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Pre and post-harvest influences on the Vitamin C (Ascorbic acid) content in citrus: A review

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Abstract
Citrus fruits are an important diet for human health by providing some nutritional and antioxidant components, especially ascorbic acid (AsA). As the major antioxidant compound, the concentration of Ascorbic acid is an important nutritional quality indicator for citrus fruit and its derivative products. Although the emphasis is on vitamin C content of harvested citrus fruit, this review of literature focuses on pre harvest and post harvest factors affecting this nutritional quality variable. Preharvest factors including genotype, cultural practices, climatic conditions, fruit maturity and postharvest management treatments such as surface coating, heat treatments, irradiation, and ethylene degreening lead to better vitamin C retention. Vitamin C retention is also improved when citrus fruits are stored in modified atmosphere packaging and controlled atmosphere (CA).

Keywords: Citrus, ascorbic acid, pre harvest, post harvest and dehydro ascorbic acid, controlled atmosphere and modified atmosphere packaging

Introduction
Citrus fruits belongs to family Rutaceae is worldwide grown and consumed because have some dietary and medicinal value such as they minimize the serious disease like neurodegenerative and cardiovascular diseases, stroke, cataract genesis, cancer and diabetes **(**Carde˜nosa *et al*., 2015) [1]. Presence of numerous groups of phytochemicals, polyphenols, and vitamins in citrus fruit increases the levels of bioactive components and antioxi-dants capacity in human diet (Ladaniya, 2008) [2]. Additionally, in comparision to other fruits, citrus fruits are one of the major contributors of dietary vitamin C to human diet (Nagy, 1980) [3]. Interestingly, orange juice of volume 200ml delivers 30-80% vitamin C (Gliszczynska-Swiglo *et al*., 2004) [4].
Vitamin C also named as ascorbic acid is highly thermolabile, water soluble vitamin, cannot formed by body and naturally occurs in fruit and vegetable. Citrus juices is rich sources of bioactive compounds, like flavonoids, carotenoids, limonoids, coumarin-related compounds, folates, essential oils, pectins and vitamin C. For quality management in fruit juices and beverages concentration of vita-min C is highly vital to monitor during processing and storage (Cortes *et al*., 2008; Serpen *et al*., 2007) [5, 6]. Concentration vitamin C in fruits and vegetables is influenced by various postharvest factors including storage conditions and postharvest stress such as physiological disorders and mechan-ical damage (Lee and Kader, 2000) [7].
Vitamin C is also recognized as ascorbic acid. First oxidation product of ascorbic acid is dehydroascorbic acid and the total vitamin C content of citrus fruit is the sum of these two biologically active compounds, AsA (ascorbic acid) and DHA (dehydro ascorbic acid) (Nováková *et al*., 2008; Valente *et al*., 2014; Gokmen *et al*., 2000) [8-10]. Ascorbic acid structurally Related to glucose is a weak sugar acid. Biologically, ascorbic acid can be found only at low pH, but in solutions above pH 5 is predominantly found in the ionized form i.e ascorbate. All of these molecules have vitamin C activity and thus are used synonymously with vitamin C, unless otherwise specified. In plants, ascorbic acid is fulfilled through the conversion of mannose or galactose (Wheeler *et al*., 1998) [11]. Glycogenolysis-dependent process accomplished the requirement of ascorbic acid in animal.

In animals that cannot synthesize vitamin C, the enzyme L-gulonolactone oxidase (GULO), that catalyses the last step in the biosynthesis (Bánhegyi *et al*., 2001). Dehydro ascorbic acid is an oxidized form of ascorbic acid. It is actively imported into the endoplasmic reticulum of cells via glucose transporters (Moy, 1998) [12]. Vitamin C is a vital antioxidant in citrus fruit influenced by various pre and post-harvest factors.

