th ed.). Kent: Woodhead Publishing/Elsevier Science. pp. 929–940. ISBN 978-0081005231. OCLC 960758611.
15. ^ Prosapio, Valentina; Norton, Ian; De Marco, Iolanda (1 December 2017). "Optimization of freeze-drying using a Life Cycle Assessment approach: Strawberries' case study" (PDF). Journal of Cleaner Production. 168: 1171–1179. doi:10.1016/j.jclepro.2017.09.125. ISSN 0959-6526.
16. ^ Ratti, C (2001). "Hot air and freeze-drying of high-value foods: a review". Journal of Food Engineering. 49 (4): 311–319. doi:10.1016/s0260-8774(00)00228-4.
17. ^ Yildirim, Selçuk; Röcker, Bettina; Pettersen, Marit Kvalvåg; Nilsen-Nygaard, Julie; Ayhan, Zehra; Rutkaite, Ramune; Radusin, Tanja; Suminska, Patrycja; Marcos, Begonya; Coma, Véronique (January 2018). "Active Packaging Applications for Food: Active packaging applications for food...". Comprehensive Reviews in Food Science and Food Safety. 17 (1): 165–199. doi:10.1111/1541-4337.12322. PMID 33350066.
18. ^ L. Brody, Aaron; Strupinsky, E. P.; Kline, Lauri R. (2001). Active Packaging for Food Applications (1 ed.). CRC Press. ISBN 9780367397289.
19. ^ Food Irradiation – A technique for preserving and improving the safety of food, WHO, Geneva, 1991
20. ^ World Health Organization. Wholesomeness of irradiated food. Geneva, Technical Report Series No. 659, 1981
21. ^ World Health Organization. High-Dose Irradiation: Wholesomeness of Food Irradiated With Doses Above 10 kGy. Report of a Joint FAO/IAEA/WHO Study Group. Geneva, Switzerland: World Health Organization; 1999. WHO Technical Report Series No. 890
22. ^ Conley, S.T., What do consumers think about irradiated foods, FSIS Food Safety Review (Fall 1992), 11–15
23. ^ Hauter, W. & Worth, M., Zapped! Irradiation and the Death of Food, Food & Water Watch Press, Washington, DC, 2008
24. ^ NUCLEUS – Food Irradiation Clearances Archived 26 May 2008 at the Wayback Machine
25. ^ Food irradiation – Position of ADA J Am Diet Assoc. 2000;100:246-253 Archived 16 February 2016 at the Wayback Machine
26. ^ C.M. Deeley, M. Gao, R. Hunter, D.A.E. Ehlermann, The development of food irradiation in the Asia Pacific, the Americas and Europe; tutorial presented to the International Meeting on Radiation Processing, Kuala Lumpur, 2006. [1]
27. ^ Navarro, Shlomo; Timlick, Blaine; Demianyk, Colin; White, Noel (March 2012). "Controlled or Modified Atmospheres" (PDF). k-state.edu. Retrieved 17 March 2018.
28. ^ Annis, P.C. and Dowsett, H.A. 1993. Low oxygen disinfestation of grain: exposure periods needed for high mortality. Proc. International Conference on Controlled Atmosphere and Fumigation. Winnipeg, June 1992, Caspit Press, Jerusalem, pp. 71–83.
29. ^ Annis, P.C. and Morton, R. 1997. The acute mortality effects of carbon dioxide on various life stages of Sitophilus oryzae. J. Stored Prod.Res. 33. 115–124
30. ^ Various authors, Session 1: Natural Air-Tight Storage In: Shejbal, J., ed., Controlled Atmosphere Storage of Grains, Elsevier: Amsterdam, 1–33
31. ^ Annis P.C. and Banks H.J. 1993. Is hermetic storage of grains feasible in modern agricultural systems? In "Pest control and sustainable agriculture" Eds S.A. Corey, D.J. Dall and W.M. Milne. CSIRO, Australia. 479–482



32. ^ Laine Welch (18 May 2013). "Laine Welch: Fuel cell technology boosts long-distance fish shipping". Anchorage Daily News. Archived from the original on 9 June 2013. Retrieved 19 May 2013.
33. ^ NWT magazine, December 2012
34. ^ "High-Pressure Processing Keeps Food Safe". Military.com. Archived from the original on 2 February 2008. Retrieved 16 December 2008.
35. ^<sup>a b c</sup> Ananou S, Maqueda M, Martínez-Bueno M and Valdivia E (2007) "Biopreservation, an ecological approach to improve the safety and shelf-life of foods" Archived 26 July 2011 at the Wayback Machine In: A. Méndez-Vilas (Ed.) Communicating Current Research and Educational Topics and Trends in Applied Microbiology, Formatex. ISBN 978-84-611-9423-0.
