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Impact of Salicylic Acid on Various Aspects of Fruits: A Review

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Abstract

Salicylic acid (C7H6O3) is classified as a phenyl propanoid compound, a safe and natural compound that unveils extraordinary probability in regulating post-harvest losses of various fruit crops. It is also applied externally at nontoxic concentrations which ultimately increases the plant resistance against fungal pathogens and also able to function as potential non-enzymatic antioxidant and regulates various plant physiological processes like ion uptake, transport, sex polarization, glycolysis and thermogenesis. The present review is compiled to evaluate the influence of SA on parameters of fruit quality including firmness, TSS, TA and amount of ascorbic acid, spoilage and physiological loss in weight in storage. Overall study showed that SA has promising effects on physico-chemical traits including total phenolics content, antioxidant activity and catalase activity of the fruits during storage period.

Key words: - Fruit, physico-chemical, salicylic acid, shelf life, senescence

1. INTRODUCTION-

It has been described that numerous fundamental biosynthetic reactions, disease resistance, ethylene action and biosynthesis, firmness, respiration activity, antioxidant systems and nutritional quality have also been influenced due to application of SA. In literature lot of references are available concerning the role of SA and its effect on physiological developments. Same has been explained by Zeraatgar et al., (2018) revealed that SA is able to extend the post-harvest quality as firmness, catalase enzyme, ascorbic acid, total phenolic content are improved greatly but total soluble solids are reduced. In a research study, they recorded improved total phenolic content (2.38 µg gallic acid/gFW), catalase enzyme (16.67 U mg-1 protein) and lowest total soluble solids content (23.11%) in jujube fruits with application of SA at 4 mM while acidity was the highest (0.45 %). But they noted that application of SA was able to delay some reducing trends in case of antioxidant and phenol. They finally revealed that SA could cause at least a 10-day postponement in the decrease of physico-chemical attributes. It was reported by Kumar and Kaur (2019) that when SA was applied as pre harvest spray at flowering stage or fruit setting (10, 20 and 30 days before harvest) at strawberry cv. Chandler, resulted in enhanced growth parameters and fruit yield. They concluded that improved plant height (10.15 cm), fruit set (82.15 %) and yield (282.06 g/plant) was obtained from plants applied with SA while these parameters were much less in control treatment. Khademi et al., (2019) revealed in a research study by treating banana fruits with salicylic acid (1 mM) and kept in cold storage at 5 °C RH 90% for 10 days. It was established that SA treated fruits retained better firmness, antioxidant capacity, improved control over weight loss and hang up of activates related to polyphenol oxidase enzyme. Haider et al., (2020) revealed that enhanced total phenolic contents, improved antioxidant activity, superoxide dismutase (SOD) and activities of peroxidases (POD) were found in mandarin fruits with application of 4mM SA. They resolved that various levels of SA (4, 8 or 12 mM) had shown promising results to discontinue fungal attack. Consequently, SA can be applied as pre-storage application at 4mM to minimize deterioration and also to retain improved levels of bioactive compounds in cold storage. Atia et al., (2020) applied SA (2.0 mmol/L) in Barhi dates at khalal maturity stage before cold storage and concluded fruit decay (%),weight loss (%) and TSS (%) also decreased but at less rapidly than control treatment.

2. Physical Characters of the Fruits

Fruit weight and Physiological loss in weight

Decrease in fruit weight is a common phenomenon during storage and it has been observed that salicylic acid may able to decline respiration activity and thereby decreases weight loss by closing of stomata openings. Loss in weight resulted from various catabolic and metabolic processes like respiration and transpiration whereas SA yields free radicals, which hinder such activities. SA decreased the weight loss during storage by lowering transpiration and respiration process. As both these processes are responsible for drawing moisture content from the fruit which in turn reflect in fruit quality. Díaz-Mula et al., (2009) also described that the PLW of apple fruit expressively decreases with application of SA in comparison to untreated ones during storage period. Lu et al.,(2010) proved that rate of respiration of pineapple were lower than those of control fruits after 20 day of cold storage that were treated with SA. Abbasi et al., (2010) recorded in peach that after 6-week of storage at 1°C, the average weight loss was least in fruits applied with SA at 1mM as compared to control treatment. Nanthawan and Kazemi et al., (2010) approved that treatment with salicylic acid showed reduced the weight loss but at the same time maximum weight loss occurred under controlled conditions in apple fruits. Obeed (2011) revealed that spray of SA 100 ppm at pea stage and version stage in grape cv. Flame Seedless considerably resulted in higher berry firmness. Prolongation of higher fruit firmness was noted when treated with salicylic acid has also been described in other fruits such as in Chinese jujube (Kaseem et al., 2011). Generally, the loss in fruit weight is caused by the deficiency of moisture due to transpiration, respiration and vapor pressure deficit (VPD) among the adjacent air and the fruits. The loss in moisture causes a rapid rise in the concentration of sugars, leading to the maturation of the fruit (Baliga et al., 2011). Salicylic acid can improve physical properties of fruits such as size in Thompson seedless grapevine. Pre-harvest spray of salicylic acid on Thompson Seedless grape increased cluster weight, length, and berry shape index compared to the control. Similarly, Khademi and Ershadi (2013) proved that regardless of SA application, weight loss increased during storage period as expected, increased volumes were recorded on the day of 42^{nd}. However, fruits applied with SA showed depressed softening rate than control. A notable increase in weight and yield of Flame Seedless grapes was recorded when vines were applied with salicylic acid (Champa et al., 2014). Brar et al., (2014) also recorded lower decrease in physiological weight loss in peach fruits with treatment of SA @ 200 ppm in comparison to control. Likewise, extended post-harvest life and improved quality was recorded in case of grape when SA was applied as pre- harvest spray @1.5 mM. Salicylic acid demonstrated higher effectiveness in reducing berry softening and suppressing other ripening associated changes (Champa et al., 2014). It is also revealed in case of guava that lowered physiological loss of weight in treated fruits might be accredited to salicylic acid in decreasing the metabolic activity with respect to respiration process and ethylene evolution (Madhav et al., 2016). Amanullah et al., (2017) accessed lowest weight loss with treatment of salicylic acid @ 600 μM followed 700 μmol in case of guava fruits. The highest weight loss was recorded with control at 5^{th} day of storage. Rahmani et al., (2017) submitted that application of SA meaningfully enhanced fruit number/tree and fruit weight in Kesar mango. Likewise, Noorullah et al., (2018) recorded that salicylic acid treated fruits had the minimum PLW, titrable acidity and such treated mango fruits can be kept for 18 days without any deceptive loss in quality. Haider et al., (2020) observed maximum loss in fruit weight (28.34%) in control fruits while minimum (16.37%) in 4 mM SA treated fruits which were 1.7 folds higher than controlled fruits. They revealed that among various levels of SA, all the levels were expressively effective to lessen weight loss in but SA levels 4 and 8 mM conserved the maximum water content of mandarin fruits during 90 days of storage. Ennab et al. (2020) evaluated the role of salicylic acid (200 and 400 ppm) in stored (23 ± 1 °C and 60–70% RH for 45 days) murcott mandarin and revealed that weight loss was significantly reduced. They concluded that salicylic acid (400 ppm) was more effective to reduce decay and weight loss in citrus fruits.