2. Pre-harvest factors affecting ascorbic acid content in citrus

2.1 Cultivar

Cultivar affects the inheritance behavior of fruit plant and upset the composition of fruit (Fanciullino *et al*., 2006) [13]. Literature suggested that in fruit juice level of ascorbic acid have been significant changed depending upon species and cultivar (Sharma *et al*., 2006; Lafuente *et al*., 2011; Sdiri *et al*., 2012) [16, 14, 15]. Mandarins (Citrus unshiu Marc.) and oranges (Citrus sinensis Osb.) are the two economical species which have been observed to have a significant difference in level of ascorbic acid (Nagy, 1980) [3]. in the pulp of oranges the ascorbic acid composition and content is generally higher than in mandarins. The maximum contents of ascorbic acid in mandarins as compared to oranges were reported by Dhuique-Mayer *et al*. (2005) [18]. In previous studies average ascorbic contents in fruit juice of mandarin and orange at the time maturity were 27.3 and 48.9 mg/100 mL juice, respectively (Yang *et al*., 2011) [17]. L-galactose pathway during ripening and the difference in the activity of ascorbic acid oxidation and recycling enzymes may responsible for huge variation in ascorbic acid concentration between mandarins and oranges (Yang *et al*., 2011 Alós *et al*., 2014) [17, 19]. Recent studies showed that Oranges, generally have maximum ascorbic acid levels (29 and 82 mg/100 mL of juice), followed by lemons (30–50 mg/100 mL), grapefruits (30–60 mg/100 mL) and mandarins (20–60 mg/100 mL) (Martí *et al*., 2009; Escobedo-Avellaneda *et al*., 2014) [20, 21]. Maximum ascorbic acid content (68 mg/100 mL) were recorded in 'Pera' oranges and minimum 41.4 and 41.1 mg/100 mL, in 'Tahiti' lime and 'Ponkan' mandarin respectively (Barros *et al*., 2012) [22]. Some authors suggested that the level of ascorbic acid was considerably affected by rootstock. Fruits from trees grafted on 'Sour' orange having maximum ascorbic acid content compared to those grafted on 'Swingle' citrumelo in the first season and on 'Cleopatra' man-darin and 'Carrizo' citrange in the second one. Bassal (2009) [23] and Cardeˇnosa *et al*. (2015) [1] suggested that choose 'Cleopatra' root-stock for achieving higher vitamin C.

2.2 Rootstock

In citrus, genetic structure of rootstock significantly influenced the biochemical characteristics including vitamin c. Sometime type of rootstock effect the fruit size nutritional status of fruit. Nagy in 1980 [3] observed lowest content of ascorbic acid where temple orange grown on sweet orange rootstock and highest ascorbic acid content in rough lemon rootstock. Superiority in ascorbic acid concentration was observed in velinca orange when budded on sour orange rootstock than budded on volkmer lemon rootstock (Hifny *et al*., 2013) [25]. Cardeˇnosa *et al*. (2015) [1] evaluated antioxidant and vitamin C activity by grafting six different citrus rootstock (Carrizo, Cleopatra,Foner-Alcaide n◦13, Forner-Alcaide n◦41, Forner-Alcaiden◦5, and Macrophylla) on lane late orange and found that minimum level of ascorbic acid in former-alcaide 41 and maximum in Cleopatra rootstock. Authors suggested that type of rootstock greatly affected the ascorbic acid content. In Egyptian condition, Bassal in 2009 [23] recently evaluated vitanmin C content of Marisol Clementine when grafted on four different rootstocks, namely, 'Carrizo' citrange, 'Cleopatra' man-darin, 'Sour' orange and 'Swingle' citrumelo and found lowest ascorbic acid content in fruit from sour orange rootstock than three others. Bassal (2009) [23] and Cardeˇnosa *et al*. (2015) [1] collectively suggested that Cleopatra is best rootstock for higher level of vitamin C content.

