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Veerasamy Pushparaj Santhi
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Masilamani Poomaruthai
Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Veerasamy Pushparaj Sarasu
Department of Clinical Microbiology, Government Medical College, Pudukkottai, Tamil Nadu, India

Kandasamy Gurusamy
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Subbaiyan Parthiban
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Karuppaiah Geetha
Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Kabeerdoss Indumathi
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Kumar Sarasu Laveena
Madras Medical College, Chennai, Tamil Nadu, India

Arunachalam Umayal
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Corresponding Author:
Veerasamy Pushparaj Santhi
Department of Fruit Science, Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Navalur Kuttappattu, Tiruchirappalli, Tamil Nadu, India

Fruits: A potential source of vitamin c as essential human nutrition and immunity development: A review

Veerasamy Pushparaj Santhi, Masilamani Poomaruthai, Veerasamy Pushparaj Sarasu, Kandasamy Gurusamy, Subbaiyan Parthiban, Karuppaiah Geetha, Kabeerdoss Indumathi, Kumar Sarasu Laveena and Arunachalam Umayal

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Abstract
Understanding the importance of food habits to boost our immune system in the circumstances pandemic diseases is highly demanded. This review ensembles the role of Vitamin C in the immune system, its fruit sources, possibilities of losing it through preservation and attempts to resolve the higher end processing modules to rescue the losses. The importance of vitamin C in the biological system is through collagen formation, cartinine systhesis and seemingly antioxidant attributes. Widely available sources of Vitamin C, especially fruits are in abundance which is not fully and effectively utilized. Fruits belonging to families Rutaceae, Rosaceae and Myrtaceae are comparatively wealthier sources of Vitamin C. There are plentiful studies which present the abundance of Vitamin C in fruit sources. Fruits widespread in all habitats tropical, subtropical, temperate and arid zones start from Mango to Hazel nut are rich in Vitamin C. Due to the sensitivity of Vitamin C to heat, temperature, pH and many other factors it is almost lost while preservation. Retention of the most vulnerable and essential ascorbic acid in human immune system is of immediate, vital and indispensable need in current scenario. Attempts are being made with substantial success in areas of high pressure processing, microwave processing, and freeze drying methods in the retention of Vitamin C in processed fruits.

Keywords: Vitamin C, ascorbic acid, cardiovascular disease, cancer, anti-inflammation, antioxidant

Introduction
The chemical name for the vitamin C is ascorbic acid. Ascorbic acid is a simple compound containing six carbon atoms, related to the monosaccharide glucose. It is stable to acid but easily destroyed by oxidation, light, alkali and heat especially in the presence of iron and copper. Most mammals can synthesis vitamin C from glucose but few including human lack of the liver enzyme gluconolactone oxidase, which is required to catalyse one step of this process. It is the lack of this enzyme that forces humans to depend on supplies of vitamin C from their food (Srilakshmi, 2011) [154]. Vitamin C is involved in many biological activities supplied as a dietary nutrient. Ascorbic acid is a compound containing six carbon atoms, related to the structure of monosaccharide glucose. It is stable to acid but easily destroyed by oxidation, light, alkali and heat especially in the presence of iron or copper. Vitamin C is an essential nutrient in many multicellular organisms, especially in humans. Ascorbic acid is a water-soluble vitamin and is found in variable quantities in fruits and vegetables and organ meats (Devaki and Reshma, 2017) [35]. The fruits guava, kiwifruit, longan and strawberry were rich in vitamin C content per gram (Isabelle *et al.* (2010) [65]. Wall (2006) [169].
Fruits and vegetables are important sources of fruits and vegetables (Odriozola-Serrano, Hernández-Jover & Martín-Belloso, 2007) [120]. Hernández, Lobo, & González (2006) [60] reported that it is an important source of nutrition for human. Vitamin C was an additive for processed foods according to Rios & Penteado (2003) [140]. L- ascorbic acid (AA), is the main biologically active form of Vitamin C and dehydroascorbic acid (DHA) is its reversibly oxidised form.

In the present review discussed about,
1. Biological function and metabolic pathways requiring vitamin C
2. Natural source of Vitamin C from tropical, sub-tropical, arid zone and temperate fruit as a source of natural vitamin C

3. Vitamin C effects on health and as human Immunity development
4. Retention of Vitamin C content by advances Processing Methods

Metabolic pathways requiring vitamin C

- Hydroxylation of proline and lysine for collagen synthesis
- Synthesis of noradrenaline from dopamine
- Synthesis of carnitine from lysine
- Activation of neuropepties
- Catabolism of tyrosine
- General antioxidant function

Recommended daily allowance

National Research Council recommends that children have to take as much as 35 mg. Males and females need 45mg. pregnant and lactating women requires 60-80mg.

The recommended Dietary Allowances of ICMR for ascorbic acid are given in table 1.

Table 1: Recommended dietary allowance of Vitamin C

Group	mg/day
Man	40
Women	40
Pregnant Women	40
Lactation	80
Infants (0-12 months)	25
Children (Boys and girls)	40

Deficiency disorders

- Scurvy- weight loss, weakness, heart palpitations, redness and swelling of gums, loosening of teeth, haemorrhage into the skin and mucous membrane, odema, hyperirritability, etc.,
- Metabolism of tyrosine and cholesterol is partially affected.
- Absorption and utilization of iron are affected.