Fruit colour

While working on guava cv. 'Baladi' it was concluded that immersion in salicylic acid at high level 500 µM had advanced effect on fruit color (ho) compared with other concentrations of salicylic acid and control treatment. In the untreated fruits, rapid loss of green colour was experienced than the treated fruits during storage (Lo'ay and Khateeb, 2011). Lolaei et al., (2012) described the same results that SA as pre-treatment application resulted in delayed the ripening process in strawberry as less redness than control ones in case of cv. Camarosa. It was established in Ber trees that application of salicylic acid (four times at 30, 60, 90, and 110 DAFB) considerably deferred the change of index in its surface colour from green-to-red by 34.2 %, after 60 days during cold storage (Cao et al., 2013). When vines of Flame Seedless grapes were sprayed with salicylic acid and evaluated during successive cold storage period (3–4 °C, 90–95 % R. H.), it was recorded that salicylic acid exhibited higher effectiveness on maintaining peel colour, reducing berry softening and effectively suppressing other ripening associated changes (Champa et al.,2014). Untreated fruits of guava lost their green colour after 7^{th} day in storage. However, salicylic acid @ 300 ppm treated fruits retained green under ambient condition fruits up to 7^{th} day of storage (Kaur, 2016). The results under cold storage conditions proved that salicylic acid @300 ppm yielded good values. On the contrary, in untreated guava fruits, rapid loss of green colour was recorded than the treated fruits. Madhav et al., (2016) conducted a study on guava fruits of cv. Allahabad Safeda and treated with SA, kept at 10°C for 12 days. It was discovered that fruits applied with SA at 2 mM, showed lowest colour change without any conflicting effect on fruit appearance and taste. When SA is applied as post-harvest application, lead to the deferment of the ripening activity of guava fruits significantly, possibly through inhibition of ethylene production process. Lokesh et al., (2019) applied SA on peach (*Prunus persica* L. Batsch., cv. Hujingmilu) and stored it at 0 °C. They concluded that SA at 1 mM improved development of flesh browning and continued softening ability of peach fruit. Salicylic acid helped to retain higher amount of volatiles (esters and lactones) than controls. On the contrary, Supapvanich et al., (2020) applied SA as postharvest treatment on fresh-cut papaya fruits cv. 'Holland' during cold storage fruits at 2 mM SA for 1 hour and then stored at room temperature (26 ±1°C) for 24 hours and revealed that colour attributes were not affected by this treatment while quality was much improved. Chavan and Sakhale (2020) worked on tomato fruit of cv. Abhinav during its storage period at 24oC by treating it with 200ppm salicylic acid and found substantial change with respect to a steady increase in colour (h).

Fruit firmness

Salicylic acid declines ethylene production rate and avoids various enzymes that cause cell wall degrading. Softening of fruits is a foremost and serious quality alteration. Salicylic acid applications helped in sustaining the marketability of guava fruits up to 3 weeks, while it was just 2 weeks in the untreated fruits. This all happened because of postponement in respiration rate of fruits (Asghari and Aghdam, 2010). During ripening process of kiwifruit, the pattern of lessening of SA was accompanying by improved softening process, while the application of acetylsalicylic acid (a derivative of salicylic acid) decelerated the softening activity of kiwifruit by inhibiting ethylene production and continuing higher levels of SA. Application of SA rises fruit firmness by lowering the action of cell wall mortifying enzyme like cellulose, polygalacturonase and xylanase (Kazemi et al., 2012). The retaining of firmness in salicylic acid treated fruits may be because of suppression of cell membrane, cell wall and decomposing chemicals such as cellulase, polygalacturonase, lipoxygenase, and pectin methyl esterase reduced rate of ethylene production (Khademi and Ershadi, 2013). The fruits under control conditions exhibited minimum fruit firmness in cold storage, which was considerably lower than all other applications during the course of study (Kaur, 2016). The influence of salicylic acid was studied in guava fruits cv. Allahabad Safeda at 1 mM and 2 mM concentration and stored at 10°C for 12 days. Thus, application of SA might be an effective substitute for improving postharvest quality and storability of guava fruit (Madhav et al., 2016). SA treatment (1mM) alleviated development of flesh browning and maintained softening ability of peach fruit after cold storage (Yang et al 2020). Supapvanich et al (2020) dipped 'Holland' papaya in salicylic acid and kept them under cold storage at 8±1°C, followed by 1 day at room temperature (31±2°C). SA treatments delayed fruit softening and improved the highest firmness. They recommended application of SA 2 mM as dip is a good substitute for improved firmness of the fruit.