2.3 Rainfall and Irrigation

Rainfall and irrigation has been significantly reduced the vitamin C (Toivonen *et al*., 1994) [28]. Juice of 'Star Ruby' grapefruits was not affected the ascorbic acid content during water strees (Navarro *et al*., 2015) [27]. A similar result was also reported by Buendía *et al*.(2008). (Navarro *et al*., 2010; Panigrahi *et al*., 2014) [26, 30] suggested availabity of 50% water to the total requirement of water trigger the ascorbic acid content in kinnow mandarin and tomato (Favati *et al*., 2009) [29]. Concentration of ascorbic acid was 15% higher than control if deficit irrigation was applied during second phase of growth (Navarro *et al*., 2010) [26]. Analysis of data suggested that the increase in concen-tration could either result from biosynthesis of AsA, in response towater stress, or the lower fruit water content, resulting from thelower plant water potential (Navarro *et al*., 2010) [26]. Increase in soluble sugar accumulation in satsuma mandarin may result from water deficit during stage II and III of fruit growth (Yakushiji *et al*., 1996) [31]. Therefore sugar is the primary source of which regulates the biosynthesis of ascorbic acid (Wheeler *et al*., 1998) [11].

2.4 Light and Temperature

Light interaction and temperature are vital factor affecting ascorbic acid content (Massot *et al*., 2013) [33]. Lee and kedar in 2000 [7] reported duration and intensity of sunlight significantly affected the synthesis of ascorbic acid. He also suggested that those have higher ascorbic acid which receives higher sunlight than shaded ones during growth period. Shading citrus fruit with the net has been reported in earlier studies to decrease canopy temperature, air temperature, fruit tem-perature, greatly affecting growth and quality (Jifon and Syvertsen, 2001; Lee *et al*., 2015; Lado *et al*., 2015) [35, 34]. A study by Magwaza *et al*. (2013) evaluate the effect of canopy position and shading on ascorbic acid on the peel of 'Nules Clementine' mandarin (C. reticulata Blanco) fruit. The results suggested that the maximum ascorbic acid content was found in the peel of sun-exposed outside fruit compared to the shaded fruit in the canopy. These findings suggest the possibility that ascorbic acid concentration in the peel could be used as a tool of fruit position within the canopy. These results were similar to those reported by Izumi *et al*. (1990) [37] who showed that exterior canopy fruit had higher AsA than interior canopy fruit. Similar result was suggested by suggested Izumi *et al*. (1990) [37] who found maximum ascorbic acid content in fruit found in the interior of canopy than exterior ones. Restriction of light to fruit decreases the ascorbic acid level in flavedo of'Navelina' orange and 'Clemenules' mandarin than fruit under light (Lado *et al*., 2015) [34]. Direct sunlight received by fruit has higher ascorbic acid content which may due to production of high carbohydrate. Some authors suggested that low content of ascorbic acid in sun shaded fruits due to low exposure of light to fruits (Ma and Chang, 2004) [35].

2.5 Fertilization

2.5.1 Macronutrients

Lee and kedar (2004) reported that nitrogen relationship with citrus tree and found that supply of nitrogen decreases the ascorbic acid level in fruits. Literature suggested that supply of nitrogen and phosphorus have been significantly reduces the level of ascorbic acid content in citrus while potassium increases the level of ascorbic acid content (Nagy, 1980) [3]. Interestingly, for 12 days at room temperature 800g/nitrogen/plant/year maintain the level of ascorbic acid acontent in acid lime (C. aurantifolia Swingle) (Prasad and Putcha, 1979) [38]. Concentration of dehydrose ascorbic acid may increase with application of potassium while decreased the level of ascorbic acid in Ray ruby. Hifny *et al*. (2013) [25] who observed that at fruit cell division stage or fruit cell expansion stages application of half of total recommended N/tree/year increased the vitamin C content compared to full recommended dosage of 400 g N/tree/year. Internal quality of fruit is influenced by application of phosphorus (Nagy, 1980) [3]. In grapefruit significant increase in the level of ascorbic was increased by phosphorus application Bar-Akiva *et al*. (1967) [39]. Optimum application of potassium (186 kg/ha) without Phosphorus increased the level of vitamin C while Optimal application of Phosphorus application (48 kg/ha) without potassium significantly decreased the concentration of vitamin in the juice of grapefruit (Dou *et al*., 2005) [40]. Alternate result was observed by Mann and Sandhu in 1988 [41]. For quality and sustained yield potassium is essential while limited result may found regarding effective yield (Nagy, 1980) [3]. Some authors suggested that treatment of potassium in lemons (Embleton and Jones, 1966) [42], oranges (Reitz and Koo, 1960) [43], and grapefruit (Smith and Rasmussen, 1960; Dou *et al*., 2005) [44, 40] have significantly increased the vitamin C. authors are agree with the stamen that higher amounts of potassium reduced the content ascorbic acid while increased the concentration of dehydrose ascorbic acid as compared to fruit from tree where none of the treatment was given.

