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Review Paper

A Review on Biological Functions and Sources of Anti-scorbutic Factor: Vitamin C

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Vitamin C is a water soluble vitamin, though discovered in the 20th century, it has its initials in the 13th and 14th century due to outbreak of scurvy in seafarer. Along with being an antiscorbutic agent it has multitudinous salubrious roles in human beings which subsume antioxidant action, a cofactor in enzymatic activity, enhancing iron absorption, pivotal role in immunity, regeneration of vitamin E, etc. Vitamin C is even propitious in preventing and treating a large number of diseases including cardiovascular, ocular, cognitive and pulmonary diseases to name a few. Humans are inept to synthesize the vitamin and require an external source to fulfil the recommended daily allowance. The present review comprises of various biological aspects of vitamin C and its sources in fruits and vegetable.

Keywords: Ascorbic acid, L-gulonolactone oxidase, Antioxidant, Immunity, Collagen, Carnitine.

INTRODUCTION

Two Norwegian physicians Axel Holst and Theodor Frolich while studying beriberi in guinea pigs, observed clinical signs of scurvy in the pigs. The induced scurvy was treated on addition of fresh fruits and fruit extracts in the diet. In 1928, Albert Szent-Gyorgyi isolated a substance from the adrenal cortex of an animal and called it 'hexuronic acid'. They suspected it to be antiscorbutic factor, but couldn't prove it. Four years later, Charles Glen King isolated vitamin C in his laboratory and concluded that it was the same as 'hexuronic acid' and Norman Haworth deduced the chemical structure of vitamin C in 1933. Haworth and Szent-Gyorgyi gave the name a-scorbic acid (due to its property of curing scurvy) or precisely L-ascorbic acid (Norum and Grav, 2002; Carpenter, 2012, Zhang, 2012).

Vitamin C (VC) is a water soluble vitamin, it has been estimated that 3 ml of water can dissolve 1 ml of it. It has an oblong crystalline structure which is white in colour and easily gets destroyed upon heating under pressure and its melting point is 190-192 ○C. Its general formula is C6H6O5 and the chemical formula is 2,3-didehydro-L-threo-hexano-1,4-lactone and the 5th carbon of the vitamin C structure is asymmetric which makes formation of two enantiomeric possible. The first oxidation product is dehydroascorbic acid (DHA) which has been analyzed to be a dimer (Kastner, 2001; Higdon and Frei, 2002; Talwar and Srivastava, 2003). L-ascorbic acid (L-AA) is the main biological form of VC which is active and DHA is an oxidation product which also has biological properties but to a subjacent level. DHA can be converted to L-AA by reducing agents and

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can even be oxidized in an irreversible manner to diketogulonic acid, which does not have any VC activity (Lee and Kader, 2000).

It has been observed in electrochemical studies that L-AA and dehydroascorbic acid form a reversible redox couple. There are four stereoisomers of the vitamin including L-AA, D-AA, D-isoascorbic acid and L-isoascorbic acid, amongst all these only L-AA has antiscorbutic activity (Tolbert et al., 1975; Mehlhorn, 1991; Bielski et al., 1975; Winkler, 1987; Chatterjee, 1970).

BIOLOGICAL FUNCTIONS

Electron Donor/Cofactor for Enzymes

The reducing action or electron donating property of vitamin C accounts for most of its physiological role in the human body. It is a specific electron donor for eight human enzymes, amongst which three participate in the post translational hydroxylation of collagen. Most of the symptoms produced by scurvy are due to defects in collagen synthesis, which include, fragility of blood vessels, mobility of teeth, diseases related to bone and connective tissue and delayed or impaired healing of wounds (Higdon and Frie, 2002). Significant increase in collagen formation has been observed in animals receiving adequate amounts of the vitamin than in animals kept on its defficiency. Van Robertson et al have observed that in the absence of VC equally large granuloma was formed, but the content of collagen present was extremely low.