Fruit spoilage

SA is mainly responsible for lowering the production rate of ethylene, preserves fruit quality and averts fungal decay of strawberry. It is a phenol that can obviate happening of ACO, precursor of ethylene gas and inclined enzyme antioxidant activity in radish seedlings (Canakci, 2008). Strawberry fruits immersed in salicylic acid solution had lower decay occurrence along with higher firmness than controlled fruits (Shafiee et al., 2010). Respiration rates and ethylene production increased the production of free radicals, which resulted in stress dependent peroxidation of lipid sheaths. These effects of ethylene can be decreased by inhibition of ethylene biosynthesis and inclined enzyme antioxidant activity (Joseph et al., 2010). SA (5 mM) treated fruits of Blood orange and observed the lowest decay, incidence of fungal green mold disease (Aminifard et al., 2013). Mohamed et al (2018) accessed the impact of salicylic acid on strawberry cvs. (Festival, Sweet Charli, and Vertona) at the 3 mM level significantly lowered occurrence of gray mold (caused by- Botrytis cinerea). Baswal et al., (2020) evaluated the impact of SA (0.001, 0.002 and 0.003 μmol L-1) on quality of Kinnow' mandarin under cold storage. They found that salicylic acid at 0.002 μmol L-1 proved to be best in lowering weight loss, spoilage and improvement in other features like firmness etc. while activities like cellulase and pectin methylesterase were also retarded to great extent.

Bio-chemical Characters of Fruits

Total soluble solids

Hussain et al. (2012) reported that the increase in the TSS of fruits in storage is due to the moisture reduction and enzyme activity in changing complex polysaccharides into simple sugars. A declining trend in fruit total soluble contents with rising salicylic acid concentration and sustained a considerably lower reducing and total sugars, than control, when immersed peach fruits in solution of salicylic acid and then transferred to 20 °C (Awad, 2013). It was recorded that pre-harvest treatment with salicylic acid considerably improved various qualities of berries including dry matter, sugar: acid ratio and fruit quality in grapes during cold storage (Yeganeh et al., 2013). Work conducted on Flame Seedless grape vine showed that clusters treated with salicylic acid efficiently delayed the deprivation of TSS. On the contrary, in control reduction of TSS of grapes was noticed after 45 days after of cold storage (Champa et al., 2014). Hajilou and Fakhimrezaei (2013) proved that SA treated apricot fruit showed higher phenolics while highest TSS was recorded the end of the storage. They revealed that post-harvest treatment with SA resulted in extended storage-life and conserved the appreciated marketing features because of inhibitory influence on fruit ripening and senescence. Afterward 21st days under cold storage conditions, SA was accessed as the unsurpassed application to preserve fruit quality including weight loss. Total soluble solids were influenced by spray of various concentrations of SA in mango cv. Kesar. However, salicylic acid was recorded as most effectual and resulted in considerably maximum TSS (Ngullie, 2014). Shrivastva et al.,(2020) at Banaras Hindu University under conditions of Varanasi designed an experiment to access the impact of SA (200, 400, 600 ppm) on storage quality of Indian jujube cv Banarasi Karaka. After analysis, they concluded that most of quality attributors (TSS, total sugar, acidity, and vitamin C) were retained in SA at 600 ppm. Acidity showed declining trend but other quality related characters like TSS exhibited increasing trend up to 6th then followed a decreasing trend. They considered and recommended the SA at 600 ppm proved to be best for quality retaining in storage (for 8 days).