Natural source of Vitamin C from tropical, sub-tropical, arid zone and temperate fruit

Vitamin C content in fruits

Among all the fruits, West Indian Cherry (Asenjo & Freire De Guzman. A.R., 1946) [8], one of the subtropical fruits has the highest Vitamin C content of 2963 mg/100g of the pulp. Aonla (Jain &D.S.Khurdiya., 2004) [69] has the second highest Vitamin C content of 478.56 mg/100ml of the juice. Carissa (Pewlong *et al*, 2014) [126] occupies the next position having an ascorbic acid content of 300.75 mg/100 g of the unripe pulp and 180.4 mg/100g of the fully ripe pulp. Guava (Golberg *et al*, 1941) [52] also has a higher ascorbic acid content of 300 mg/100g. The other fruits occupy the consecutive position in the vitamin C content order with their respective values as follows: Rose Apple (Minh, 2014) [103] has 292.59 mg of ascorbic acid/100g of pulp. Mango (Ribeiro *et al*, 2007) [46] and bilimbi (Yan *et al*, 2013) [175] contains 182mg of AA/100 g of pulp. Pomegranate (Opara *et al*, 2008) [123] contains 118.4 mg AA/100g of peel and 72 mg/100 g of aril. These seven fruits have the highest Vitamin C content. Next to that, higher content of AA is found in the following fruits: Carambola (Yan *et al*., 2013) [175] has 120.74 mg AA/100 g of DW and persimmon (Yaqub *et al*, 2016) [176] has 70 mg AA/100g. Chestnut (Baros *et al*, 2011) contains 69.3 mg of AA/100g of DW. Bael (Sharma *et al*, 2007) [150] has 66 mg of AA/100 g of pulp, apricot (Munzuroglua *et al*, 2003) [110] has 62 mg AA/g, strawberry (Moor *et al*, 2005) [105] has 62 mg /100 g, sweet orange (Okwa & Emenike., 2006) [122] has 61.6 mg AA/100g, blackberry (Guedes *et al*,2013) has 55.78 mg AA/100g, papaya (Wall, 006) has 51.2 mg AA/100g.

The fruits having medium vitamin C content are as follows: Custard apple (Amoo *et al*, 2008) [106] has 50 mg AA/100g, kiwi (Esch *et al*, 2010) [37] has 46.8 mg of AA/100g, mandarin orange (Navarro *et al*,2011) [113] has 41.9 mg AA/100 ml, passion fruit (Suntornsuk *et al*, 2002) [155] has 39.1 mg AA/100 g, rambutan (Wall, 2006) [169] has 36.4 mg AA/100 g, olive (Lopez *et al*, 2005) [89] has 36.1 mg AA/100 g, jackfruit (Ibrahim *et al*, 2013) [64] has 31.55 mg of AA/100g, litchi (Wall, 2006) [169] has 27.6 mg AA/100g, raspberry (Ancos *et al*,2000) [7] has 26.2 mg AA/100g, durian (Ashraf *et al*,2010) [9] has 25.13 mg AA/100g, ber (Tembo *et al*, 2008) [160] has 23 mg AA/100 g, sour cherry (Wojdylo *et al*,2014) has 22.11 mg AA/100 g, avocado (Talabi *et al*., 2016) [158] has 21.3 mg AA/100 g, acid lime (Rangel *et al*, 2011) [134] and bread fruit (Huang *et al*, 2000) [62] has 20 mg of AA/100 g, jamun (Shahnawaz *et al*, 2009) [149] has 19.14 mg AA/100g, walnut (Ogunmoyole & Kade &Korodele 2011) [121] has 18.22mg AA/g, fig (Guvenc., 2009) [55] has 17.6 mg AA/100 g, date Palm (Chaira *et al*,2009) [26] with 17.5 mg AA/100 g, sweet tamarind (Lal &Vishal Nath,2017) [82] has 13.8 mg AA/100 g, loquat (Ghasemnezhad *et al*,2011) [49] has 12.8 mg AA/100 g, peach (Gill *et al*,2002) [51] has 12.6 mg AA/100 g, sweet cherry (Gundogdu & Ugur Bilge. 2012) [54] with 11.4 mg AA/100 g. Following this, the fruits having a lower Vitamin C content ranging from 0.1 to 10 mg of AA/100 g of the pulp are as follows: plum (Gill *et al*, 2002) [51] contains 9.5 mg AA/100, sapota (Ahmed *et al*,2011) [4] and pear (Sanchez *et al*,2003) [143] have 8 mg AA/100 g, blackcurrant (Milivojevic *et al*, 2010) has 7.6 mg AA/g, mangosteen (Manurakchinakorn *et al*, 2004) [94] has 6.75 mg AA/100 g, pineapple (Nweze., 2015) [119] with 6.14 mg AA/100 ml, pistachio nut (Bullo *et al*, 2015) [19] has 5.6 mg AA/100g, phalsa (Sinha *et al*,2015) [151] and grapes (Daniel *et al*, 1932) [33] approximately have 4 mg AA/100 g, banana (Wall, 2006) [169] has 3.3 mg AA/100 g, hazel nut (Koksal *et al*,2006) has 2.45 mg AA/100 g. Least value of Vitamin C are found in fruits like macadamia nut (Munro & Manohar L.Garg.,2008) and pecan nut (Wakeling *et al*,2001) [168] which has a content of approximately 1 mg of AA/100 g. Apple (Jacobo *et al*,2011) [68] has 0.46 mg AA/l and almond (Christian &Mark E.Ukhun.,2006) has most least content of Vitamin C of 0.03 µg of AA /g of pulp. Natural source of Vitamin C content of tropical, sub-tropical, arid zone and temperate fruit in Table 2.