36. ^ Yousef AE and Carolyn Carlstrom C (2003) Food microbiology: a laboratory manual Wiley, Page 226. ISBN 978-0-471-39105-0.
37. ^ FAO: Preservation techniques Fisheries and aquaculture department, Rome. Updated 27 May 2005. Retrieved 14 March 2011.
38. ^ Alzamora SM, Tapia MS and López-Malo A (2000) Minimally processed fruits and vegetables: fundamental aspects and applications Springer, p. 266. ISBN 978-0-8342-1672-3.
39. ^<sup>a b</sup> Alasalvar C (2010) Seafood Quality, Safety and Health Applications John Wiley and Sons, Page 203. ISBN 978-1-4051-8070-2.
40. ^ Leistner I (2000) "Basic aspects of food preservation I by hurdle technology" International Journal of Food Microbiology, 55:181–186.
41. ^ Leistner L (1995) "Principles and applications of hurdle technology" In Gould GW (Ed.) New Methods of Food Preservation, Springer, pp. 1–21. ISBN 978-0-8342-1341-8.
42. ^ Lee S (2004) "Microbial Safety of Pickled Fruits and Vegetables and Hurdle Technology" Archived 1 September 2011 at the Wayback Machine Internet Journal of Food Safety, 4: 21–32.
43. "Food Additives & Ingredients - Overview of Food Ingredients, Additives & Colors". FDA Center for Food Safety and Applied Nutrition. Retrieved 11 April 2017.
44. ^ "Food Ingredients and Packaging Terms". FDA. January 4, 2018. Retrieved 9 September 2018.
45. ^ Codex Alimentarius. "Class Names and the International Numbering System for Food Additives. food additives" (PDF).
46. ^ See also "Food Additives", Food and Drug Administration website
47. ^ Erich Lück and Gert-Wolfhard von Rymon Lipinski "Foods, 3. Food Additives" in Ullmann's Encyclopedia of Industrial Chemistry, 2002, Wiley-VCH, Weinheim. doi:10.1002/14356007.a11\_561
48. ^ "Press release: Some Common Food Additives May Pose Health Risks to Children". American Academy of Pediatrics. July 23, 2018.
49. ^<sup>a b</sup> Bucci, Luke (1995). Nutrition applied to injury rehabilitation and sports medicine. Boca Raton: CRC Press. pp. 151. ISBN 0-8493-7913-X.
50. ^ Rev. Lyman Abbott, ed. (1900). The Outlook (Vol. 65). Outlook Co. p. 403.
51. ^ Epstein, S (March 1973). "The Delaney Amendment". Preventive Medicine. 2 (1): 140–149. doi:10.1016/0091-7435(73)90016-9. PMID 4803324.
52. ^ Reuber, M D (August 1978). "Carcinogenicity of saccharin". Environmental Health Perspectives. 25: 173–200. doi:10.1289/ehp.7825173. ISSN 0091-6765. PMC 1637197. PMID 363408.
53. ^ Assessment of technologies for determining cancer risks from the environment. Darby, Pennsylvania, USA: DIANE publishing. 1981. p. 177. ISBN 1-4289-2437-X.
54. ^ Whysner, J.; Williams, GM. (1996). "Saccharin mechanistic data and risk assessment: urine composition, enhanced cell proliferation, and tumor promotion". Pharmacol Ther. 71 (1–2): 225–52. doi:10.1016/0163-7258(96)00069-1. PMID 8910956.
55. ^ Dybing, E. (December 2002). "Development and implementation of the IPCS conceptual framework for evaluating mode of action of chemical carcinogens". Toxicology. 181–182: 121–5. doi:10.1016/S0300-483X(02)00266-4. PMID 12505296.
56. ^ Food Standards Australia New Zealand (2007). "Choosing the Right Stuff - the official shoppers' guide to food additives and labels, kilojoules and fat content". Archived from the original on 14 May 2009. Retrieved 3 May 2009.
57. ^ "Loading..." [www.understandingfoodadditives.org](http://www.understandingfoodadditives.org).
58. ^ "Loading..." [www.understandingfoodadditives.org](http://www.understandingfoodadditives.org).
59. ^ Martin Downs, MPH (17 December 2008). "The Truth About 7 Common Food Additives". WebMD.



60. ^ Fennema, Owen R. (1996). Food chemistry. New York, N.Y: Marcel Dekker. pp. 827. ISBN 0-8247-9691-8.
61. ^ McCann, D; Barrett, A; Cooper, A; Crumpler, D; Dalen, L; Grimshaw, K; Kitchin, E; Lok, K; et al. (2007). "Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial". *Lancet*. 370 (9598): 1560–7. doi:10.1016/S0140-6736(07)61306-3. PMID 17825405. S2CID 10654579.