Ascorbic acid

Huang et al., (2008) described that salicylic acid influenced ethylene production procedure and declined respiration rate and improved quantities of ascorbic acid in cara cara' navel orange. Better value of organoleptic rating (7.94) in guava fruits was recorded under Punjab conditions with salicylic acid @ 200 ppm which was significantly advanced than salicylic acid @300 ppm treatment. Control fruits had exhibited considerably reduction in palatability rating from 7th day to 14th day of storage period. It was noted that on the 21st day of storage in all the treatments (including control) got blemished. The fruits of guava when immersed in salicylic acid at high level 500 µM, had less IL per cent degradation in total phenol, fruit browning and sustained the vitamin C (Lo'ay and Khateeb, 2011). Aghdam et al., (2011) stated that softening process was prevented and improved levels of ascorbic acid occurred when SA was applied exogenously in kiwi fruits in cold storage. Salicylic acid exhibited less weight loss and improvement in vitamin C content and redness than the control in strawberry fruit. It was described that application of SA deferred ethylene production and the beginning of the climacteric peak of respiration process improved its storekeeping quality (Lolaei et al., 2012). SA treatment helped against decrease in vitamin C level in jujube while deferred the process of deteriorative oxidation reaction if plum fruits. It was found that SA at 2.0 mmol L-1 concentration could be applied at commercial level to protect peach fruits without any kind of spoilage for up to 30 days (Tareen et al., 2012). While working with mango cv. Kesar at Navsari, (Ngullie, 2014) reported that amount of ascorbic acid (mg/100g pulp) in mango got affected with treatment of SA. However, the maximum amount of ascorbic acid was accessed when the mango trees were treated with SA and minimum was in control. It was concluded that ascorbic acid content in guava cv. Allahabad Safeda had decreased irrespective of chemical treatments during storage period. Salicylic acid treatments helped in maintenance of ascorbic acid at considerably higher levels as compared to untreated fruit. Ascorbic acid level was much lesser in untreated ber fruits (Gill and Bal, 2016). Application of Salicylic acid in peach maintained the higher level of ascorbic acid. Maximum palatable guava fruits cv. Shweta were recorded with salicylic acid @300 ppm application with mean (7.93) organoleptic rating and it was closely followed by 7.65 with salicylic acid @ 200 ppm under cold storage conditions which was statistically at par with salicylic acid @ 100 ppm. It was reported that organoleptic rating of fruits improved significantly up to 14th day of storage with salicylic acid treatments under cold storage (Kaur, 2016). Gimenez et al., (2016) also supported the fact that an initial increase is recorded in antioxidant enzymatic activity of the fruit after treatment with SA which might be the cause of environmental stress (low temperature) and it inclines ROS level at transcript and protein etc. Which in turn modifies the cellular homeostasis. Habibi et al., (2020) evaluated postharvest effects of treatments with methyl jasmonate (MeJA) and methyl salicylate (MeSA) on antioxidant systems and sensory quality of blood oranges (150 days at 3 °C plus 2 days at 20 °C, shelf life). They found increased total antioxidant activity (TAA) and ascorbic acid (AA) decreased during cold storage, all these changes being delayed in treated fruit and they had observed great differences with the 50 µmol L−1 MeJA and 100 µmol L−1 MeSA treatments. They concluded that 100 µmol L−1 MeSA was the most effective for retaining fruit quality.

Total sugars (reducing and non-reducing sugars)

Asghari and Aghdam, 2010) supported this outcome of earlier research work done, lowering content of sugars in fruits might be break down of starch and decreased levels of invertase activity by the way it is also linked with decline in non-reducing sugars. However, salicylic acid @ 2000 ppm was found to be the most effective and resulted in improvement of reducing sugars in mango. It was reported that treatment of SA helps to avoid action of SPS enzyme and retains cell wall enzymes which continue reducing, non-reducing sugars including SSC. On the other many research scholar have reported that the buildup of reducing sugars might be due to enhanced translocation of photosynthetic materials to fruits and crashing of starch throughout ripening. Similar findings were also reported by Kumar and Reddy (2008). Lu et al., (2010) recorded that ascorbic acid content in pineapple treated with salicylic acid under cold storage conditions and found that it was much higher than control treatment but total acidity and total sugar were lower. A study was conducted at Navsari Agricultural University, Gujarat on mango cv. Kesar that reducing sugars were influenced by salicylic acid (Ngullie, 2014). Shehzad et al.,(2016) evaluate the pre and postharvest application of SA on storage life and quality of mango cv. 'Kensington Pride'. They immersed partially ripened fruits in four levels of SA (0, 8, 12 and 16 mM) for 5 minutes and stored at 12°C for 15 days. They revealed that SA 16 mM showed minimum reduction in reducing, non-reducing, total sugars, total phenolic, total antioxidants, and total flavonoids. They recommended that to decrease the storage losses SA should be used. Kumar and Kaur (2019) conducted a research experiment to access the influence of SA on in storage behaviour of strawberry cv. Chandler. They recorded average maximum total sugars (6.49%), non-reducing sugars (1.28%) and reducing sugars (5.22%) with post-harvest application of SA 4 while it was at its minimum in control. In their experiment, total sugars first showed increasing trend up to 8th day of storage then a sudden decline was noted. They found 6 mM SA was most effective when applied as post-harvest application. They explained that increase might be due to hydrolysis of starch into sugars and decline when this hydrolysis is complete and leads to no further increase and subsequently a decline in sugars which may be primary substrates for respiration.

Total phenolics content (TPH)

Functional quality is mainly decided by phenolic compounds by playing a significant role in neutralizing reactive oxygen species in turn minimization of molecular damage. Drogoudi and Tsipouridis, (2007) accessed a substantial linear relationship between total polyphenols and total antioxidant capability of fruits since these are biochemical compounds with improved antioxidant activity, so one of the explanations for the rise in antioxidant capacity of fruits with use of SA can be its impact on phenolic materials of the fruit. Remorini et al. (2008) also supported the fact that phenolic compounds are associated with the enzymatic and chemical alterations throughout fruit development which in turn lessens the astringency of a fruit. Likewise, Ghasemnezhad et al., (2010) revealed that the level of total phenolic compounds decreases due to decomposition of cell structure so as to facilitate senescence phenomena. There are ample evidences in literature that SA helps in accumulation phenolic substances along with increasing antioxidant activity and prevents cell membrane degradation by destroying free radicals (Sayyari et al., 2011). Hajilou and FakhimrezaeI (2013) accessed the impact of SA (1.0, 2.0, or 3.0 mM) as post-harvest application on apricot (Prunus armeniaca L.) cv. Asgar-Abad'. They concluded that fruiyts that were treated with salicylic acid at 3 mM exhibited maximum phenolics content during the storage. Sartip and Hajilou, (2015) also recommended that such phenolic compounds when incorporated in fruits during storage, and that may be the main reason for lowering the amount of this compounds. As for as the influence of SA impact is concerned their application brought about an important rise in the amount of total phenolics content (Zeraatgar et al., 2018). Haider et al (2020) also evaluated the influence of postharvest treatment of SA (4, 8 or 12 mM) on quality of mandarin and stored at 5 ± 1 °C and 90 ± 5% RH for 90 days. They observed maximum antioxidant activity and total phenolic contents in SA treated fruits especially with concentration of 4mM of SA.