Table 2: Natural source of Vitamin C content of tropical, sub-tropical, arid zone and temperate fruit Crops

S. No	Common Name of The Fruit	Botanical Name	Family	Vitamin- C /Ascorbic Acid Content (/100g)	Reference
1.	Mango	*Mangifera indica L.*	Anacardiaceae	0.56 mg(seed) 25.3-182.55mg pulp)	Fowomola.,2010 Ribeiro *et al*,2007 [46]
2.	Banana	*Musa sp.*	Musaceae	3.3mg	Wall, 2006 [169]
3.	Guava	*Psidium guajava*	Myrtaceae	300mg	Golberg *et al*,1941 [52]
4.	Papaya	*Carica papaya*	Caricaceae	51.2mg	Wall, 2006 [169]
5.	Sapota	*Achras sapota*	Sapotaceae	8.90mg	Ahmed *et al*, 2011 [4]
6.	Grape	*Vitis vinifera*	Vitaceae	4mg	Daniel *et al*,1932 [33]
7.	Acid lime	*Citrus aurantifolia*	Rutaceae	20mg	Rangel *et al*, 2011 [134]
8.	Sweet orange	*Citrus sinensis*	Rutaceae	19.36-61.60mg	Okwa & Emenike.,2006 [122]
9.	Mandarin orange	*Citrus reticulata*	Rutaceae	419mg/l	Navarro *et al*,2011 [113]
10.	Jack fruit	*Artocarpus heterophyllus*	Moraceae	17.82-31.55mg	Ibrahim *et al*,2013 [64]
11.	Avocado	*Persea ameriana*	Lauraceae	14.63mg(raw seed) 4.5-21.3mg(pulp)	Talabi *et al.*, 2016 [158]
12.	Pineapple	*Ananas comosus*	Bromeliaceae	6.4±0.18mg/100ml	Nweze.,2015 [119]
13.	Mangosteen	*Garcinia mangostana L.*	Clusiaceae	6.75±0.05mg(fresh cut) 4.1±1.2mg(ripe)	Manurakchinakorn *et al*,2004 [94]
14.	Litchi	*Litchi chinensis*	Sapindaceae	27.6mg	Wall.,2006 [169]
15.	Loquat	*Eriobotrya japonica*	Rosaceae	12.8mg	Ghasemnezhad *et al*,2011 [49]
16.	Rambutan	*Nephelium lappaceum*	Sapindaceae	36.4mg	Wall.,2006 [169]
17.	Carambola	*Averrhoa carambola L.*	Oxalidaceae	120.74±0.46mg /100g DW	Yan *et al.*, 2013 [175]
18.	Durian	*Durio zibethinus*	Malvaceae	18.87-25.13mg	Ashraf *et al*,2010 [9]
19.	Bilimbi	*Averrhoa bilimbi*	Oxalidaceae	182.98±0.42mg /100g DW	Yan *et al.*, 2013 [175]
20.	Passion fruit	*Passiflora edulis*	Passifloraceae	39.1mg	Suntornsuk *et al*,2002 [155]
21.	Bread fruit	*Artocarpus altilis*	Moraceae	20mg	Huang *et al*,2000 [62]
22.	Rose apple	*Syzygium jambos*	Myrtaceae	292.59mg	Minh.,2014 [103]
23.	Aonla	*Phyllanthus emblica*	Phyllanthaceae	478.56mg/100ml	Jain & D.S.Khurdiya.,2004 [69]
24.	Ber	*Ziziphus mauritiana*	Rhamnaceae	18-23mg	Tembo *et al*,2008 [160]
25.	Pomegranate	*Punica granatum*	Punicaceae	52.8-72 mg(aril) 118.4mg(peels)	Opara *et al*, 2008 [123]
26.	Carissa	*Carissa carandas*	Apocynaceae	300.75±57.65mg (unripe) 180.40±43.09mg (fully ripe)	Pewlong *et al*,2014 [126]
27.	Custard apple	*Annona squamosus*	Annonaceae	50mg(ripe fruit) 43.38mg(juice)	Amoo *et al*,2008 [106]
28.	Fig	*Ficuscarica*	Moraceae	12.2-17.6mg(fresh)	Guvenc.,2009 [55]
29.	Date palm	*Phoenix dactylifera*	Arecaceae	2.4-17.5mg	Chaira *et al*,2009 [26]
30.	Phalsa	*Grewia asiatica*	Malvaceae	4.385mg	Sinha *et al*,2015 [151]
31.	Jamun	*Syzygium cumini*	Myrtaceae	19.14mg	Shahnawaz *et al*,2009 [149]
32.	Bael	*Aegle marmelos(L.)*	Rutaceae	66mg	Sharma *et al*,2007 [150]
33.	West Indian Cherry	*Malpighiae marginata*	Malpighiaceae	1707-2963mg	Asenjo &Freire DeGuzman.A.R.,1946 [8]
34.	Sweet tamarind	*Tamarindus indica*	Fabaceae	13.8mg	Lal&Vishal Nath.,2017 [82]
35.	Apple	*Malus domestica*	Rosaceae	0.46±0.01mg/l	Jacobo *et al*,2011 [68]
36.	Pear	*Pyrus communis*	Rosaceae	5.5-8.4mg	Sanchez *et al*,2003 [143]
37.	Peach	*Prunus persica*	Rosaceae	3.6-12.6mg	Gill *et al*,2002 [51]
38.	Plum	*Prunus domestica*	Rosaceae	9.5mg	Gill *et al*,2002 [51]
39.	Strawberry	*Fragaria×ananassa*	Rosaceae	54-62mg	Moor *et al*,2005 [105]
40.	Sweet cherry	*Prunus savium*	Rosaceae	6.01-11.448mg	Gundogdu & Ugur Bilge.,2012 [54]
41.	Sour cherry	*Prunus cerasus*	Rosaceae	5.45-22.11mg	Wojdylo *et al*,2014
42.	Blackberry	*Rubus ursinus*	Rosaceae	42.69-55.78mg	Guedes *et al*,2013
43.	Raspberry	*Rubus idaeus*	Rosaceae	220.67- 310.89mg/kg²	Ancos *et al*,2000 [7]
44.	Blackcurrants	*Ribes nigrum L.*	Grossulariaceae	7.60mg/g FW	Milivojevic *et al*,2010
45.	Apricot	*Prunus armeniaca*	Rosaceae	62mg/g	Munzuroglua *et al*,2003 [110]
46.	Kiwi	*Actinidia deliciosa*	Actinidiaceae	46.8mg(conventional) 51.4mg(organic)	Esch *et al*,2010 [37]
47.	Persimmon	*Diospyros kaki*	Ebenaceae	7.5-70mg	Yaqub *et al*,2016 [176]
48.	Olive	*Olea europaea*	Oleaceae	36.1mg	Lopez *et al*,2005 [89]
49.	Almond	*Prunus dulsis*	Rosaceae	0.030µg/g	Christian &Mark E.Ukhun.,2006
50.	Walnut	*Juglans regia*	Juglandaceae	18.22±0.45mg/g	Ogunmoyole &Kade I.J &Korodele B.,2011 [121]
51.	Pecan nut	*Carya illinoinensis*	Juglandaceae	1.1mg	Wakeling *et al*,2001 [168]
52.	Pistachio nut	*Pistacia vera L.*	Anacardiaceae	5.6,3mg(raw,roasted)	Bullo *et al*,2015 [19]
53.	Macadamia nut	*Macadamia integrifolia*	Proteaceae	1.2mg	Munro&Manohar L.Garg.,2008
54.	Chest nut	*Castanea alnifolia*	Fagaceae	400-693mg/kg DW	Baros *et al*,2011
55.	Hazel nut	*Corylus avellana*	Corylaceae	2.45mg	Koksal *et al*,2006

