

Review Article

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Impact of Chemicals on the Ripening Physiology of Fruits

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ABSTRACT

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The invention of new chemicals or molecules, which may lead to or delay the ripening process of fruits, so that losses due to their perishable nature and short storage life can be easily handled. By doing this manipulation, we can avoid huge economic losses during the peak fruit season. It is prudent to use chemicals within safe limits so that they do not have a negative effect on a healthy human being. Certain chemicals increase the ripening process only if they are used in higher quantities but lead to a decline in the shelf life of treated fruits. In addition, the fruits have decayed very early compared to untreated fruits. In this article, we are focusing on the possibilities of manipulation in the process of maturation by the use of different chemicals.

Introduction

Guava is a very important fruit crop, grown in several parts of the world because of its wider adaptability. This fruit is also known as the "apple of the tropics" and is popularly known as the "poor man's apple" because of its availability and lower cost. Due to its nutritional value, refreshing taste and pleasant taste, this fruit is of great benefit to consumers. This fruit belongs to the Myrtaceae family and is native to Tropical America. The highest production of guava in India is in Uttar Pradesh, accounting for 22.93 per cent of total production. Punjab ranks 7th in the production of guava with a total area of 8690 ha and a total production of 195600 MT

and a share of 4.83 percent of India's total production (Anon, 2018). Guava flowering occurs twice in northern India. It is a good source of iron, including pectin and vitamins such as 'A,' 'C,' E, thiamine, niacin and riboflavin, along with minerals such as Ca (14-30 mg/100 gm) and P (23.37 mg/100 gm) etc. Guava fruits are used for direct consumption or for processing purposes in the manufacture of various products (Boora, 2012). Up to harvesting, the life of fruit can be categorized into three stages:

Fruit set
Development of fruit
Ripening of fruit

Fruit ripening is a genetically programmed process. Fruit ripening is a very complicated process resulting from a change in the taste, colour, texture and other characteristics of the fruit. When ripening is at an early stage due to the production of a high amount of ethylene, respiration is at its peak, while this rate is almost persistent and shows little decline towards senescence, indicating a decrease in ethylene production (Bouzayen *et al.*, 2010). Dal RI *et al.*, (2010) concluded that ethylene plays an important role in the development and growth of grapevine berry. Korban *et al.*, (2010) also stated that the change in fruit texture is affected by genetic regulatory factors such as environmental conditions. At the time of the respiration process, complex molecules are broken into simpler ones, resulting in energy supply. Tripathi *et al.*, (2016) indicated from cellular metabolic activity that the process of fruit maturation is a distinguishing feature throughout the different phases of fruit life-like fruit development, maturation and senescence. Ripening process is the beginning of the senescence process and is an irreversible activity involving several biochemical, physiological and organoleptic changes (Joshi *et al.* 2017). These alterations include changes in fruit colour, flavour, texture, sugar content, carbohydrate content, phenolic compounds, organic acids along with pigment formation, starch breakdown and aroma development, flavourings, etc. As a result, I concluded that fruits that are climatic in nature depend directly on ethylene because these fruits ripen with the help of ethylene, while non-climatic fruits will only ripen and mature if they are still attached to the parent plant (Pathak *et al.*, 2018).

Ethephon

According to Marzouk and Kassem (2011), the fruit can be consumed directly after ethephon therapy, but at the same time, the

shelf life of the fruit is decreased. When etherel is applied to fruit, it is decomposed and results in the production of ethylene in fruit and, ultimately, it is ripened (Singh *et al.*, 2018). Sapkota *et al.*, (2020), examined the result of ethephon application to kiwi fruit and found that fruit treated with 700 ppm ethephon had the highest TSS (16.63 ° brix) at the end of the ripening period, while a minimum TSS (12 ° brix) was found in control fruit 30 days after treatment. When the ripening period was at its peak, maximum PLW (17.28 per cent), maximum TSS / TA (25.57), lowest titrable acidity (0.66 per cent) and highest pH value (4.08) were found in fruit with 700 ppm while control fruits showed minimum TSS / TA (12.1), lowest PLW (11.8 per cent), maximum acid content (1.1 per cent) and lowest pH (3.5). Minimum shelf life (16.25 days) was found in fruit with 700 ppm followed by 500 ppm (22.13 days) and maximum shelf life (48.25 days) was found in the control treatment. Dong *et al.*, (2020) showed that the early colouring of grapefruit was promoted by the exogenous application of ethephon. Soluble solids increased in ethephon therapy while titrated acidity decreased. Lavanya *et al.*, 2019, observed that dipping of 750-ppm ethephon at 20°C for approximately 5 min, 80 per cent of RH in mango cv. Neelum showed good results with regard to the maturation process. Sabuz *et al.*, (2019) assessed the effect of six different concentrations (0, 250, 500, 750, 1000 and 10,000 ppm) of ethephon on the ripening of banana fruits. After treatment, the fruit was stored at $23 \pm 2^\circ\text{C}$ with a RH of 80 ± 5 per cent. Fruits treated with ethephon @500-1000 ppm were observed to be fully ripened on the 4th day of storage while 250 ppm and control were unripe and fruit, while ethephon @10000 ppm resulted in over ripened fruit on the 4th day of storage on the other hand, 6th day fruits treated with 250 ppm ethephon were ripened and fruit with ethephon @500-1000 ppm was over ripened