It was also observed that the level of collagen in granulomas could be increased to the normal concentrations on administration of VC and concentration of hydroxyproline in the granulomas in each case paralleled collagen concentration. This suggested that ascorbic acid might be essential for hydroxyproline synthesis. In case of wound healing, accumulation of collagen takes place at a lower rate in case of VC deficiency, but the collagen deposition in the deficient wounded tissue increases more than in the normal tissue repair on administration of the vitamin (Van Robertson, 1959). VC deficiency prevents maturation of fibroblast but proliferative power of the cells remains unaltered and maturation of fibroblasts is essential for collagen formation, this may explain the indirect effect of VC deficiency in collagen formation (Mitoma and Smith, 1960). In the presence of extreme unfavourable condition collagen formation still takes place if VC is present and in case of VC deficiency formation of collagen either halts or the present collagen destroys the existing collagen through self degradative process (Gross, 1959).

VC is a cofactor for two a-ketoglutarate requiring dioxygenase reactions i.e.-N-trimethyllysine hydroxylase and -y-butyrobetaine hydroxylase. These are two of the reactions of carnitine biosynthesis process. L-carnitine is required for transport of fatty acids from cytosol to mitochondria and plays a pivotal role in modulating energy metabolism. Fatty acids are processed by beta-oxidation to produce biological energy in the form of adenosine triphosphate (ATP). It has been observed that chronic fatigue patients have lower concentration of L-carnitine in their serum and it is used to treat patients suffering from fatigue and lethargy. The two symptoms, i.e. fatigue and lethargy, early signs of scurvy, are related to carnitine biosynthesis (Rebouche, 1991; Eaton and Bartlett, 1996; Pliopys and Pliopys, 1995; Pliopys and Pliopys, 1997). VC is one of the three substrates for dopamine beta-monooxygenase (Dβ-M), Dβ-M acts as a catalyst in the conversion of dopamine to the neurotransmitter, norepinephrine. The reaction takes place in the neurosecretory vesicles of the adrenal medullae and the large dense-cored synaptic vesicles of the sympathetic nervous system (Wimalasena and Wimalasena, 1995).

Other activities of VC include metabolism of cholesterol to bile and steroid metabolism. A study was carried by Harris et al to test the role of VC deficiency in bile metabolism and the study concluded that in VC deficient guinea pigs the bile acid pool size and excretion rate were reduced to half (Harris et al., 1979). VC plays a role in steroid metabolism by acting as a cosubstrate of the enzyme 7α-monooxygenase. Level of VC concentration alters the activity of p450 and monooxygenases and also enhances the hydroxylation of xenobiotics and carcinogens by the p450 family of enzymes (Yang et al., 1992). Nitric oxide the synthesis product of nitric oxide synthase (NOS) plays major roles in maintaining endothelial functions. It is the main vasodilatory substance released by the endothelium, plays antiproliferative, antithrombotic, and anti-inflammatory functions in the vascular tissue.

Ascorbate is the depropanated form of VC and it prevents the action of the NOS cofactor BH4. BH4 on the other hand hampers the physiological role played by NOS as it promotes transfer of electron to oxygen in place of L-arginine. This results in generation of superoxide instead of nitric oxide. This reaction is known as “NOS uncoupling” (Ladurner, 2012). VC is even a cofactor for prolyl and lysyl hydroxylases which are involved in the synthesis of hydroxyproline and hydroxylysine. It is required for maintaining prolyl and lysyl in an active form. Ascorbate forms prolyl residues in extension which is the cell structure protein hence indicating role of intracellular ascorbate in growing cell (Smirnoff, 1996; Naidu, 2003).

Antioxidant Activity

VC by donating its electrons prevents other compounds from being oxidized, due to this property, it has been considered as a powerful antioxidant. It acts against almost every physiologically reactive oxygen species and reactive nitrogen species, including superoxide, hydroperoxyl radicals, aqueous peroxyl radicals, singlet oxygen, ozone, nitrogen dioxide, nitroxide radicals, and hypochlorous acid. These species can be divided into four types, the first type includes compounds with unpaired electrons for e.g. superoxide, hydroxyl radical, peroxyl radicals, sulphur radicals and nitrogen-oxygen radicals.

The second group has compounds which are reactive but are not radicals. These include hypochlorous acid, nitrosamines and other nitrosating compounds, nitrous acid related compounds and ozone. The third type enlists compounds which are

formed by first reacting with either of the first two groups and followed by reaction with VC. The fourth type includes transition metal-mediated reactions involving iron and copper (Padayatty et al., 2003). The mono-anion form of VC i.e. ascorbate is the prime chemical species of VC at physiological pH. It undergoes two reversible and consecutive oxidations of one electron which results in the generation of dehydroascorbate and ascorbate free radicals (AFR) (Duarte and Lunec, 2005; Wilson, 2002).