Vitamin C effects on health and as human Immunity development: Mechanism of actions of Vitamin C

Vitamin C is a biological reducing agent especially during hydroxylation reactions and it is an antioxidant that protects the body against damaging oxidizing agents (Ramani, 2009) [132].

Collagen synthesis

Collagen synthesis is essential for maintaining normal vascular function. It is a major structural protein of connective tissue (which binds cells and tissues together), bone, teeth, cartilage, skin and scar tissue. Vitamin C is specifically required by the fibroblast cells of connective tissue (responsible for collagen synthesis) and the bone forming osteoblasts within bone. Vitamin C acts as a cofactor non-heme iron α-ketoglutarate- dependent dioxygenases such as prolyl 4-hydroxylase by keeping in a catalytically active reduced state which is required for the action of specific hydroxylyase enzymes required for the synthesis of collagens (Libby & Aikawa, 2002) [87]. Vitamin C deficiency may result in improper dentin layer formation in tooth (Srilakshmi, 2011) [154]. The dentrin layer of tooth does not form normally during vitamin C deficiency. This results in teeth that are structurally week and more prone to mechanical injury and decay. Skin grafts to repair burned tissue have been found to heal more quickly when adequate vitamin C is present (Srilakshmi, 2011) [154].

Carnitine synthesis

Vitamin C is required for the synthesis of carnitine. Carnitine is small nitrogen containing organic compounds involved in the transport of fatty acids into mitochondria to be oxidised to release energy for use by cells.

Regulation of hypoxia –inducible factor 1α

Ascorbate assists in the hydroxylation of Hypoxia Inducible Factor 1 **α (**HIF -1 α) which is responsible for the cellular response to low oxygen conditions (Semenza, 2001; Schofield and Ratcliffe, 2004) [148, 21]. When certain fast growing tumors create a hypoxic environment HIF - 1α hydroxylation is repressed which in turn promotes angiogenesis & tumour growth (Flashman *et al*, 2010) [43].

Activation of hormones

Many peptide hormones and hormone releasing factors are synthesised as precursor molecules that are enzymatically modified into their active forms. Vitamin C is essential for the activation of bombesin (human gastrin-releasing peptide) calcitonin, gastrin, oxytocin, throtropin, corticotrophin, vasopressin, growth hormone- releasing factor.

Drug detoxification

Vitamin C is required for the optimal activity of various drug detoxifying metabolic systems within the body. These include the mixed function oxidase system and the flavin monooxygenase system in the liver.