while rotten fruit was over ripened. Pendharkar *et al.*, (2011) treated bananas with different concentrations of ethephon @500,750 and 1000 ppm and found that 1000 ppm is best suited for early fruit ripening. In an ethephon effect study on passion fruit, it was shown that 600 mg / kg was the best treatment, while low ethephon concentrations had a much lower effect on passion fruit (Li *et al.*, 1919).

Absciscic acid

ABA play a significant role throughout the life cycle of a plant. This includes the development of seed and its dormancy, the response of the plant to various stresses and ripening of fruit. The concentration of Absciscic acid is very less concentration in unripe fruits, but its concentration starts increasing with the ripening of the fruit. Exogenous ABA application accelerates respiration and production of ethylene, which results in increased ripening of fruits (Zhang *et al.*, 2009). ABA inclines ethylene release in climacteric type fruits that is why it is known as ripening control factor (Zhang *et al.*, 2009, b). Application of ABA leads to the production of those metabolites, which are involved in the process of fruit ripening i.e. ABA increases ripening in fruits (Giribaldi *et al.*, 2010). Setha (2012) suggested that the application of ABA on fruits play a significant role in regulating the rate of fruit ripening.

Wang *et al.*, (2019) suggested that ABA biosynthesis promoted by ethylene through PpERF3's regulation of the expression of ABA biosynthesis genes PpNCED2/3. Liu (2019) observed that ABA appeared to modulate ripening by interfering not only genes related to cell wall and ethylene but also with the help of genes, which are related to auxin. Siebeneichler *et al.*, (2020) suggested that sucrose application in

unripened strawberries results in ripening induction, which depends on the ABA and its derivatives. Pharmacological experiments and network correlation analysis with amine, which is an ABA biosynthesis inhibitor, showed that change in levels of ABA has a straight effect in increasing β carotene content and which is then responsible for the phenotype like increased shelf life. Therefore, change in the levels of β carotene will not only result in an improved nutritional value, but it also increases shelf life (Diretto *et al.*, 2020). Balate *et al.*, (2020) found that quality of fruits could be improved by increasing the SS, ratio SS/TA of fruits, with the application of Absciscic acid to roots and leaves. It is proposed that SIPYL9 plays an important role in the regulation of flower abscission and ripening in tomato because it is involved in ABA signalling (Kai *et al.*, 2020).

Nitric Oxide (NO)

It is reported that the level of nitric oxide is more in unripe fruits in comparison to ripe fruit. In research, it is found that level of NO is highest in cherry and tomato fruits when they are at the unripe stage. Treatment of NO in banana fruits results in delayed ripening because of less ethylene production (Cheng *et al.*, 2009). Sahu *et al.*, (2020) used SNP (sodium nitroprusside) which is a nitric oxide donor in case of guava fruits. In this study, SNP treatment (@ 0.5, 1.0, and 1.5 mM) was used along with control treatment and matured green fruits, which were immersed for 5 minutes. After this treatment, fruits were stored at $20 \pm 3^\circ\text{C}$. Out of these treatments, the best results were found in SNP@1.0 mM, in this study fruits decay loss (22.22%) and minimum weight loss (16.31%) was noted on 12th day of storage. Fruits treatment with 1 mM SNP exhibited a delay in ripening, minimum chlorophyll loss (53.23%) and slow growth of carotenoid pigments. Guava treatment before storage

with 1 mM SNP resulted in the least loss of TSS and acidity in comparison to fruits under control. Loss in phenols (22.25%), antioxidant capacity (25.61%), flavonoids (26.14%), ascorbic acid (21.30%) and radical scavenging activity (RCA) 34.21% was least in fruits treated with 1.0 mM SNP. This study concluded that post-harvest/shelf life of guava might be increased by 1.0 mM SNP treatment. Gheysarbigi *et al.*, (2020) sprayed SNP on pistachio fruits with 0, 15, 30, 45 and 60 μM for 30 seconds and packing of these fruits were in a plastic tray and then wrapped with LDPE (low-density polyethylene) and stored in cold storage at $2 \pm 1^\circ\text{C}$ and $93 \pm 2\%$ RH for 60 days. The results proved that SNP @ 15 and 30 μM was most beneficial for the reduction of hull browning and in increasing the postharvest life as compared to the control treatment.