3,4-methylenedioxy-N-methylamphetamine (MDMA) induces 5-hydroxytryptamine (5-HT) neurotoxicity as MDMA initiates formation of hydroxyl radicals which leads to oxidative stress. In a study role of VC on generation of hydroxyl radical by MDMA was tested and the results presented that VC reduces formation of hydroxyl radical thus decreasing the oxidative stress (Shankaran et al., 2001). VC is a chain-breaking antioxidant along with others like tocopherol (vitamin E), ubiquinol, β-carotene etc (Niki, 1991). It has the calibre to provide protection to cytosolic and membrane components of a cell from oxidative damage.

VC scavenges free radical species generated in the cytosol as a by-product of cellular metabolism, hence acting as a primary antioxidant. In case of cell membranes it acts as an indirect antioxidant by reducing the α-tocopheroxyl radical to α-tocopherol whereas it interacts directly with the plasma membrane as an antioxidant. VC can donate electrons to a trans-plasma membrane electron transfer activity in the erythrocytes and nucleated cells. It can donate either one or two electrons in redox reactions and almost 99% of VC is available in the form of monoanion at physiological pH (May, 1999).

The unpaired electrons present on the ascorbyl radical have a delocalized nature which makes them comparatively unreactive. It has the ability of donating electron to other free radicals, which makes it stabilized and prevents the propagation of radicals which leads to lipid peroxidation. Frei et al. have stated that VC prevents formation of lipid hydroperoxides, these hydroperoxides are derived from unsaturated phospholipids, glycolipids, and cholesterol. They are intermediates of peroxidative reactions and are not detoxified by the endogenous plasma antioxidants, hence leading to detrimental effects on vital tissues.

The study by Ashton et al presented that VC prevents ESR signal and free radical-mediated lipid peroxidation products in human blood pre- and post-exercise (Ashton et al., 1999; Girotti, 1998). VC acts as the defence against free radicals in whole blood and plasma. In the presence of free transition metal catalysts it even acts as a pro-oxidant. VC is the only endogenous antioxidant, which completely protects the lipids from detectable peroxidative damage caused by aqueous peroxyl radicals. It acts as a more potent antioxidant than protein thiols, α-tocopherol, bilirubin, or urate under such condition. It traps almost all the peroxyl radicals in the aqueous phase before they diffuse into the plasma lipids (Frei et al., 1989).

Human corneal endothelial cells (HCEC) are derived from neural cells and form a monolayer of hexagonal cells. Their primary role is to maintain corneal clarity by regulating corneal hydration. They are arrested in post-mitotic state and their loss due to aging or diseases of corneal endothelium progresses to corneal oedema and finally to blindness. They even play a dominant role in maintaining corneal transparency by regulating corneal hydration. In a clinical study effect of L-ascorbic acid 2-phosphate (oxidation-resistant derivative of L-AA) on growth of HCECs was examined and it was observed that L-ascorbic acid 2-phosphate enhanced the proliferation and replicative lifespan of HCECs from patients with a wide range of ages. The exact mechanism was not clear but, its antioxidant property was suspected to be the prime vindication (Schmedt et al., 2012; Shima et al., 2011).

Cigarette smoking causes oxidative damage to tissues as it inactivates antiproteinases, activates endogenous phagocytic cells, and leads to oxidation of low density lipoprotein. A study conducted by Frei et al (1991) presented that VC is the most potent antioxidant and only natural component protecting lipoprotein lipids from harmful effects of cigarette smoking and peroxidation damage.

Iron Absorption

The enhancing effect of VC on iron absorption was first stated by Moore and Dubach in 1951 (Hallberg et al., 1986). Literature suggests that in animal models there is increased iron absorption from ferrous sulphate when it is supplemented with vitamin C, whereas in humans, it has been suggested that greater plasma iron is increased if iron dosage is supplemented with VC and the observed effect was dose related (Brise and Hallberg, 1962). In 1972 Glover et al stated that increased amount of VC was retained in the spleen of scorbutic guinea pigs when compared to normal pigs and liver uptake of iron was more as compared to spleen but lower in value in the scorbutic animal (Glover et al., 1972). Litschitz (1971) further evaluated and concluded the same results and even stated that on administration of VC there was release of iron from spleen but not from the liver. Friedman and Osaki (1974) concluded that liver contains an enzyme ferric reductase, which helps it to recover iron from ferritin storage for use even in the state of deficiency, whereas spleen lacks this enzymatic activity and hence require VC for release of iron.