Anti-oxidant action

In all of its known functions, vitamin C functions as a potent reducing agent that efficiently quenches potentially damaging free radicals produced by normal metabolic respiration of the body. At physiological concentrations, vitamin C is a potent free radical scavenger in the plasma, protecting cells against oxidative damage caused by ROS. The antioxidant property of ascorbic acid is attributed to its ability to reduce potentially damaging ROS, forming, instead, resonance-stabilized and relatively stable ascorbate free radical (AFR) serving as a one-electron donor. Within cells, NADH- and NADPH-dependent reductases have affinity for lesser radical concentrations and AFR is reduced to ascorbate. If the AFR significantly accumulates in areas not accessible to these enzymes, or if its concentration exceeds their capacity, two molecules of the AFR reactor dismutate to form one molecule each of ascorbate and DHA. This shows the cytoprotective functions such as prevention of oxidation induced DNA mutation, lipid protection against peroxidative damage and oxidized amino acid residue repair for protein integration. Since oxidative stress is involved in the pathogenesis of many morbid conditions, vitamin C (frequently administered in combination with other antioxidants) have been often used to prevent or treat several diseases due to its antioxidant properties.

A variety of damaging oxidising agents occur in the body, as a result of normal metabolic processes and exposure to drug and environmental pollutants. Arrange of enzymes and antioxidant reducing agents (including vitamin E, Beta carotene and vitamin C) are able to convert these oxidising agents to harmless substances that can be excreted. It can also regenerate the reduced from of vitamin E converting that vitamin back into the form in which it can act as an antioxidant. Vitamin C is known to be involved in regulating cholesterol metabolism and in maintain the structure of blood vessels and the antioxidants affects of the vitamin might prevent tissue damage that leads to cardiovascular disease. Vitamin C is a reducing agent which acts against free radical produced by normal metabolic respiration. It is a free radical scavenger which protects cells against oxidative damage cause by ROS (Carr & B Frei, 1999; Izzi *et al*, 2012; Izzi *et al*, 2012; Marzocchella *et al*, 2011) [66, 67, 25, 78].

The anti-oxidant action of vitamin C accounts accounts for so many of in cytoprotective functions such as,

- Prevention of DNA mutation induced by oxidation (Lutsenko *et al*, 2002; Noroozi *et al*, 1998; Pflaum *et al*, 1998; Sweetman *et al*, 1997) [90, 117, 127, 156].
- Protection of lipids from peroxidative damage (Barja *et al*,1994; Kimura *et al*, 1992) [12, 72].
- Maintaining protein integrity (Barja *et al*, 1994; Cadenas *et al*, 1998; Hoey & Butler, 1984; Heitzer *et al*, 2001) [12, 61].

This makes vitamin C suitable to prevent or treat several diseases.

Iron Metabolism

Vitamin C acts as reducing agent that is able to keep ferric ions in ferrous form and facilitate absorption. Vitamin C forms soluble complexes with ferric ions, which preserve the iron solubility on the more alkaline duodenal pH. Vitamin C also assists in the transfer of iron from blood plasma into ferritin for storage in the liver as well as the release of iron from ferritin when required. The role of ascorbate in iron metabolism is related not only to enhanced absorption but also to intracellular metabolism of iron binding protein (Srilakshmi, 2011) [154]. Vitamin C also aids calcium absorption by preventing the incorporation of calcium into insoluble complexes. Vitamin C converts inactive form of folic acid inot its active form dihydrofolic acid and tetra hydro follic acid and also stabilises the active form. Vitamin c alleviates allergic reactions, enhances immune function, stimulates formation of bile and facilitates the release of some steroid hormones. Vitamin C is necessary for the conversion of cholesterol to bile acids and has been reported to be involved in the detoxification of many chemical carcinogens.

Pro – oxidant action

In conditions such as low concentration acid or in the presence of free transition metals, such as copper and iron, Vitamin acts as function as a pro-oxidant. vitamin c acts as a pro-oxidants (Buettner & Jurkiewicz, 1996) [18]. Metal ions are indeed reduced by ascorbate and, in turn, may react with hydrogen peroxide leading to the formation of highly reactive and damaging hydroxyl radicals. The pro-oxidant activity of vitamin C leads to the formation of ROS or glycated proteins. On the other hand, *in vitro* model suggested that certain prooxidant effects of ascorbate such as the capacity to promote protein thiol oxidation in rat liver microsomes can also be advantageous.

The activity leads to the formation of ROS or glycated proteins (Barja *et al*, 1994; 51 Kimura *et al*, 1992) [12, 72]. But researcher also suggest that in some cases the pro – oxidant action of vitamin C can be advantageous.

Anti-carcinogenic effects of vitamin c

Since the mid 90's, it has been theorized that vitamin c might reduce the incidence of malignancies. High therapeutic dose of vitamin c administered intravenously has been found to increase the average survival of advanced cancer patients in addition to the benefit of increased wellbeing and reduced pain. This is due to the anti – inflammatory action of vitamin c which prevents DNA mutation induced by oxidation. High plasma concentrations of vitamin c neutralizes mutagenic ROS and decreases oxidative stress-induced damage to the cellular DNA.

The pro-oxidant function of vitamin C makes it cancer cell killer given it is administered intravenously. This action is achieved by the formation of H_2O_2 diffuses into tumor cells and causes damage to the DNA and mitochondria, killing the cells rapidly (Hyslop *et al*, 1998; Ahmad *et al*, 2005; Comelli *et al*, 2003; Renis *et al*, 2008; Mc Cormick, 1959) [63, 3, 30, 92, 101].