Antioxidant activity (AOX)

Remorini et al., (2008) proved that antioxidant activity in a fruit may vary with growth and fruit ripening phase. Lessening of total antioxidant during storage period can be net result of enzymatic and non-enzymatic reactions that may lead to destruction of fruit cell membranes, cell wall, generation of free radicles and reactive oxygen and use of antioxidants in cellular metabolism, could be the possible reason. Ascorbic acid present in a fruit is able to influence the antioxidant activity as it is vital member of antioxidants family. It has been described that enzyme activity (phenylalanine ammonia-lyase), a principal enzyme in phenylpropanoids metabolism, increases the buildup of various phenolic compounds along with antioxidant properties and synthesis in also increased and finally tissue resistance is increased against living and non-living stressors. Reports are available regarding activities of senescence related enzymes (ACO, PME, ACC, cellulose, and PG) are also lowered which in turn declines the transpiration and respiration rate (Aghdam et al., 2011). In such salicylic acid is able to control weight loss from the kiwifruit. Wang et al., (2015) experimented on quality attributes of apricot stored at 2 °C for 25 days after application of salicylic acid. They recorded improved hydrophilic total antioxidant activity and reduced the lipophilic total antioxidant activity. Zeraatgar et al., (2018) revealed that SA has profound effect on antioxidant activity. When fruits are treated with SA

(4 mM) variable rates (high and low) of antioxidant activity were recorded in jujube to the tune of 76.76 mmol Trolox/g(with SA) and in control (65.93 mmol Trolox/g). Haider et al.,(2020) accessed the impacts of SA (2, 4, , 6, 8 or 12 mM) as post-harvest application on mandarin and kept in storage at 5 ± 1 °C and 90 ± 5% RH for three months. They concluded that total phenolic contents, superoxide dismutase (SOD) enzymes, maximum antioxidant and activities of peroxidases (POD) were improved with 4mM SA and all treatments of SA worked well against fungal attack in storage. It can safely be used to decline decay percentage and to retain improved levels of bioactive compounds but for 3 months only.

Catalase activity (CAT)

Jing et al., (2008) revealed that the impact of SA can be linked with its capability of enhancement of antioxidant enzymes, which retains nutritional value by avoiding the effect of free radicles. Huang et al., (2008) studied the impact of salicylic acid on Cara cara' navel orange (stored under 6 °C and 20 °C). They observed that pretreatment with salicylic acid result in accelerated accumulation of H_2O_2 and inclined SOD but decelerated rate at which CAT increased in storage at 6°C and 20 °C as compared to control treatments. It was established that antioxidant system in plants is greatly improved with external application of salicylic acid but at suitable concentrations. Tareen et al.,(2012) worked of peach fruit to judge its post-harvest life after treatment with SA (0, 0.5, 1.0, 1.5 or 2.0 mmol L^{-1}) in cv. 'Flordaking'. After treatment fruits stored at 0 °C for 5 weeks. They recorded that all levels of salicylic acid proved best in improving activity catalase (CAT), peroxidase (POD) and superoxide dismutase (SOD) during storage period. While salicylic acid at 2.0 showed promising results in decreasing the activity of fruit browning enzyme polyphenol oxidase (PPO) activity. Asghari and Aghdam, (2010) explained that salicylic acid is liable for inclination in antioxidant enzymes activity by expressing the alternate oxidase genes and all together (antioxidants) lessens the toxic effect of free radicles and avoid any kind of stress for the plant cell. Asghari et al.,(2016) carried out research experiment to evaluate the effects of salicylic acid (0, 1, and 2 mMol L-1) on post-harvest life of grapes stored at 0±0.5C with 90-95% RH for 45 and 90 days in Urmia university. They concluded that application of 2 mM salicylic acid was able to retain antioxidant activity by inclining catalase activity. To access the activity of CAT, APX enzymes and fruit quality in cold stored Clementine mandarins and fruits were dipped in SA or ASA (*1mM, 2mM*) and stored at 40°F, RH 85-90 %. It was concluded that application of ASA or SA at higher levels proved to be effective in prevention of lessening of ascorbic acid content and APX and CAT activities were greatly improved with application of 2*m*M SA. Zeraatgar et al., (2018) carried out research studies in jujube and proved that increase in SA concentration is directly associated with CAT activity, so as the lowest and the highest catalase activity was recorded in 4 mM conc. to the tune of 16.67 U. mg-1 (protein content) and control as 14.33 U mg-1(protein content).

Conclusion

The importance of SA as pre- or post-harvest treatment might work as an innovative technology for enriching nutritional quality of fruit. From the current studies, it could be determined that applications of SA significantly retains better fruit color, maximum fruit firmness, TSS, total sugars, ascorbic acid content and observed minimum physiological weight loss and fruit spoilage as compared to untreated fruits. However, application of 4 mM SA showed improved levels of phenolic contents, ascorbic acid contents, catalase and antioxidative activity effectively in long term storage.