2.5.2 Micronutrients

Several studies on effect of micronutrient on vitamin C content showed significant results. In kinnow mandarin treatment of zinc 0.5% and boron 0.4% increased the content of vitamin C than control (Mishra *et al*., 2003) [47]. In 'Kagzi' limes (C. aurantifolia Swingle) when Zn (0.6 percent) and 2,4-D (20 ppm) were applied during spring and summer season increased the ascorbic acid concentration (Babu *et al*., 1984). However, traetment of boric acid was reported to significantly reduce the content of ascorbic acid in 'Kinnow' mandarin fruit (Ullah *et al*., 2012) [45]. Auxin in plant meristem may be found due participation of boron. Increase in the level of bound auxin and reduction in the indole acetic acid (IAA)-oxidase activity occurs due to deficiency of boron which ultimately increased the concentration of vitamin C. Vitamin C is important factor of judging juice quality and it was influenced by 2,4-D and SA+Zn+K combinations. Highest vitamin C content was recorded in juice collected from fruit of tree treated with 2,4-D+Zn+K and lowest in case of control in kinnow (Ashraf *et al*., 2013) [46]. Application of 0.6% zinc sulfate exhibited the highest increase in ascorbic acid contents as compared to the control tree in kinnow mandarin (Razzaq *et al*., 2013) [48]. Similar result was found by Nakhlla (1998) [49] in 'Navel' oranges, observed that Zn sprays improved vitamin C content in fruit.

2.5.3 Plant growth hormone

Vitamin-C is a powerful antioxidant and is an important part of human nutrition. It helps to save the human from many serious diseases and scavenges the reactive oxygen species (ROS) produced in the body. In various species of citrus vitamin-C contents in fruits varies by the environmental factors, time of fruit harvesting, plant vigour, age of plant and by application of growth regulators. So the vitamin-C was act as quality parameter for the plants sprayed with various growth regulators. Observations revealed the significant results for treatments. On 27-12-2005 maximum vitamin-C contents (25.67 mg/100g) were observed in case of 10 ppm NAA 24.37 mg/100g while minimum vitamin-C contents (17.76) were observed in case of Control. Similarly on 02-02- 2006 maximum vitamin-C contents (45.30 mg/100g) were observed again in 15 ppm NAA 44.44 mg/100g respectively (Nawaz and Khan 2008) [50]. It is obvious that all the growth regulators treatments significantly increased the vitamin-C contents of Kinnow. 2,4-D and NAA treatments proved better compared to Gibbrellic acid treatments; as the concentration of Auxin (2,4-D or NAA) increases vitamin-C contents also increases. Time of harvesting significantly affects the vitamin C content, concentration of Vitamin-C increases so the fruits which are harvested earlier have less amount of Vitamin-C compared to the fruits which are harvested later. Results regarding this parameter of study were found to be in agreement with that of Xiao *et al.,* (2005) who also observed that preharvest application of growth regulators increased vitamin-C contents of the citrus fruits. Saleem and Malik (2007) [51] were observed that maximum vitamin C content was found in case of 25ppm GA_3 and minimum in case of control. Vitamin C is important factor of judging juice quality and it was influenced by 2,4-D and SA+Zn+K combinations. Highest vitamin C content was recorded in juice collected from fruit of tree treated with 2,4-D+Zn+K and lowest in case of control in kinnow (Ashraf *et al*., 2013) [46].