62. ^ Amchova, Petra; Kotolova, Hana; Ruda-Kucerova, Jana "Health safety issues of synthetic food colorants" *Regulatory Toxicology and Pharmacology* (2015), 73(3), 914-922.doi:10.1016/j.yrtph.2015.09.026
63. ^ Vettorazzi, Ariane; López De Cerain, Adela; Sanz-Serrano, Julen; Gil, Ana G.; Azqueta, Amaya (2020). "European Regulatory Framework and Safety Assessment of Food-Related Bioactive Compounds". *Nutrients*. 12 (3): 613. doi:10.3390/nu12030613. PMC 7146632. PMID 32110982.
64. ^ Chassaing, Benoit; Compher, Charlene; Bonhomme, Brittaney; Liu, Qing; Tian, Yuan; Walters, William; Nessel, Lisa; Delaroque, Clara; Hao, Fuhua; Gershuni, Victoria; Chau, Lillian; Ni, Josephine; Bewtra, Meenakshi; Albenberg, Lindsey; Bretin, Alexis; McKeever, Liam; Ley, Ruth E.; Patterson, Andrew D.; Wu, Gary D.; Gewirtz, Andrew T.; Lewis, James D. (March 2022). "Randomized Controlled-Feeding Study of Dietary Emulsifier Carboxymethylcellulose Reveals Detrimental Impacts on the Gut Microbiota and Metabolome". *Gastroenterology*. 162 (3): 743–756. doi:10.1053/j.gastro.2021.11.006. PMC 9639366. PMID 34774538. S2CID 244050800.
65. ^ Chassaing, Benoit; Koren, Omry; Goodrich, Julia K.; Poole, Angela C.; Srinivasan, Shanthi; Ley, Ruth E.; Gewirtz, Andrew T. (5 March 2015). "Dietary emulsifiers impact the mouse gut microbiota promoting colitis and metabolic syndrome". *Nature*. 519 (7541): 92–96. Bibcode:2015Natur.519...92C. doi:10.1038/nature14232. PMC 4910713. PMID 25731162.
66. ^ Ostrowski, Matthew P.; La Rosa, Sabina Leanti; Kunath, Benoit J.; Robertson, Andrew; Pereira, Gabriel; Hagen, Live H.; Varghese, Neha J.; Qiu, Ling; Yao, Tianming; Flint, Gabrielle; Li, James; McDonald, Sean P.; Buttner, Duna; Pudlo, Nicholas A.; Schnizlein, Matthew K.; Young, Vincent B.; Brumer, Harry; Schmidt, Thomas M.; Terrapon, Nicolas; Lombard, Vincent; Henrissat, Bernard; Hamaker, Bruce; Eloie-Fadros, Emiley A.; Tripathi, Ashootosh; Pope, Phillip B.; Martens, Eric C. (April 2022). "Mechanistic insights into consumption of the food additive xanthan gum by the human gut microbiota". *Nature Microbiology*. 7 (4): 556–569. doi:10.1038/s41564-022-01093-0. PMID 35365790. S2CID 247866305.
67. ^ Sonnenburg, Erica D.; Sonnenburg, Justin L. (June 2019). "The ancestral and industrialized gut microbiota and implications for human health". *Nature Reviews Microbiology*. 17 (6): 383–390. doi:10.1038/s41579-019-0191-8. PMID 31089293. S2CID 153314897.
68. ^ Weaver, Connie M; Dwyer, Johanna; Fulgoni, Victor L; King, Janet C; Leveille, Gilbert A; MacDonald, Ruth S; Ordovas, Jose; Schnakenberg, David (23 April 2014). "Processed foods: contributions to nutrition". *American Journal of Clinical Nutrition*. 99 (6): 1525–1542. doi:10.3945/ajcn.114.089284. ISSN 0002-9165. PMC 6410904. PMID 24760975.
69. ^ "Food processing: The advantages of processed foods". The European Food Information Council. 1 May 2010. Retrieved 5 August 2019.
70. ^ <sup>a b</sup> Nutrition, Center for Food Safety and Applied (2020-02-20). "Overview of Food Ingredients, Additives & Colors". FDA.
71. ^ "PART 171—FOOD ADDITIVE PETITIONS", The CRC Master Keyword Guide for Food, CRC Press, pp. 596–601, 2003-11-25, doi:10.1201/9780203504529-50, ISBN 9780429211027, retrieved 2021-10-13
72. ^ Nutrition, Center for Food Safety and Applied (2021-09-17). "Guidance for Industry: Recommendations for Submission of Chemical and Technological Data for Direct Food Additive Petitions". U.S. Food and Drug Administration. Retrieved 2021-09-29.
73. ^ International Organization for Standardization. "67.220: Spices and condiments. Food additives". Retrieved 23 April 2009.