Vitamin C's role in increasing collagen synthesis and decreasing hyaluronidase (Cameron & Rotman, 1972) [23] is also hypothesized to prevent cancer spread by increasing the extracellular matrix and mechanically blocking metastasis (Cameron *et al*, 1979; Bei *et al*, 2012; Bei *et al*, 2009) [24].

Despite all of this, there still exists a controversy in the therapeutic action of vitamin C in cancer patients due to failure of studies and inconsistent results which was only be solved by further researchers (Creagan *et al*, 1979; Moertel *et al*, 1985) [31].

Vitamin C and cardiovascular diseases

Vitamin C, being a free radical scavenger, prevents ROS mediated cardiovascular diseases (Izzi *et al*, 2012; Izzi *et al*, 2012; Taniyama & K K Griendling, 2003; Bei *et al*, 2011; Fiaccavento *et al*, 2006; Masuelli *et al*, 2008) [66, 67, 159, 42, 100]. The collagen synthesis property helps from proper folding of triple helical collagen which strengthens extracellular matrix without which blood vessels and especially capillaries become prone to rupture (Sotiriou *et al*, 2002) [153]. Vitamin C also prevents apoptosis in endothelial cells in addition to prevention of potent endothelial dysfunction (Nakata & Maeda, 2002) [112].

Role of Vitamin C in critically ill patients

Vitamin C concentration in plasma and leukocytes in critically ill patients have given the impression that it is inversely related to multiple organ failure and directly to survival. Vitamin C and other anti – oxidants are shown to increase speed of recovery in patients with sepsis (Recchioni *et al*, 2002; Rossig *et al*, 2001; Saeed *et al*, 2003; Schor *et al*, 1983) [139, 141, 142, 147]. Vitamin C also Improves receptiveness to norepinephrine, angiotensin and vasopressin (vasoconstrictors) which is of great use in patients with CVD (Ferlitsch *et al*, 2005; Pleiner *et al*, 2003) [41, 130]. Ascorbate also prevents edema by restricting endothelial permeability (Kirsch & de, 2000) [73].

Vitamin C effects on nervous system

Neutrotransmitter synthesis: Vitamin C is required to sustain the activity of the copper containing enzyme dopamine oxygenase, which catalyses the oxidation of dopamine to form the neurotransmitter nonepinephrine. Vitamin C also appears to be involved in the hydroxylation of tryptophan during the biosynthesis of serotonine. The involvement of vitamin C in the synthesis of neurotransmitters probably explains the presence of high concentration of vitamin C in brain and adrenal tissues.

Vitamin C seems to have improved neurotransmission this enhancing processes such as learning, memory and locomotion (Grunewald, 1993; Rebec & Pierce, 1994) [2, 138]. Oral intake of vitamin C has been observed to reduce fear in animal experiments (Parle & Dhingra, 2003; De & Furlan, 1995) [125, 134]. Adequate dietary intake of vitamin C has shown reduced incidence of Alzheimer's disease (Morris *et al*, 1998; Engelhart *et al*) [106]. It can also use to protecting against parkinson's disease by increasing the bio availability of levodopa (Nagayama *et al*, 2004) [111].

Vitamin C in ocular diseases

The combination of ascorbate with certain other anti – oxidant vitamins and minerals slows down the progression of cataract, macular degeneration and other causes which lead to loss of visual acuity (Fan *et al*, 2006; Evans,2008; Evans & Henshaw,2008; Jesus *et al*, 2008) [40, 38, 39, 88].

Effect of processing on **retention of Vitamin C content in fruits**

Fruits are the major source of natural vitamin C and is present in reduced (L-ascorbic acid, AsA) and oxidized (L-dehydroascorbic acid monomer, DHA) form. Both AsA and DHA exhibit vitamin C activity and the AsA could transform into DHA by enzymatic and nonezymatic oxidation during processing and storage (Martí *et al*., 2009; Wechtersbach *et al*., 2011) [97, 171].

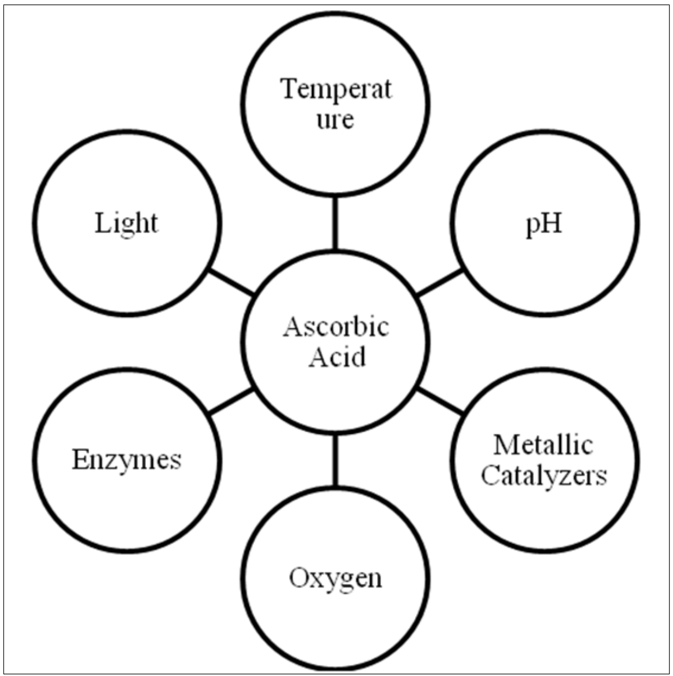
Vitamin C is also essential for the synthesis of collagen, radical scavenger activity and NO-sparing function and has been widely applied in the cosmetic industry (Phillips *et al*., 2016) [128]. With so many important roles, the retention of vitamin C in products has been regarded as a reliable and representative index during their processing (Giannakourou and Taoukis, 2003; Xiao *et al*., 2014) [50, 174].