Potassium permanganate (KMnO_4)

It has been proved in many scientific research experiments that KMnO_4 decreases the ripening process of fruits. KMnO_4 is a stable purple solid compound and is used to extend the shelf life of fresh produce (Resende *et al.*, 2001). It reduces the level of ethylene in fruits by oxidizing to CO_2 and H_2O . Oxidation of ethylene by potassium permanganate results in carbon dioxide and H_2O formation (Sorbent systems, 2005). It has been proved that with an increase in the quantity of KMnO_4 , level of ethylene gas is decreased and it was estimated that 20 gm of KMnO_4 is able to reduce about 2.2% of ethylene (Correa *et al.*, 2005). Osman *et al.*, (2008) also advocated that potassium permanganate is a strong oxidizing agent, which readily oxidize ethylene and delays ripening in climacteric fruits such as banana, kiwi fruit, tomato, mango and avocado. Treatment with KMnO_4 decreases post-harvest losses, which help in delaying in the ripening process of fruits (Ishaq *et al.*, 2009).

Kaur and Kuldip (2011) concluded in peach fruits that KMnO_4 treated showed less spoilage and physiological loss in weight during storage in comparison to control. Elzubeir *et al.*, (2018) resulted that waxing of tomato fruits with 1.0 and 2.0 gm potassium permanganate, delayed the ripening by 1, 3 and 4 days, respectively, in comparison to the control one. Packing of fruits in carton boxes with 1 and 2 g potassium permanganate, respectively reduce the weight loss of fruits by 29.1 %, 38.1 % and 46.0 % (with 0.0, 1.0 and 2.0 g potassium permanganate, respectively), in comparison to control one. Iqbal *et al.*, (2019) suggested that a KMnO_4 treated wrapping material could be utilized for enhancing the shelf life of tomatoes, which retards respiration rate, and delaying in ripening. The effect of ethylene treatments in different concentrations and packaging types on banana fruit was studied to improve storage life and physicochemical quality. As ethylene, absorbent zeolite and KMnO_4 were used in storage along with banana at $25\text{--}28^\circ\text{C}$ of temperature and 85–95% of RH. Physicochemical analysis (e.g. total soluble solids, weight loss, firmness, peel colour changes and TA) were performed to estimate the effect of treatments during storage. Results showed that KMnO_4 -zeolite (T_4 : 10g) showed reduction (the higher amount was applied) and retarded the change in colour of peel, firmness (28.2%), percent weight loss (9.62%), TA (0.084% malic acid), TSS (12.1% Brix) and the banana storability (Yin *et al.*, 2020).

Oxalic acid

Oxalic acid treatment decreases the deterioration of fruits throughout storage. Increased shelf life and lower decay rate were observed in mango fruits when treated with 5mm oxalic acid after harvesting and in controlled atmosphere storage (Zheng *et al.*, 2005). Production of ethylene is very less in

fruits, which treated with oxalic acid @5mm in comparison to control fruits (Zheng *et al.*, 2007). Wang *et al.*, (2008) also advocated that production of ethylene is reduced in fruits treated with oxalic acid @ 5 mm which delays the senescence in jujube fruit. Wu *et al.*, (2011) treated plum fruits with oxalic acid @ 5mm and packed in polyethene bags and stored at 25°C for 12 days and found that oxalic acid treated fruits has more shelf life in comparison to control fruits. Treatment of oxalic acid @ 20mm results in reduced respiration rate and declined production of ethylene in banana fruits in comparison to control (Huang *et al.*, 2013). Ali *et al.*, (2019) submitted that application of oxalic acid before harvesting of fruits might be helped in maintaining the quality of kiwifruit and delay in ripening of fruit, improvement in ascorbic acid content and ethanol fermentation regulation.