Vitamin C has been considered as the only dietary constituent derived from plants that have been considered to increase the absorption of non-heme iron in human beings. Its stimulating effect has been proven when it is administered along with inorganic iron and the effect arises when it was ingested with food. A study presented that the iron absorption escalated from 0.8% to 7.1% when VC concentration was increased from 25 to 1000 mg (Cook and Reddy, 2001). In a study by Sayers et al effect of VC supplementation on iron absorption was tested in maize, wheat and soya and the study concluded that the addition of VC enhanced absorption of both intrinsic as well as extrinsic iron (Sayers et al., 1973). In a study an almost threefold increase in iron absorption was observed on addition of vitamin C. The mechanism of action behind augmentation of iron absorption is either due to the ability of VC to convert ferric to ferrous ions or by forming soluble iron complexes. Thus preventing the

effect of various ligands which bind iron ion and inhibit non-heme iron absorption, the list of ligands include tannins, phytates, phosvitine, calcium and phosphate salts and antacids (Hallberg et al., 1986; Monson et al., 1978).

In 1991 Cook et al (1991) stated that the influence of dietary enhancers and inhibitors of non-heme iron absorption was more on single diets tested in the morning than on whole diets, on testing in the same individual. Monsen et al (1978) observed that 75 mg of VC increases about fourfold iron absorption in females with low iron stores and approximately twofold increase in males with an average of 1000 mg iron storage.

Effect On Immune Response

Vitamin C supplement augments components of human immune system, both types, i.e. innate as well as adaptive immune system. These components include the antimicrobial activities, lymphocyte proliferation, chemotaxis and delayed-type hypersensitivity. Leukocytes have high concentrations of ascorbate, the level of VC in leucocyte is 20-30 times higher than in plasma and ascorbate has also been observed to be involved in leukocytes migration and phagocytosis, induction and elevation of the expression of hypersensitivity, increasing interferon production and improving natural killer cell activities (Talwar and Srivastava, 2003; Wintergerst et al; Thomas and Holt, 1978). It inhibits the formation of proinflammatory cytokines and protects the immune cells from oxidative stress caused by reactive oxygen species produced during the inflammatory response and respiratory burst (Wintergerst et al., 2006; Holmannova et al., 2012; Kennes et al., 1983).

Studies have shown that VC causes a major increase in the synthesis of immunoglobulin (Ig) G and IgM and in the serum levels of IgA, IgM and C-3 complement. The effect has been reported to be more pronounced on the synthesis of IgG than on IgM (Prinz et al., 1977; Vallance, 1977).

Regeneration of Vitamin E

It was observed in 1941 that VC has the capability of increasing the antioxidant potential of vitamin E present in lard and cottonseed oil. In the 1968 Tappel suggested that VC could regenerate vitamin E from vitamin E radical, which is formed while acting on lipid peroxyl radical as an antioxidant (Myllyla et al., 1984). Niki et al (1984) stated that regeneration of tocopherol radical by vitamin C on quenching the peroxyl radicals generated by oxidation of methyl linoleate in solution.

Few in vitro studies suggested that have suggested that this regeneration by VC takes place by the donation of hydrogen atom (Mukai et al., 1991; Packer et al., 1979). Chan et al (1991) stated that Vitamin E can be regenerated in the human cell homogenates thus concluding that maintenance of membrane tocopherol status may be an important function of VC which operate in group thus confirming maximum membrane protection against oxidative damage.

Antihistaminic Effect

Histamine is a major mediator of inflammatory and allergic reactions, it regulates neuronal activity, controls vascular tone, changes endothelial permeability, regulates gastric acid secretion and takes part in inflammatory responses. Vasodilation and increased vascular permeability aggravates the fight-flight response and increase in its concentration affects circulatory and immunological homeostasis in a negative manner. In state of stress, ascorbate is moved out of the tissues, this is considered to be a natural defence mechanism for detoxifying excess of histamine.