Thermal processing is frequently used for vegetables and fruits preservation processes, such as blanching, drying, and cooking etc. However, vitamin C can be easily degraded and very sensitive to various external factors, especially high temperature, oxygen, light (Leong and Oey, 2012; Phillips *et al*., 2016) [85, 86, 128].

Thus, many researchers have focused on different processing methods andoptimize processing conditions to develop the best processing technology andmaximum vitamin C retention. The elucidation of the degradation mechanismof vitamin C under different processing techniques for different kinds of materialswould be very useful for better control of the processing parameters so as toenhance vitamin C retention (Jun Wang, *et al*.2017) [70].

Factors influencing the degradation of Vitamin C

The vitamin C has the least stability among all kinds of vitamins and is easily destroyed during processing and storage, depending on many variables such as pH (Munyaka *et al*., 2010; Wechtersbach *et al*., 2011) [171], temperature (Rattanathanalerk *et al*., 2005; Tiwari *et al*., 2009) [136], light (Zhan *et al*., 2012; Noichinda *et al*., 2007) [177, 116], and the presence of enzymes (Munyaka *et al*., 2010), oxygen (Martínez-Sánchez *et al*., 2011) [98], hydrogen peroxide (Özkan *et al*., 2004) [124], and metallic catalyzers (Santos and Silva, 2008; Santos and Silva, 2009; Lee and Kader, 2000) [84, 167]. It is illustrated in Fig. 1.



Santos and Silva., 2008

Fig 1: Factors influencing the degradation of Vitamin C

Effect on pH

The pH influences not only ascorbic acid accumulation during plants' growth but also the stability during post-harvest storage. It is well known that low pH could enhance the stability of vitamin C, especially for DHAA. On the other hand, acid such as hydroxyl acid, citric and malic can dissociate a large number of hydrogen ions (H+) which in turn stabilize vitamin C by chelating prooxidant metals. On the other hand, low pH inactivate enzymes (such as ascorbic acid oxidase, ascorbic acid peroxidases) can hinder the degradation of vitamin C.

Effect of temperature

Vitamin C belongs to the heat sensitive substance. It is believed that the higher processing temperature the higher losses of vitamin C in the products (Munyaka *et al*., 2010; Leong and Oey, 2012; Wawire *et al*., 2011; Phillips *et al*., 2016) [85, 86, 170, 128]. Kuljarachanan *et al*. (2009) [75] reported that drying temperature was the major factor controlling the degradation of vitamin C in lime residues and the higher drying temperature results in lower vitamin C content. Processing at lower temperatures, such as by freeze-drying, is more effective in preserving vitamin C. Barbosa *et al*. (2015) [11] compared the influence of spray drying, freeze drying and convective hot air drying on vitamin C content of orange powder. The result showed that total vitamin C content for freeze and convective dried sample was 22.2±1.4 mg/100mL and 14.0±1.9 mg/100mL, respectively. Higher vitamin C retention was obtained with high temperature due to the short processing time consumed. For example, the use of ultra-high temperature (UHT, 135-140 o C, 3-4 s) for juice to prevent microorganism spoilage and contamination of pathogens, results in higher nutrition (including vitamin C) retention than low temperature long time (LTLT, 60 oC, 30 min) pasteurization and high temperature short time (HTST, 72-75 oC 20 s or 82-85 o C, 15 s) pasteurization (Chavan *et al*., 2016) [28]. During hot air drying at 40, 50, 60, and 70 o C), the highest ascorbic acid degradation of papaya at the lowest temperature (40 oC) was found by Kurozawa *et al*. (2014) [76], who attributed this phenomenon to the longest drying time. Similar findings have also been reported by Marfil *et al*. (2008) [95], Kaya *et al*. (2010), and Mrad *et al*. (2012) [107].

Effect of Light

During the growing season of vegetables and fruits, the amount and intensity of light have a definite influence on the quantity of vitamin C formed, which is related to synthesis from sugars supplied through photosynthesis in plants. Generally, the higher the light intensity during growth, the higher the ascorbic acid content in plant tissues (Lee and Kader, 2000) [84, 167].

Effect of enzymes

Enzymes, such as ascorbic acid oxidase (AAO), polyphenol oxidase (PPO) and peroxidase (POD) present in almost all fruits, not only causes loss of organoleptic qualities including color and off-flavor by enzymatic reactions but also degradation of nutrients though redox reactions during processing, transportation and storage (Mai and Glomb, 2013; Altunkaya and Gökmen, 2008) [93, 5]. It has been demonstrated that ascorbic acid degradation is closely related to ascorbic acid oxidase (AAO) and ascorbic acid peroxidases (APx) by facilitating oxidation of vitamin C (Nishikawa *et al*., 2003; Munyaka *et al*., 2010) [114]. AAO catalyses the oxidation of ascorbic acid in the presence of molecular oxygen resulting in dehydroascorbic acid and water, while APx catalyses the reduction of hydrogen peroxide by ascorbic acid, leading to the production of water and dehydroascorbic acid (Nishikawa *et al*., 2003; D¹browska *et al*., 2007) [114, 32]. Therefore, blanching is frequently employed to slow down or hinder the vitamin C degradation by destroying the AAO, PPO and POD enzymes.