74. Erich Lück and Gert-Wolfhard von Rymon Lipinski "Foods, 3. Food Additives" in Ullmann's Encyclopedia of Industrial Chemistry, 2002, Wiley-VCH, Weinheim. doi:10.1002/14356007.a11\_561
75. ^ Evans, G., de Challemaison, B., & Cox, D. N. (2010). "Consumers' ratings of the natural and unnatural qualities of foods". *Appetite*. 54 (3): 557–563. doi:10.1016/j.appet.2010.02.014. PMID 20197074. S2CID 41078790.
76. ^ Ashagrie, Z. Z., & Abate, D. D. (2012). IMPROVEMENT OF INJERA SHELF LIFE THROUGH THE USE OF CHEMICAL PRESERVATIVES. *African Journal of Food, Agriculture, Nutrition & Development*, 12(5), 6409-6423.
77. ^ Kumar, H., Jha, A., Taneja, K. K., Kabra, K., & Sadiq, H. M. (2013). A STUDY ON CONSUMER AWARENESS, SAFETY PERCEPTIONS & PRACTICES ABOUT FOOD PRESERVATIVES AND





FLAVOURING AGENTS USED IN PACKED /CANNED FOODS FROM SOUTH INDIA. National Journal of Community Medicine, 4(3), 402-406.

78. <sup>a b</sup> Msagati, Titus A. M. (2012). The Chemistry of Food Additives and Preservatives. Retrieved from <http://www.ebib.com>
79. <sup>a b</sup> Dalton, Louisa (November 2002). "Food Preservatives". Chemical and Engineering News. 80 (45): 40. doi:10.1021/cen-v080n045.p040. Retrieved 9 February 2012.
80. <sup>a</sup> "Using Preservatives". Retrieved 9 February 2012.
81. <sup>a</sup> Shaw, Ian C. (2012). Food Safety: The Science of Keeping Food Safe. Retrieved from <http://www.ebib.com> (306- 334)
82. <sup>a</sup> "The search is on for new cosmetic preservatives". Chemical & Engineering News. Retrieved 2021-10-25.
83. <sup>a</sup> Wilson, Bee (2018-03-01). "Yes, bacon really is killing us". The Guardian. London. ISSN 0261-3077. Archived from the original on 2021-02-10. Retrieved 2021-02-14. In trade journals of the 1960s, the firms who sold nitrite powders to ham-makers spoke quite openly about how the main advantage was to increase profit margins by speeding up production.
84. <sup>a</sup> Doward, Jamie (2019-03-23). "Revealed: no need to add cancer-risk nitrites to ham". The Observer. London. Archived from the original on 2021-01-26. Retrieved 2021-02-14. The results show that there is no change in levels of inoculated *C. botulinum* over the curing process, which implies that the action of nitrite during curing is not toxic to *C. botulinum* spores at levels of 150ppm [parts per million] ingoing nitrite and below.
85. <sup>a b</sup> (Bhat, Rajeev; Alias, Abd Karim; Paliyath, Gopinadham (2011). Progress in Food Preservation. Retrieved from <http://www.ebib.com>
86. <sup>a</sup> Riva Pomerantz (Nov 15, 2017). "KOSHER IN THE LAB". Ami. No. 342. p. 88.
87. <sup>a</sup> P'EREZ-D'IAZ, I.M; MCFEETERS, R.F (May 2010). "Preservation of Acidified Cucumbers with a Natural Preservative Combination of Fumaric Acid and Allyl Isothiocyanate that Target Lactic Acid Bacteria and Yeasts". Journal of Food Science. 75 (4): M204–M208. doi:10.1111/j.1750-3841.2010.01587.x. PMID 20546411.
88. <sup>a</sup> Kumar, H. N. Harsha; Jha, Anshu Kumar; Taneja, Khushboo K.; Kabra, Krishan; Sadiq, Hafeez M. (2013). A Study On Consumer Awareness, Safety Perceptions & Practices about Food Preservatives and Flavouring Agents used in Packed/Canned Foods from South India. National Journal of Community Medicine, 4(3), 402.
89. <sup>a</sup> Theron, M. M. & Lues, J. F. (2007). Organic acids and meat preservation: A review. Food Reviews International, 23, 141-158.
90. <sup>a</sup> Field, Simon Quellen (2008). Why There's Antifreeze in Your Toothpaste: The Chemistry of Household Ingredients. Chicago: Chicago Review Press.
91. <sup>a b</sup> Antinoro, L. (2008). EN Rates 12 Common Food Additives As Safe Or Sorry Ingredients. (Cover story). Environmental Nutrition, 31(5), 1-4.
92. <sup>a</sup> Barrett, J. R. (2007). "Hyperactive Ingredients?". Environmental Health Perspectives. 115 (12): A578. doi:10.1289/ehp.115-a578. PMC 2137120. PMID 18087571.