Future Prospects:

Several approaches of prolonging the shelf-life have been established and suggested use of plant growth regulators and chemicals for different kinds of fruits and different kinds of packaging materials along with ethylene absorbent. The reaction of the different fruits varies with their kinds and prevailing conditions. Therefore, it may be obligatory to find out an appropriate technology for lengthening the shelf life of fruits. Encouraging results are obtained under cold conditions but these facilities are not accessible to the poor farmers of rural area. Hence, extending shelf life under normal condition is the need of countryside India. Nevertheless, research under cold storage conditions should not be ignored because SA treatment maintained higher contents of ascorbic acid and increased the antioxidant capacity in fruits.

References

Abbasi, N., S. Hafeez, M.J. Tareen, E.W. Hewett, J.W. Johnston and F. Gunson, (2010). Salicylic acid prolongs shelf life and improves quality of 'Maria Delicia' peach fruit. *Acta Hort*., 880: 91-97.

Aghdam, M.A., Motallebiazar, A., Mostofi, Y., Moghaddam, J.F., Ghasmnezhad, M., (2011). Salicylate affects the quality of Hayward kiwifruits during storage at low temperature. J. Agric. Sci. 3, 149–156.

Amanullah Sikandar, Sajid Mateen, Qamar Muhammad Bilal, Saeed Ahmad. (2017). Post-harvest treatment of salicylic acid on guava to enhance the shelf life at ambient temperature. *Int. J. Bio. Sci.*, 10(3): 92-106.

Aminifard, M.H., S. Mohammadi and H. Fatemi, (2013). Inhibition of green mould in blood orange (*Citrus sinensis* var. Moro) with salicylic acid treatment. *Arch Phytopathol. Pl. Prot.*, 46: 695-703.

Asghari, M. and M.S. Aghdam, (2010). Impact of salicylic acid on post-harvest physiology of horticultural crops. *Trends Food Sci. Tech.,* 21: 502-09.

Asghari, Mohammadreza, Leila AhadI, and Sajjad Riaie. (2016) "Effect of postharvest salicylic acid and Aloe vera gel on postharvest storage and antioxidant properties of Table Grape (cv. Gizel uzum).": 677-685.

Atia A, Abdelkarim D, Younis M, Alhamdan A (2020). Effects of pre-storage dipping in calcium chloride and salicylic acid on the quality attributes of stored Khalal Barhi dates. Int J Agric & Biol Eng,; 13(3): 206–212**.**

Awad, R. M.,(2013). Effect of post-harvest Salicylic acid treatments on fruit quality of peach cv" Flordaprince" during cold storage. *Australian J. Basic and Applied Sciences.* 7 (7): 920-927.

Baliga M S, Baliga B R V, Kandathil S M, Bhat H P, Vayalil P K. 2011. A review of the chemistry and pharmacology of the date fruits (Phoenix dactylifera L.). Food Res. Int.,; 44:1812–1822.

Baswal, A. K., Dhaliwal, H. S., Singh, Z., Mahajan, B. V. C., & Gill, K. S. (2020). Postharvest application of methyl jasmonate, 1-methylcyclopropene and salicylic acid extends the cold storage life and maintain the quality of ‘Kinnow’mandarin (Citrus nobilis L. X C. deliciosa L.) fruit. Postharvest Biology and Technology, 161, 111064.

Brar J.S., N. Gupta and M.S. Gill, (2014). Effect of pre and post-harvest treatments of salicylic acid on quality characteristics of peach (*Prunus persica* L.) fruits during storage. *Prog. Hort.,* 46:217-21.

Canakci, S.,(2008). Effects of salicylic acid on fresh weight change, chlorophyll and protein amounts of radish (*Raphanus sativus* L.) seedlings. *J. Biol. Sci.,* 8: 431-435.

Cao, J.K., J.Q. Yan, Y.M. Zhao, W.B. Jiang,(2013). Effects of four pre-harvest foliar sprays with aminobutyric acid or salicylic acid on the incidence of post -harvest disease and induced defense responses in jujube (*Zizyphus jujuba* Mill.) fruit after storage. *J. Hort. Sci. Biotech.,* 88**:** 338-44.

Champa, W. H., M. I. S. Gill, B. V. C. Mahajan and N. K. Arora, (2014). Pre-harvest salicylic acid treatments to improve quality and post-harvest life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. *Journal of Food Science and Tech.,* 52(6): 3607-3616.

Chavan, R. F., & Sakhale, B. K. (2020). Studies on the effect of exogenous application of salicylic acid on post-harvest quality and shelf life of tomato fruit Cv. Abhinav. Food Research, 4(5), 1444-1450.

Díaz-Mula, H.M., P.J. Zapata, F. Guillén, D. Martínez-Romero, S. Castillo, M. Serrano and D. Valero, (2009). Changes in hydrophilic and lipophilic antioxidant activity and related bioactive compounds during post-harvest storage of yellow and purple plum cultivars. *Post-harvest Biol. Technol.,* 51:354–363.

Drogoudi PD, Tsipouridis CG (2007). Effects of cultivar and rootstock on the antioxidant content and physical characters of clingstone peaches. *Scientia Horticulturae* 115(1):34-39.

Ennab, H.A.; El-Shemy, M.A.; Alam-Eldein, S.M.(2020). Salicylic Acid and Putrescine to Reduce Post-Harvest Storage Problems and Maintain Quality of Murcott Mandarin Fruit. *Agronomy*, 10, 115.

Ghasemnezhad, M., Shiri, M.A., Sanavi, M., (2010). Effect of chitosan coatings on some quality indices of apricot (Prunus armeniaca L.) during cold storage, Caspian J. Env. Sci, 8: 25-33.