Regular intake of VC results in a decrease in level of histamine, which causes an increase in leukocyte chemotaxis (Kim et al., 2013; Johnston et al., 1992). Studies have concluded that the increase in bronchial responsiveness due to heavy smoking and in allergic rhinitis is aggravated in presence of VC deficiency and administration of VC increases the brochoconstrictive response (Bucca et al., 1989; Bucca et al., 1990). VC even prevents capillary fragility and venular bleeding caused by increased levels of histamine (Clementson, 2004).

SYNTHESIS AND SOURCES OF VITAMIN C

VC is synthesized by a number of animals excluding human beings, teleost fishes, anthropoid primates, guinea pigs, some kinds of bat and passeriformes bird species. The process involves the reduction of l-glucuronate derived from UDP-glucuronate to l-gulonate. This leads to an inversion of the numbering of the carbon chain as the aldehyde function of d-glucuronate becomes a hydroxymethyl group in the resulting l-gulonate. L-gulonate is converted to its lactone and the resultant lactone is further oxidized to l-ascorbate. The last step is catalyzed by l-gulonolactone oxidase (GLO). The inability of humans to synthesize VC is due to GLO deficiency in the species.

Man has genes homologous to the rat (rats are capable of synthesizing VC) GLO but the gene has been mutated. When nucleotide sequence alignment of one exon of rat was compared to corresponding exon in these mutated primates, the results presented that in latter species mutation has occurred several times leading to conversion of active GLO gene to non-functional GLO gene. Literature also suggests that this mutation was advantageous to some species as GLO produces hydrogen peroxide which is otherwise harmful for health (Smirnoff et al., 2001; Smirnoff, 2001; Ohta and Nishikimi, 1999).

Other than animals most of the plants and yeast also form VC, yeast accumulate D-erythroascorbic acid (D-EAA), an analogue of VC when they were grown in the presence of intermediates of VC synthesis in animals and plants, including substrates L-gulonolactone, L-galactonolactone or L-galactose and the enzymes involved are D-arabinose dehydrogenase and D-arabinonolactone oxidase (Hancock and Viola, 2002).

The biosynthesis process of VC in plants and yeast has been observed to be different in them from the animals. Wheeler et al in 1998 stated that biosynthesis of VC in plants involve the conversion of GDP-D-

mannose to GDP-L-galactose, the reaction is catalysed by GDP-mannose-30, 50-epimerase, the immediate precursor of VC. L-galactose released from the nucleotide is the immediate precursor of L-galactono-1,4-lactone, which by the action of a dehydrogenase is converted to VC. L-galactonolactone dehydrogenase is the substrate to plants homologue to GLO in animals (Wheeler et al., 1998; Valpuesta and Botella, 2004).

It has been estimated that approximately 90% of VC of humans is supplied by fruits and vegetables. The concentration of VC in plants varies from species and cultivars, it is destructed if the fruits or vegetables are mishandled or due to adverse storage environment. There is an increase in the destruction of the vitamin when the storage period is increased, in case of higher temperatures, low relative humidity, physical damage and low temperature conditions. Literature suggests that the flavedo portion of citrus fruits has a fourfold higher level of VC, that its juice and skin tissue has a higher concentration of the vitamin than the pulp which might be to provide protection to the fruit from light and oxidation.

Other factors affecting the content of VC in fruit and vegetables are light exposure, kind of fertilizer used, ripening, etc. Fruits on exposure to sunlight attain higher concentration of VC than on keeping them in the shade, use of rich sulphur fertilizer reported to increase the VC level more than poor sulphur fertilizer. When fruits and vegetables were left on plant, fruit had higher content of VC than the one which were taken off the plant before ripening (Prasad et al., 2010; Lee and Kader, 2000; Vallejo et al., 2003). Content of VC in different fruits and vegetables has been tabularised in table 1 and 2.