2.5.4 Organic and Inorganic fertilizers

Organic agriculture is necessary for protection of microbes present in soil as they are less harmful than inorganic fertilizers. Organic foods are challenge in market due high cost compared to inorganic foods. O'Connell *et al*., 2012; Kleemann, 2013 [54, 41] evaluated the vitamin C and price variation of citrus in market grown organically and inorganically In citrus, variation in vitamin C was reported by (Tarozzi *et al*., 2006; Lester *et al*., 2007; Duarte *et al*., 2012 [61]; C¸ andır *et al*., 2013) [55,]. (Rapisarda *et al*., 2005) [56] suggested higher vitamin C content in citrus produced organically than inorganic ones. Similar results were reported in 'Tarocco' oranges (Tarozzi *et al*., 2006) [55], 'Newhall' and 'Navelina oranges (Raigón, 2007) [57], "Valencia late" and 'Baia' oranges (Duarte *et al*., 2010) [60], 'Rio Red' grapefruit (Lester *et al*., 2007), 'Nules' and 'Okitsu' mandarin (Raigón, 2007) [57]. Elhassan *et al*., 2011 [58]; Roussos, 2011 [59] evaluate none of the significant difference versus organic and inorganic way of farming. Organic way of farming significantly increased the ascorbic acid concentration in Baia and Velanica oranges while none of the significant differences were observed in Newhall', 'Lane late', 'Dalmau', and 'Rohde' oranges produced by organic and inorganic ways (Tarozzi *et al*. 2006) [55]. Duarte *et al*., 2012 [61] reported organically produced mandarin ('Fina', 'Fortune', 'Fremont', 'Hernandina', Ortanique' and 'Tangera') have higher ascorbic acid content. Above discussed literature more favoured with organic farming than inorganic farming.

2.6 Harvesting time and maturity.

Variation in ascorbic acid concentration formed during the time of tissue formation in citrus (Yang *et al*., 2011) [17]. Vitamin C content in oranges, tangerines and grapefruit follow decreasing order as harvested mid and late respectively (landiya *et al.,*). In fruits of 'Satsuma' mandarin and two commercial 'Navel' orange cultivars, Yang *et al*. (2011) [17] evaluated ascorbic acid concentration during phases II and III of fruit develop-ment. These authors showed that ascorbic acid content in pulps of fruit had significant changes between mandarin and orange, and observed pulp tissue directly related to cultivar and the stage of development.

3. Post harvest factors affecting ascorbic acid content in citrus

3.1 Ethylene degreening

Citrus, greatly influenced by external colour in market because it is too hardly to maintain external and internal correspondly. Interestingly, ethylene degreening make possible this condition at same time (Conesa *et al*., 2014; Moscoso-Ramírez and Palou 2014; Tietel *et al*., 2010) [62-64]. Fully mature citrus fruit more demanded by every consumer in market than unripe fruit. Sdiri *et al*., 2010 demonstrated that none of the significant changes in vitamin content of the fruit was reported after treatment with ethylene but it improved the colour of citrus fruit. Chaudhary *et al*., 2012 [65] and Sdiri *et al*., 2010 reported reduction of vitamin C content in star ruby grapefruit after treatment of ethylene degreening in cold storage. Mayouni *et al*., 2011 [67] observed other results and found that ethylene degreening significant effect the sensory acceptability of 'Miho' Satsuma mandarins but none of the significant changes in vitamin C content of 'Clemenpons' and 'Clemenules' clementines and 'Miho' Satsuma mandarins were observed. Since ethylene degreening showed effect only on external quality of fruit without any impairment in vitamin C concentration.

3.2 Chemical treatment

Fruits are perishable goods hence deteriorate easily after harvesting. Post harvest treatment with chemical directly reduces the deterioration and increases the shelf life of fruit. Lee and Kedar 2000 [7] have been observed post harvest chemical treatments cause fluctuation in nutrition composition. Akhtar *et al*. (2010) [68] demonstrated that postharvest treatment of 3% calcium chloride (CaCl2) is beneficial in loquat for ascorbic acid retention. On the other hand, Sohail *et al*. (2015) evaluated alternate results in peach with similar treatment. Duan *et al*. (2016a) [69] and Duan *et al*. (2016b) [70] found that sodium dehy-droacetate had insignificant effect on vitamin C content in Satsuma mandarin and Ponkan fruit. Similarly, vitamin C content in sodium bicarbonate treated 'Wuzishatangju' mandarins was similar to the untreated fruit (Hong *et al*., 2014) [71]. In 'Valencia' and 'Siavarz' oranges Ansari and Feridoon (2007) [72] also reported an insignificant effect of Thiobendazol fungicide on vitamin C content.