Gill, K. S., H. S. Dhaliwal, B. V. C. Mahajan, G. Paliyath and R. S. Boora,(2016). Enhancing post-harvest shelf life and quality of guava (*Psidium guajava* L.), cv. Allahabad Safeda by pre-harvest application of hexanal containing aqueous formulation. *Post-harvest Biology and Techn.,* 112: 224-232.

Gill, P. P.S. and J. S. Bal,(2016). Effect of growth regulator and nutrients spray on control of fruit drop, fruit size and quality of ber under sub-montane zone of Punjab. *J. Hort. Sci.,* 4 (2): 161-163.

Gimenez, M.J., Serrano, M., Valverde, J.M., Martinez, R.D., Castillo, S., Valero, D., Guillen, F., (2016). Pre harvest salicylic acid and acetylsalicylic acid treatments preserve quality and enhance antioxidant systems during postharvest storage of sweet cherry cultivars. J. Food Sci. Agric. https://doi.org/10.1002/jsfa.7853

Habibi, F., Ramezanian, A., Guillén, F., Serrano, M., & Valero, D. (2020). Blood oranges maintain bioactive compounds and nutritional quality by postharvest treatments with γ-aminobutyric acid, methyl jasmonate or methyl salicylate during cold storage. Food chemistry, 306, 125634.

Haider, S. A., Ahmad, S., Khan, A. S., Anjum, M. A., Nasir, M., & Naz, S. (2020). Effects of salicylic acid on postharvest fruit quality of "Kinnow" mandarin under cold storage. Scientia Horticulturae, 259, 108843.

Hajilou, J. and S. Fakhimrezaei, (2013). Effects of post-harvest calcium chloride or salicylic acid treatments on the shelf life and quality of apricot fruit. *The Journal of Horticultural Science and Biotech.* 88(5): 600-601.

Huang, R., R. Xia, Y. Lu, L. Hu and Y. Xu, (2008). Effect of pre-harvest salicylic acid sprays treatment on post-harvest antioxidant in the pulp and peel of 'Cara cara' navel orange (*Citrus sinensis* L. Osbeck). *Journal of the Science of Food and Agriculture.* 88: 229–236.

Hussain P R, Meena R S, Dar M A, Wani A M. (2012). Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of Red delicious apple. J. Food Sci. Technol.,; 49(4): 415–426.

Jing-Hua Y, Yuan G, Yan-Man L, Xiao-Hua Q, Zhang MF (2008). Salicylic acid-induced enhancement of cold tolerance through activation of antioxidative capacity in watermelon. Scientia Horticulturae 118(3):200-205.

Joseph, B., D. Jini and S. Sujatha, (2010). Insight into the role of exogenous salicylic acid on plants grown under salt environment. *Asian J. Crop Sci.,* 2: 226-235.

Kaseem, H. A., R. S. Al-Obeed, M.A. Ahmed and A. K. H. Omar.(2011). Productivity, fruit quality and profitability of jujube trees improvement by pre-harvest application of agrochemicals. *Middle-East J. Sci. Res.*, 9:628-37.

Kaur Parambir,(2016). Shelf life enhancement studies in guava (*Psidium guajava* L.) cv. Shweta. M.Sc. Thesis submitted, PAU, Ludhiana.

Kazemi, M., M. Aran and S. Zamani (2012). Effect of calcium chloride and salicylic acid treatments on quality characteristics of kiwifruit (*Actinidia deliciosa* cv. Hayward) during storage. *American Journal of Plant Physiology*. 6:183–189.

Khademi, O., Ashtari, M., & Razavi, F. (2019). Effects of salicylic acid and ultrasound treatments on chilling injury control and quality preservation in banana fruit during cold storage. Scientia horticulturae, 249, 334-339.

Khademi, Z. and A. Ershadi,(2013). Post-harvest application of salicylic acid improves storability of peach *(Prunus persica* cv. Elberta) Fruits. *International J. Agri. and Crop Sci.*, 5(6): 651.

Kumar M.A. and Y. N. Reddy,(2008). Preliminary investigations on the effect of foliar spray of chemicals on flowering and fruiting characters of mango cv. Baneshan. *Res. J. Agri. and Biol. Sci.*, 7 (2): 150-156.

Kumar Sunil and Kaur Gurpinder.(2019). Effect of pre harvest application of salicylic acid on plant growth parameters and yield of strawberry cv. Chandler. Journal of Pharmacognosy and Phytochemistry 2019; SP4: 85-87**.**

Lo'ay, A.A. and A. Y. El Khateeb, (2011). Delaying guava ripening by exogenous salicylic acid. *J. Plant Prod. Mans. Univ.*, 2: 715-724.

Lokesh G., Madhumathi C., Rama Krishna CM, Tanuja Priya B. and Kadiri L. (2020). Effect of Salicylic Acid and Potassium Silicate on Shelf Life of Mango (*Mangifera Indica* L.) Cv. Alphonso. *International Journal of Chemical Studies;* Vol 8, No 2, 2020; PP: 437-440

Lolaei, A., B. Kaviani, M.A. Rezaei, M.K. Raad and R. Mohammadipour,(2012). Effect of pre- and post-harvest treatment of salicylic acid on ripening of fruit and overall quality of strawberry (*Fragaria ananasa* Duch cv. Camarosa) fruit. *Ann. Biol. Res.,* 3(10): 4680-4684.

Lu, X. H., D. Q. Sun, Y. W. Mo, J. G. Xi and G. M. Sun, (2010). Effects of post-harvest salicylic acid treatment on fruit quality and anti-oxidant metabolism in pineapple during cold storage. *The Journal of Horticultural Science and Biotech*. 85(5): 454-458.