Table 1 – Content of vitamin C in Vegetables (Nutrient Data Laboratory, 2010)

Sr. No	Source	Vitamin C Content (mg/100gm)
1.	Pepper, hot chilli, green, raw	242.5
2.	Pepper, sweet, yellow, raw	183.5
3.	Peppers, hot chilli, red, raw	143.7
4.	Drumstick pods, raw	141.0
5.	Pokeberry shoots, raw	136.0
6.	Parsley, fresh, raw	133.0
7.	Mustard spinach, tender green, raw	130.0
8.	Kale, scotch, raw	130.0
9.	Peppers, sweet, red, raw	127.7
10.	Kale, raw	120.0
11.	Peppers, jalepano, raw	118.6
12.	Vinespinach (basella), raw	102.0
13.	Taro, tahitian, raw	96.0
14.	Broccoli leaves, raw	93.2
15.	Broccoli flower duster	93.2
16.	Pepper, Hungarian, raw	92.9
17.	Broccoli, raw	89.2
18.	Cauliflower, green, raw	88.1
19.	Bitter gourd, leafy tips, raw	88.0
20.	Brussels sprouts, raw	85.0
21.	Bitter gourd (pods), raw	84.0
22.	Pepper, banana, raw	82.7
23.	Peppers, sweet, green, raw	80.4
24.	Lambsquarter, raw	80.0
25.	Sesbania flower, raw	73.0
26.	Mustard green, raw	70.0
27.	Cress, garden, raw	69.0
28.	Kohlrabi, raw	62.0
29.	Peas, edible-podded, raw	60.0
30.	Chives, raw	58.1
31.	Cabbage, red, raw	57.0
32.	Swamp cabbage (skunk cabbage)	55.0
33.	Taro leaves, raw	52.0
34.	Drumstick leaves, raw	51.7
35.	Cabbage, Danish, domestic, raw	51.0
36.	Cauliflower, raw	48.2
37.	Dock, raw	48.0
38.	Cabbage, Chinese (pak choi), raw	45.0
39.	Winged beans, leaves, raw	45.0
40.	Peppers, Serrano, raw	44.9
41.	Lotus root, raw	44.0
42.	Amaranth leaves, raw	43.3
43.	Watercress, raw	43.0
44.	Wasabi root, raw	41.9
45.	Peas, green, raw	40.0
46.	Pigeonpeas, immature seeds, raw	39.0
47.	Seaweed, laver, raw	39.0
48.	Kidney beans, mature seeds, raw	38.7
49.	Cornsalad, raw	38.2
50.	Jute, potherb, raw	37.0
51.	Cabbage, raw	36.6
52.	Cowpeas, leafy tips, raw	36.0
53.	Collards, raw	35.3
54.	Borage, raw	35.0
55.	Dandelion greens, raw	35.0
56.	Squash, Zucchini, barley, raw	34.1
57.	Broad beans, immature seeds, raw	33.0
58.	Butterbur (fuki), raw	31.5
59.	Garlic, raw	31.2
60.	Cabbage, savoy, raw	31.0
61.	Chard, Swiss, raw	30.0
62.	Beet greens, raw	30.0
63.	New Zealand spinach, raw	30.0
64.	Radish, white icicle, raw	29.0
65.	Radish seeds, sprouted, raw	28.9
66.	Spinach, raw	28.1
67.	Pumpkin flower, raw	28.0
68.	Coriander (cilantro) leaves, raw	27.0
69.	Onions, welsh, raw	27.0
70.	Rutabagas, raw	25.0
71.	Chicory greens, raw	24.0
72.	Lima beans, immature seeds, raw	23.4
73.	Tomatoes, green, raw	23.4
74.	Okra, raw	23.0
75.	Radish oriental, raw	22.0
76.	Beans, pinto, sprouted, raw	21.7
77.	Taro shoots, raw	21.0
78.	Turnips, raw	21.0
79.	Yam bean (jicama)	20.2

Table 2 – Content of Vitamin C in fruits (Nutrient Data Laboratory, 2010)

Sr. No	Source	Vitamin C Content (mg/100gm)
1.	Camu camu, raw (Justi et al., 2000)	2800.0
2.	Acerola, raw	1667.6
3.	Guava, raw	228.3
4.	Lemon, raw	182.0
5.	Currants, European black, raw	181.0
6.	Kiwifruit, raw	92.7
7.	Longans, raw	84.0
8.	Litchi, raw	71.5
9.	Orange with peel	71.0
10.	Jujube, raw	69.0
11.	Persimmons, native, raw	66.0
12.	Pummel, raw	61.0
13.	Papaya, raw	60.9