3.3 Surface coating and waxing

In fruits postharvest coating of wax (Chitosan and polyethylene shellac) increases the shelf life, minimize water loss, maintain internal and external quality as well as surface appearance in citrus (To˘grul and Arslan, 2004; Chien and Chou, 2006; Chien *et al*., 2007; Contreras-Oliva *et al*., 2011b) [73-75]. Chein and Chou (2006) [76] demonstrated chitosan with lower molecular weight (92.1kDa) is highly beneficial for maintaining vitamin C content and fungus activity in Tankan citrus fruit as comapared to chitosan with higher molecular weight (357.3kDa). Similar result was observed by Ali *et al*., 2009 [77] demostrated that retention of vitamin C content with Arabic gum. Similarly, Baldwin *et al*. (1995) [98] reported that a commer-cial polysaccharide-based coating and shellac wax have insignificant effect in retaining vitamin C of 'Valencia' oranges. Coatings and waxes act as gas barrier which inhibit the potential autoxidation of ascorbic acid in the presence of Oxygen (To˘grul and Arslan, 2004) [73]. Contreras-Oliva *et al*., (2011b) studied Vitamin C content in Velanica oranges for 16 weeks at 5ºC storage with relative humidity 95% after treatment with five hydrox-ypropyl methylcellulose (HPMC)–lipid edible coatings and observed insignificant effect on those fruits treated with commercial wax (polyethylene shellac).

3.4 Heat treatment

Most of the fruits and vegetables are subjected to heat treated before canning because it is effective against overall acceptability, maintain organoleptic properties and antimicrobial. Temperature and time of treatment depends upon produce. (Lurie, 2016) [79] studied hot air treatments (HAT) at temperatures between 30 and 40 ◦C and hot water dips (HWD) at 50 to 63 ◦C in fruits and vegetables. Schirra *et al*., reported post harvest heat treatment (48 hr at 37ºC) in 'Tarocco', 'Moro' and 'Sanguinello' blood oranges and found significant changes in ascorbic acid content after 3 weeks when stored at 8ºC. Similarly, in velanica oranges Bassal and El-Hamahmy (2011) [80], Erkan *et al*. (2005a) and Mohamed *et al*. (2002) studied insignificant effect on vitamin C content although hot water treatment (5 min at 50 ◦C) reduced chilling injury and maintained the overall external fruit quality. However, the same treatment significantly increased vitamin C in 'Navel' oranges (Bassal and El-Hamahmy, 2011) [80]. Alternate results may found due to different morphological and structural properties. Application of 'March' grapefruit, 'Wuzishatangju' and 'Satsuma' mandarins with HWD (3 min at 45–50 ◦C) also had no effect on vita-min C (Hong *et al*., 2014; Mohamed *et al*., 2002; Shen *et al*., 2013a, 2013b) [71,].

3.5 Irradiation

Citrus fruits are greatly influence by orange fruit borer and Mediterranean fruit fly (De Bortoli *et al*., 2015) [81]. Some physical and chemical methods are followed for elimination of these insects Gaffney *et al*., 1990 [82]; Moy and Wong, 1996) [12]. Hallman (1999) studied heat treatment, cold temperature and controlled atmosphere fruit decay by insects. But these are time taken methods than irradiation as safe and quick. Follett (2004) and Follett and Neven (2006) [83] stated none of the significant effect on fruit quality. (De Bortoli *et al*., 2015) [81] resulted gamma rays have not influence the vitamin C level of velanica oranges. Similarly, 70–700 Gy doses irradiation had no significant effect on vitamin C levels of early-season 'Rio Red' grapefruit (Patil *et al*., 2004; Vanamala *et al*., 2005) [84]. However, in late-season 'Rio Red' grapefruit irradiation doses of 200 Gy or higher, significantly reduced vitamin C content after 4 weeks of storage at 10 ◦C (Patil *et al*., 2004) [84]. This shows that the response of vitamin C to irradiation also depends on harvesting time. Improved vitamin C retention in certain citrus fruit has been reported following irradiation treatment. For instance, exposure of 'Moroccan' clementines (Citrus clementina Nour) to 0.3 kGy stimulated an increase in vitamin C content during storage at 3 ◦C and 84% relative humidity for 49 days (Mahrouz *et al*., 2002) [85]. Khalil *et al*. (2009) [87] also evaluate higher vitamin C retention in gamma irradiated (0.25 kGy) blood red oranges than found in untreated fruit. Ladaniya *et al*. (2003) [2] found that irradiation treatment can partially oxidize ascorbic acid. This may explain the loss of vitamin C after irradiation treatment in some citrus fruits.