Effect of oxygen

The vitamin C degradation is closely associated with oxygen. Oxygen is indispensable in the oxidative degradation pathway of vitamin C. The rate of degradation of vitamin C is directly related to increased oxygen concentration during food processing. Therefore, vacuum and/or inert gas condition is a very useful protective atmosphere to prevent oxidation of vitamin C (Ramesh *et al*., 1999) [133]. The vitamin C retention of papaya and guava in inert gas heat pump dryer was higher than the product dried under normal air (Hawlader *et al*., 2006) [58]. The most commonly used inert gases are nitrogen, carbon dioxide, superheated steam. Furthermore, decreasing the area exposed to the oxygen can also reduce the degradation of vitamin C.

Effect of water activity

Vitamin C destruction rates increased with increased water activity, and vitamin C was more rapidly destroyed in desorption system than in the adsorption system due to decrease in viscosity and possible dilution in the aqueous phase (Lee and Labuza, 1975; Laing *et al*., 1978) [83, 81]. The effect of water content on vitamin C degradation is more complex compared with other factors as water content brings both negative and positive effect at the same time (Santos and Silva, 2008). High water content brings negative effect on vitamin C degradation by diluting the ascorbic acid concentration, which results to a lower degradation rate.

Retention of Vitamin C content by advances Processing Methods

In the area of advanced processing technologies covers technology for both preparation and preservation of foods and biomaterials. These include high-pressure processing and use of various electric methods such as microwave, pulsed electric fields and between electric fields, ohmic processing. One tremendous advantage of these advanced methods is the uniform application of pressure or electric fields to the product as a whole, rather than needing to rely on heat or freezing temperature penetration from the external surface to the container. During pressurization, the heating of the material is generally less than if temperature was the only means of preservation. Electric field processing generates heat locally, which also minimizes the amount of heat required. Advanced processes therefore minimize the temperature (and hence the quality) gradient in the product and shorten the process time required. (Diane *et al*.,2011) [36].

High Pressure processing (HPP)

Somya Tewari *et al*. (2016) [152] stated that High pressure processed foods have a better stability of AA during refrigeration storage as compared to thermally processed ones. These studies establish the positive implications of HPP and justify its potential use as a promising preservation technique to safeguard AA in food products. Sanchez-Moreno *et al*. (2009) [144] summarized a number of recent manuscripts on a variety of fruit and vegetable pieces, purees and juices in which vitamin C retention after HPP processing was generally above 80%.

Microwave processing

Picouet *et al*. (2009) [129] found that total vitamin C content in apple puree was similar before and after the microwave process, however, ascorbic acid content decreased (43% retention) and dehydroascorbic acid increased (57%). As mentioned above, vitamin C content in microwaved apricots was reported to increase 260% (Karatas and Kamsl., 2007) [71] In a comparison of vitamin C content in tomatoes, Begum and Brewer (2001) [14] found that the content of this vitamin decreased after boiling-water blanching (65% retention), but there was only 10% loss after the microwave blanching method. Wojdylo *et al*. (2009) [172] studied the effect of microwave vacuum drying on strawberries, in a very thorough manuscript which reported results on a dry weight basis. Microwave energy levels of 240, 360 and 480 W were utilized, and vitamin C losses were only 13–40%, with the highest losses occurring under the 480 W conditions.

Freeze drying

Freezing drying is considered as one of the best methods to keep the quality attributes of the materials submitted to drying processes since the combination between absence of liquid water and low temperature stop most degradation reactions (Ratti, 2001) [137]. Nogueira *et al*. (1978) [115] freeze-dried red guava pulp and its ascorbic acid content was retained by 92%. Guava was also freeze-dried by Marques *et al*.(2006) [96]. Chang *et al*.(2006) [27] carried out drying experiments with two different tomato varieties was large. Considering both varieties, the retention of ascorbic acid in freeze-dried tomato cubes was higher than 90% without any sample pre-treatments, During the freeze-drying process, the temperature of the product is pretty low, which reduces degradation reactions and does not make the drying time crucial.

To obtain the maximum vitamin C retention, many innovative technologies have been explored, such as vacuum, freeze-drying, microwave and High pressure processing etc. With high-quality demand for processed food, determination of vitamin C degradation during processing should give more priorities in the future research and for optimization of the processing for vitamin C preservation.

Conclusion

The paper is a quintessence of developments in the inclusion of diet which will fortify human immune system amidst the pandemic cloudiness that has bordered the world and individual’s biological system. Already known activity of ascorbic acid as potential antioxidant, also plays a role in drug detoxification, iron metabolism and many metabolic pathways involved in immune system are always in need of Vitamin C. There has been presented a fruit sources of vitamin C in a capsule form which are of wide habitats and readily available at our vicinity. The spotlight on per daily requirements imposes the need of regular uptake of the same so as to get enhanced results. Second important highlight of the paper in the attempts made to preserve Vitamin C while processing which is otherwise degraded due to multiple factors. Sensitivity of Vitamin C even to light shows the importance of improved processing techniques. Finally the promising nature of the High pressure processing than thermal processing; potential reduction in degradation loss of Vitamin C by microwave vaccum drying and freeze drying has widened the roads towards improved immunity of the human biological system.

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