14.	Orange, Navels, raw	59.1
15.	Strawberries, raw	58.8
16.	Abiyuch, raw	54.1
17.	Orange, all commercial variety	53.2
18.	Clementines, raw	48.8
19.	Orange, California, Valencia's, raw	48.5
20.	Pineapple raw	47.8
21.	Oranges, Florida, raw	45.0
22.	Kumquats, raw	43.9
23.	Currants, red and white, raw	41.0
24.	Grapefruit, pink and red, California and Arizona, raw	38.1
25.	Carissa (natal plum)	38.0
26.	Grapefruit, pink and red, Florida, raw	37.0
27.	Grapefruit, white, Florida	37.0
28.	Guavas strawberry	37.0
29.	Melons, cantaloupe, raw	36.7
30.	Mangos, raw	36.4
31.	Mulberries, raw	36.4
32.	Sugar-apples (sweetsop), raw	36.3
33.	Elderberries, raw	36.0
34.	Carambola (starfruit), raw	34.4
35.	Grapefruit, pink, red and white, raw	34.4
36.	Grapefruit, white, all areas, raw	33.3
37.	Grapefruit, white, California	33.3
38.	Feijoa, raw	32.9
39.	Grapefruit, pink and red, raw	31.2
40.	Passion fruit, raw	30.0
41.	Passion fruit, purple, raw	29.8
42.	Limes, raw	29.1
43.	Breadfruit, raw	29.0
44.	Gooseberries, raw	27.7
45.	Tangerines (Mandarin oranges), raw	26.7
46.	Pitanga (Surinam-cherry), raw	26.3
47.	Raspberries, raw	26.2
48.	Rowal, raw	25.8
49.	Sapote, mamey, raw	23.0
50.	Rose apple, raw	22.3
51.	Melons, casaba, raw	21.8
52.	Blackberry, raw	21.0
53.	Soursop, raw	20.6

EXCESS DOSAGE

Though claimed to have low toxic levels, excessive intake of VC has been related to few systemic pathologies. The most common ones reported till date are diarrhoea, abdominal cramps, gastrointestinal disturbances, flatus and nausea. Next to them is an increase in the formation of stones in kidney, mechanism behind it are its conversion to oxalate and its potential urinary acidifying properties (Institute of Medicine. Food and Nutrition Board, 2000; Jacob and Sotoudeh, 2002; Blanchard and Tozer, 1997). Recommended daily allowance as per individuality has been summarised (table 3 & 4).

Table 3 – Tolerable dose for an individual (Institute of Medicine. Food and Nutrition Board, 2000)

Sr. No	Individual	Tolerable Upper Intake Level
	Paediatric	
1.	0–12 months	Not countable
2.	1–3 years	400 mg
3.	4–8 years	650 mg
4.	9–13 years	1,200 mg
5.	14–18 years	1,800 mg
6.	Pregnant female 14 - 18 years	1,800 mg
7.	Lactating female 14 - 18 years	1,800 mg
	Adults	
1.	Above 19 (Male)	2,000 mg
2.	Above 19 (Female)	2,000 mg
3.	Pregnant female	2,000 mg
4.	Lactating female	2,000 mg

Table 4 – Recommended Daily Allowance for Individuals (Institute of Medicine. Food and Nutrition Board, 2000)

Sr. No	Individual	Recommended Daily Allowance (RDA)
	Paediatric	
1.	Birth - 6 months *	40 mg AI×
2.	Infants 6 - 12 months*	50 mg AI×
3.	Children 1 - 3 years*	15 mg
4.	Children 4 - 8 years*	25 mg
5.	Children 9 - 13 years*	45 mg
6.	Adolescent female 14 - 18 years	65 mg
7.	Adolescent male 14 - 18 years	75 mg
8.	Pregnant female 14 - 18 years	80mg
9.	Lactating female 14 - 18 years	115 mg
	Adults	
1.	Male over 18 years	90 mg
2.	Female over 18 years	75mg
3.	Pregnant female over 18 years	85 mg
4.	Lactating female over 18 years	120 mg
	Individuals who smoke require more vitamin C than non smokers.	35 mg/day

***Male & Female**
×Adequate Intake

CONCLUSION

It can be concluded that VC is a wonder vitamin, it is necessary for varied biological processes to occur and protects the body from a myriad of harmful elements. We mentioned various sources of this vitamin along with approximate content in each. We recommend increasing intake of these fruits and vegetables so that maximum benefit can be availed as per individual requirements.

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