4. Storage conditions

Duration of storage condition greatly affect the vitamin C content of fruit. Few literatures is available on effect of vitamin C content during storage. Various scientist observed effect of storage conditions on vitamin C content, such as temperature and relative humidity (Lee and Kader, 2000) [7], controlled atmosphere (Del-Valle *et al*., 2009) [92], as well as modified atmosphere packaging (Chaudhary *et al*., 2014; Jawandha *et al*., 2014; Piga *et al*., 1997) [66]

4.1 Temperature and relative humidity

For long term storage of citrus fruits require optimal temperature and relative humidity. Changes in the concentration of vitamin C concentration have reported by various scientists. Temperature is important tool for long term management of fruit quality and shelf life (Lee and Kader 2000) [7]. Lee and Kedar (2000) [7] evaluated decay and nutrition loss between harvesting and storage. for maintaining the quality of fruit, low temperature stunted the growth of fungus metabolism of fruit (Ladanyia and Ladaniya, 2010) [2]. Generally, vitamin C is also lost in refrigerated conditions, the expected loss is more under ambient conditions. Qiu and Wang (2015) [88] reported maximum vitamin C content in satsuma mandarin when stored at 4ºC than 20ºC. Long time storage decreases the vitamin C in citrus. No significant changes was reported in vitamin C content of 'Tarocco' blood oranges stored at 8 ◦C and 22 ◦C respectively after 85 days at room temperature (Rapisarda *et al*., 2001) [56]. At 4 ◦C and 87% relative humidity for 2 months and at ambient storage conditions of 'Miyagawa' satsuma mandarins no significant difference was observed (Yang *et al*., 1997) [17]. Vitamin C content should be found better in blood red sweet orange stored at 10◦C than at5 or 20 ◦C (Rab *et al*. (2012) [86]. Loss of vitamin C in fruits are lower at 10 ◦C i.e 0.7% per day and higher at 5 and 20 ◦C 1.4 and 0.9% per day respectively. The storage of fruit at 10 ◦C also led to reduced incidence and prevalence of Penicillium digitatum. Generally, 'Star Ruby' grapefruit stored at 10 ◦C had superior organoleptic proper-ties compared to fruit stored at 6 ◦C (Pailly *et al*., 2004) [89]. Storage of grapefruit at 2ºC had no significant change in vitamin C concentration (Lado *et al*., 2015) [34].

4.2 Controlled atmosphere

Controlled atmosphere reduce the rate of ethylene production, thus retain the vitamin C content in fruit (Luengwilai *et al*., 2007; Sritananan *et al*., 2006) [91]. Lananiya and Landaniya (2010) reported effective of controlled atmosphere on shelf life and quality. Similarly, Del-Valle *et al*., 2009 [92]; Ladaniya and Singh, 2000 [2]; Luengwilai *et al*., 2007 [90]; Sritananan *et al*., 2006 [91] also reported prolonged shelf life of horticultural produce in controlled atmosphere. Fewer studies examined the effectiveness of vitamin C content in control atmosphere. In 'Valencia' oranges none of the Valle *et al*. (2009) [92] reported that control atmosphere maintain the vitamin C content in processed clemenules mandarin. Vitamin C content had higher in processed clemenule mandarin stored at controlled atmosphere (11% O2; 10% CO2) than in normal air for 20 days. Higher oxygen in controlled atmosphere had increased the vitamin C content in fruit than lower oxygen with controlled atmosphere (Del-Valle *et al*., 2009) [92]. Controlled atmosphere greatly affect the shelf life, organoleptic characters, weight, as well as nutritional status of fruit. Few literatures is available in relation to these characters. To prove, there is vital need of researches for evolution.