Ripening process of plum fruits at the time of their storage was delayed when treated with oxalic acid, in comparison to control (Martínez *et al.*, 2019). Uzumcu *et al.*, (2020) investigated the effect of oxalic acid before the harvesting of fruits on shelf life of apricot cv. 'Roxana'. For this purpose, different dosages (0, 1, 2, 4 and 8 mM) of oxalic acid solution were applied 7 days before optimal harvest stage. After harvesting fruits at optimal stage (firm-ripe stage), were immediately transported to the postharvest physiology laboratory and kept at room (20±1°C) temperature and 50–60% relative humidity conditions for 8 days for shelf-life evaluation. During the storage period, an analysis was carried out at an interval of 2 days concerning physical and chemical traits like fruit firmness, fruit colour soluble solids content, titratable acidity, and evaluation of loss of weight, ethylene production and respiration rate. As a result, all treatments of oxalic acid performed better in comparison to control fruits in terms of quality parameters.

Salicylic acid

Babalar *et al.*, (2007) studied the effect of different concentrations of SA on strawberry fruits and found that application of SA @2mm resulted in a reduction in the production of ethylene and fungal decay. SA @ 2mm retains the best quality of strawberry fruits compared to other treatments and control. It was observed that the treatment of SA on sugar apple resulted in reduced respiration rate and inclined the activity of antioxidant enzymes. Mo *et al.*, (2008) concluded that fruits SA treated fruits showed delayed in the ripening of fruits of sugar apple. Loss in weight of fruits is reduced in kiwifruits fruits, which are treated with SA in comparison to control (Fattahi *et al.*, 2010). Bal et al (2019) proved that level of bioactive compounds and high quality of fruit can be maintained by using alginate enriched with salicylic acid than any other coating treatments during storage at 0–1°C of 40 days. Lo'ay (2017) also advocated that SA proved to be effective in delaying fruit ripening along with preserving cluster quality of grapes cv. Superior seedless. Lo'ay and Khateeb (2011) also advocate delaying in ripening in guava fruit. Ansarifar *et al.*, (2019) evaluated that the highest fruit firmness in salicylic acid (11.46N) treatments. Soluble solids content and improved shelf life were observed in salicylic acid (27.5 days) treated fruits, while it is only 14 days in case of controlled apricot fruits.

Hydrogen Sulphide (H₂S)

Hu *et al.*, (2014) advocated that the shelf life of pear slices could be increased by the application of H₂S by inhibiting developments of many fungal pathogens. Treatment with H₂S @ 45 and 90 µmol L⁻¹ delayed the maturation and senescence in case of kiwifruit (Zhu *et al.*, 2014). Treatment of H₂S with 1mm of sodium hydrosulphide results in

delayed ripening of banana and deferred the senescence (Ge *et al.*, 2017). Hu *et al.*, (2019) showed that by the inhibition of synthesis of endogenous ethylene and regulating ethylene signal transduction exogenous H₂S results in delayed fruit softening and the ripening process of tomato fruit at the time of storage. Yao *et al.*, (2020) found that change of colour in tomato fruit was delayed by application of H₂S and it maintained higher chlorophyll, lowered flavonoids throughout storage, and

increased the post-harvest life of fruits. By regulating cell wall degrading enzyme genes and affecting ethylene signal transduction pathway genes, H₂S delays the senescence and ripening of kiwifruit (Lin *et al.*, 2020).

Besides, above said chemicals some other molecules are also used for this purpose. Various scientist have performed research studies in different crops as summarized in following table

S.No.	Chemical	Crop	Result	Reference
1	Kinetin	Sapota	Delay in ripening	Kaur <i>et al.</i> , 2019b
2	1 MCP	Plum	Extend shelf life, Reduces weight loss	Xu <i>et al.</i> , 2020
3	Methyl jasmonate	Strawberry	Accelerate ripening Process	Han <i>et al.</i> , 2019
4	Methyl salicylate and 1 MCP	Tomato	Delay in ripening of fruit	Min <i>et al.</i> , 2018
5	Sodium benzoate	Pear	Increases shelf life	Kaur <i>et al.</i> , 2019
6	Sodium dichloroisocyanurate	Banana	Delay in ripening and senescence	Wu <i>et al.</i> , 2018

Future perspectives

Fruit development and ripening are prime and significant phases in plant life in field of horticulture. Many research trials are still going on these phases due to short shelf life and perishable nature of the fruit. These are the prime causes for huge and considerable economic losses. From review of literature, it is concluded that ethylene plays a critical role in ripening process, but recently, focus is done on the concept that some other molecules including processes are also responsible for the same. It is need of the hour to develop and field test transgenic plants that are specifically suited to grow well in sustainable agricultural systems that have nominal dependence on chemical involvement and synergistic impact on metabolism of the plant. Short shelf life and perishable nature of the fruit can be managed by finding such chemicals or compounds, which can early or delay the ripening process

in fruits. By doing so we can avoid huge economic losses due to market glut of main production season.

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