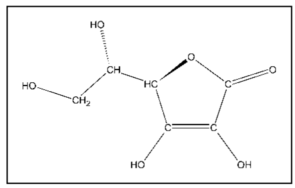
10. Ascorbic Acid



CHEMICAL NAME = ascorbic acid
CAS NUMBER = 50–81–7
MOLECULAR FORMULA = $C_6H_8O_6$
MOLAR MASS = 176.1 g/mol
COMPOSITION = C(40.92%) H(4.58%) O(54.50%)
MELTING POINT = 192°C
BOILING POINT = decomposes
DENSITY = 1.95 g/cm^3

Ascorbic acid, a water-soluble dietary supplement, is consumed by humans more than any other supplement. The name *ascorbic* means antiscurvy and denotes the ability of ascorbic to combat this disease. Vitamin C is the L-enantiomer of ascorbic acid. Ascorbic acid deficiency in humans results in the body's inability to synthesize collagen, which is the most abundant protein in vertebrates. Collagen is the fibrous connective tissue found in bones, tendons, and ligaments. Scurvy produced from a lack of vitamin C results in body deterioration, producing tender joints, weakness, and ruptured blood vessels. The rich supply of blood vessels in the gums, coupled with the wear associated with eating, produces one of the first visible signs of scurvy: bleeding, sensitive gums eventually leading to the loss of teeth.

Signs of scurvy have been found in the human remains of ancient civilizations. Scurvy affected soldiers, Crusaders, and settlers during the winter months, but it is mostly associated with sailors. Long sea voyages where crews were isolated from land for extended periods increased during the age of exploration. These voyages relied on large staples of a limited variety of foods that were eaten daily, and it was typically several weeks to several months before staples could be replenished. The lack of fruits, vegetables, and other foods containing vitamin C in sailors' diets ultimately resulted in high occurrences of scurvy. For example, it is believed that approximately 100 of 160 of Vasco da Gama's crew that sailed around the Cape of Good Hope died of scurvy. The first extensive study of scurvy was conducted by the Scottish naval surgeon James Lind (1716–1794) in response to the high death rate of British sailors. In 1747, Lind varied the diets of sailors suffering from scurvy during a voyage and discovered that sailors who consumed citrus fruit recovered from the disease. Lind published his findings in his Treatise on Scurvy in 1753. Although Lind's work provided evidence that citrus fruit could combat scurvy, the disease continued to plague sailors and explorers into the 20th century. Many people discounted Lind's work, sailors were reluctant to change their standard diet, and it was difficult or expensive to provide the necessary foods to combat scurvy. Although there were notable exceptions, such as the voyages of Captain James Cook (1728–1779), and although certain foods were known as antiscorbutic, scurvy persisted throughout the 19th century.

During the first decades of the 20th century, researchers discovered the need for essential vitamins and the relation between diet and deficiency diseases. Between 1928 and 1933, research teams led by Albert Szent-Györgyi (1893–1986), a Hungarian-born researcher working at Cambridge, and Charles G. King (1896–1988), working at Columbia University in the United States, isolated ascorbic acid. Szent-Györgyi obtained the substance from the adrenal gland of bovine kidneys (King isolated it from lemons) and called it hexuronic acid. Subsequent research in which he isolated hexuronic acid from paprika and conducted experiments on guinea pigs demonstrated that hexuronic acid alleviated scurvy. Hexuronic acid was shown to be the same as vitamin C, which had been identified as Lind's antiscorbutic substance by the two researchers Alex Holst (1861–1931) and Theodore Frohlich in 1907. In 1934, Norman Haworth (1883–1950), working with Edmund Hirst (1898–1975) in England, and Poland's Thadeus Reichstein (1897–1996) succeeded in determining the structure and synthesis of vitamin C. Vitamin C was the first vitamin to be produced synthetically. Szent-Györgyi received the Nobel Prize in medicine or physiology in 1937, and during the same year Haworth received the Nobel Prize in chemistry, in a large part for their work on vitamin C.

Until the 20th century, it was thought that scurvy was confined to humans. Most plants and animals have the ability to synthesize ascorbic acid, but it was discovered that a limited number of animals, including primates, guinea pigs, the Indian fruit bat, and trout, also lack the ability to produce ascorbic acid. In vertebrates, ascorbic acid is made in the liver from glucose in a four-step process. Each step requires a specific enzyme and humans lack the enzyme required for the last step, gulonolactone oxidase.

Ascorbic acid is produced synthetically using the Reichstein process, which has been the standard method of production since the 1930s. The process starts with fermentation followed by chemical synthesis. The first step involves reduction of D-glucose at high temperature into D-sorbitol. D-sorbitol undergoes bacterial fermentation, converting it into L-sorbose. L-sorbose is then reacted with acetone in the presence of concentrated sulfuric acid to produce diacetone-L-sorbose, which is then oxidized with chlorine and sodium hydroxide to produce di-acetone-ketogulonic acid (DAKS). DAKS is then esterified with an acid catalyst and organics to give a gulonic acid methylester. The latter is heated and reacted with alcohol to produce crude ascorbic acid, which is then recrystallized to increase its purity. Since the development of the Reichstein process more than 70 years ago, it has undergone many modifications. In the 1960s, a method developed in China referred to as the two-stage fermentation process used a second fermentation stage of L-sorbose to produce a different intermediate than DAKS called KGA (2-keto-L-gulonic acid), which was then converted into ascorbic acid. The two-stage process relies less on hazardous chemicals and requires less energy to convert glucose to ascorbic acid. The annual global production of ascorbic acid is approximately 125,000 tons.

Sodium, potassium, and calcium salts of ascorbic acids are called ascorbates and are used as food preservatives. These salts are also used as vitamin supplements. Ascorbic acid is water-soluble and sensitive to light, heat, and air. It passes out of the body readily. To make ascorbic acid fat-soluble, it can be esterified. Esters of ascorbic acid and acids, such as palmitic acid to form ascorbyl palmitate and stearic acid to form ascorbic stearate, are used as antioxidants in food, pharmaceuticals, and cosmetics.

As noted, vitamin C is needed for the production of collagen in the body, but it is also essential in the production of certain hormones such as dopamine and adrenaline. Ascorbic acid is also essential in the metabolism of some amino acids. It helps protect cells from free radical damage, helps iron absorption, and is essential for many metabolic processes. The dietary need of vitamin C is not clearly established, but the U.S. National Academy of Science has established a recommended dietary allowance (RDA) of 60 mg per day. Some groups and individuals, notably Linus Pauling in the 1980s, recommend dosages as high as 10,000 mg per day to combat the common cold and a host of other ailments. Table 10.1 lists the amount of vitamin C in some common foods.

Table 10.1 Vitamin C Content of Foods

Food	Vitamin C in mg/100g
Rose hip	2,000
Red pepper	200
Broccoli	90
Beef liver	30
Orange	50
Lemon	40
Apple	6
Banana	9
Cabbage	30
Grapefruit	30

Appreciable amounts of vitamin C are loss when fruits and vegetables are cooked. When using heat to process foods such as in canning and preserving, vitamin C is lost.