5. Bruising and mechanical decay

Mostly, quality of fruits and vegetables changed during with mechanical damage (Opara and Pathare, 2014) [93]. Similarly, significant changes were reported in vitamin C by bruising and mechanical damage (Lee and Kedar, 2000) [7]. Therefore, handing of produce after harvesting includes sorting, grading, packaging damage the horticultural produce with high extent. Post harvest bruising and mechanical damage cause loss of nutrition and significant economic loss (Opara and Pathare, 2014) [93]. Hence, careful handling of produce after harvesting is necessary to protect the produce bruising. Only few researchers have paid attention on reduction in ascorbic acid content by mechanical damage. For evolution, there is need of researches on reduction in ascorbic acid during brusing. In velenica oranges lower ascorbic acid was found due to damage in fruit (Miranda *et al*., 2015) [94]. some authors suggested that processing reduced the ascorbic acid content in fruits. Silva *et al*., 2006 [96] observed reduction in ascorbic acid content in orange juice during processing. Therefore, it is necessary to use preventive measure during processing of fruit. Vitamin C content in 'Tahiti' limes, 'Murcott' tangor and 'Rainha' tangerine significantly decreased as the impact energy and intensity of mechanical damage increased (Durigan *et al*., 2005; Montero *et al*., 2009) [95]. Hence, further researches have been made to check the impact of bruising and post harvest mechanical injury on vitamin C content of fruit.

6. Physiological disorders and Postharvest decay

Citrus, a non climatric fruit, is more prone to different physiological disorders in cold chain. These disorders are divided into two parts i.e chilling injury and non-chilling injury. Chilling injury can br found at freezing temperature and non chilling injury found at below freezing temperature. Discoloration of fruit, cracks and stem end break are common symptoms in citrus at very low temperature. There has been lot of literature available on effect of chilling injury on vitamin C content but few scientists Cronje *et al*. (2011) [97], Magwaza *et al*. (2012) [98], Magwaza *et al*. (2014) [99] and Porat *et al*. (2004) [100] observed soluble sugars, titratible acidity and rind quality parameters in citrus. Bassal and El-Hamahmy, 2011 [80] were observed maximum vitamin C content in Navel orange injured by chilling. In velanica oranges, Erkan *et al*. (2005a) reported none of the significant impact on vitamin C content when stored for 6months at 4◦C. Similarly, in star ruby orange insignificant changes had found in vitamin C content (Chaudhary *et al*., 2014) [66]. Interestingly, intensity of chilling injury reduced the vitamin C content in Clementine mandarin (Erkan *et al*., 2005b). Such a huge fluctuation in vitamin C content during chilling injury may be found due to difference in cultivar but scientists have need more reasearchs to validate the variation in vitamin C recorded by previous researchers for future of fruit processing industry.

Diseases and decay after harvesting causes Loss of external and nutritional quality (Droby *et al*., 1993) [102]. Few researchers have been targeted to study the impact of decay on vitamin c content in citrus. Chaudhary *et al*. (2012 and 2014) [65, 66] and Hong *et al*. (2014) [71] found that decay has insignificant effect on vitamin C con-tent of 'Star Ruby' grapefruit and 'Wuzishatangju' mandarins. Also, decay had no effect on vitamin C content of 'Valencia' oranges for6 months at 4◦C and 90% RH (Erkan *et al*., 2005b).

7. Conclusion

Ascorbic acid was observed among reviewed literature that it is highly sensitive to various preharvest factors, including scion-rootstock relationship, climatic conditions, cultural practices, hormones, light, and temperature. In general, the largest differences in vitamin C composition observed are mostly attributed to genetic factors, mostly species, cultivars and rootstock-scion interaction. This confirms that the selection of genotypes with a potential to increase amounts of vitamin C is a more important factor than climatic conditions and cultural practices. Evidence from the literature review also showed that surface coatings such as shellac wax significantly reduce vitamin C loss. The effect of irradiation treatments on vitamin C content in citrus fruit has also been discussed in this review. Literature evidence also showed that the loss of vitamin C loss is reduced in CA and MAP.

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