Madhav, J, V., S. Sethi, R.R. Sharma, and S. G. Rudra(2016). Impact of Salicylic acid on the physiological and quality attributes of guava (*Psidium guajava* L.) fruits during storage at low temperature. *Indian J. of Agri. Sci.*, 86(9): 2390-2397.

Mohamed, R. A., A. K. Abdel Baset and D. Y. Abd-Elkader, (2018). Salicylic acid effects on growth, yield, and fruit quality of strawberry cultivars. *Journal of Medicinally Active Plants*. 6(2): 1-11.

Nanthawan, H. and Kanlayanarat, S. (2010). Effect of anti-transpirants on freshness and storage life of rambutan fruit (Nephellium lappaceum L.). Food Chemistry, 68, 471–474.

Ngullie, Chonpenthung R., (2014). Effect of acid and humic acid on flowering, fruiting, yield and quality of mango (*Mangifera indica* L) cv. Kesar. Thesis submitted to the Navsari Agricultural University Navsari, Gujarat.
Noorullah, R. (2018). Effects of Silicon Sources and Salicylic Acid on Quality and Shelf Life of Mango Fruits (Mangifera indica L.) cv. Kesar. *International Journal of Agriculture Sciences, ISSN*, 0975-3710.
Obeed, R. S.,(2011). Enhancing the shelf life and storage ability of Flame Seedless grape by agro chemicals pre-harvest foliar applications. *Middle-East J. Sci. Res.,* 8 (2): 1936-1943.
Rahmani, N, T. R. Ahlawat, S. Kumar and N. K. Mohammadi, (2017). Improving productivity in Mango (*Mangifera indica* L.) cv. Kesar through foliar sprays of silicon and salicylic acid. *International Journal of Chemical Studies,* 5(6): 1440-1443.
Remorini D, Tavarini S, Degl'Innocenti E, Loreti F, Massai R, Guidi L (2008). Effect of rootstocks and harvesting time on the nutritional quality of peel and flesh of peach fruits. *Food Chemistry* 110(2):361- 367.
Sartip G, Hajilou J (2015). Effect of preharvest application salicylic acid on physicochemical characteristics of apricot (Prunus armeniaca l.) fruits cv. 'Shamlou' during storage. Journal of Crops Improvement 17(1):81-91.
Sayyari, M., Babalar, M., Kalantari, S., Martínez-Romero, D., Guillén, F., Serrano, M., Valero, D. (2011). Vapour treatments with methyl salicylate or methyl jasmonate alleviated chilling injury and enhanced antioxidant potential during postharvest storage of pomegranates. Food Chemistry, 124(3), 964-970.
Shafiee, M, T. S. Taghav iand M. Babalar. (2010). Addition of salicylic acid to nutrient solution combined with post-harvest treatments (hot water, salicylic acid, and calcium dipping) improved post-harvest fruit quality of strawberry. *Scientia Hort.,* 124: 40-45.
Shehzad, S., Ahmad, S., Jaskani, M. J., ud din Taj, S., & Shafqat, W. (2016) Pre and Postharvest Treatment of Salicylic Acid to Improve the Fruit Quality and Shelf Life of Mango (Mangifera indica L.). Proceedings of Pakistan Society for Horticultural Science. 2nd International Conference on Horticultural Sciences, February 18-20, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Punjab 38040, Pakistan.313-322.
Shrivastva D., Kumar P.A., P. S. Surendra and B. Kalyan. (2020). Pre-Harvest Application of Salicylic Acid and Propyl Gallate to Preserve Postharvest Quality of Ber (Ziziphus maurtiana Lamk) Fruits cv Banarasi Karaka. Int. J. Curr. Microbiol. App. Sci. 9(04): 2914-2923.
Supapvanich, S., Boonyaritthongchai, P., & Wongs-Aree, C. (2017). Physicochemical changes in 'Holland' papaya fruit treated with quarantine hot water incorporated with salicylic acid dip during cold storage. In VI International Conference Postharvest Unlimited 1256 (pp. 223-230).
Tareen, M. J., N. A. Abbasi and I. A. Hafiz, (2012). Post-harvest application of salicylic acid enhanced antioxidant enzyme activity and maintained quality of peach cv. 'Flordaking' fruit during storage. *Scientia Hort.* 142: 221-228.
Wang, Z., Ma, L., Zhang, X., Xu, L., Cao, J., & Jiang, W. (2015). The effect of exogenous salicylic acid on antioxidant activity, bioactive compounds and antioxidant system in apricot fruit. Scientia Horticulturae, 181, 113-120.
Yang, C., Duan, W., Xie, K., Ren, C., Zhu, C., Chen, K., & Zhang, B. (2020). Effect of salicylic acid treatment on sensory quality, flavor-related chemicals and gene expression in peach fruit after cold storage. Postharvest Biology and Technology, 161, 111089.
Yeganeh, M.A., E. Hadavi and M. Kalhori. (2013). Effects of Salicylic acid on quality of 'Bidaneh Sefid' table grapes during cold storage. *International J. Agriculture and Crop Sci.* 5(18): 2041.
Zeraatgar Hadi, Davarynejad Gholam Hossain, Moradinezhad Farid, Abedi Bahram, (2018). Effect of Salicylic Acid and Calcium Nitrate Spraying on Qualitative Properties and Storability of Fresh Jujube Fruit (Ziziphus jujube Mill.). Not Bot Horti Agrobo, 2018, 46(1):138-147.