POSTHARVEST QUALITY MANAGEMENT IN BANANA CV. NENDRAN (*Musa* spp.)

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(*Musa* spp.)

by

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THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **"POSTHARVEST QUALITY MANAGEMENT IN BANANA CV. NENDRAN (*Musa* spp.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani
Date: 18/09/2020

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CERTIFICATE

Certified that this thesis entitled **"POSTHARVEST QUALITY MANAGEMENT IN BANANA CV. NENDRAN (*Musa* spp.)"** is a record of bonafide research work done independently by Ms. Aparna Nath S. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Aparna Nath S. S.

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LIST OF ABBREVIATIONS

%	: Per cent
cm	: Centimetre
DAS	: Days after storage
et al.	: Co-workers
g	: Gram
Kg	: Kilogram
hr	: Hour
KAU	: Kerala Agricultural University
mg	: Milligram
min	: Minutes
mL	: Millilitre
mm	: Millimetre
L	: Litre
ºC	: Degree celsius
RH	: Relative Humudity
rpm	: Revolutions per minute
Sec	: Second
viz.	: Namely
ºB	: Degree Brix
CO_2	: Carbon dioxide

cv. : Cultivar

Fig. : Figure

OA : Oxalic Acid

GA_3 : Gibberellic Acid

SA : Salicylic Acid

$CaCl_2$: Calcium chloride

nm : Nanometer

NS : Non Significant

O_2 : Oxygen

PLW : Physiological Loss in Weight

N : Newton

ppm : Parts per million

CD : Critical difference

SE : Standard Error

TSS : Total Soluble Solids

Sl. : Serial

Via : through

µm : micromole

GRAS : Generally Recognized As Safe

ACC : 1-aminocyclopropane carboxylic acid

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Introduction

1. INTRODUCTION

Banana is one of the world's most important fruit crops and India is the largest producer with more than 50 different cultivars. Among them 'Nendran' (*Musa* AAB) is the most popular variety of Kerala for domestic as well as export market and there is a growing demand for Nendran as a table fruit and for processing because of its high nutritional value.

Banana being a climacteric fruit continues its metabolic activities *viz*., respiration, transpiration, ripening and remain biologically active leading to high perishability. So, it is necessary to comprehend the management practices to enhance the shelf life of fruits without quality loss and thus to minimize postharvest losses. Banana fruits are generally harvested at mature green stage transported to markets and later got ripened before reaching to the consumer. Hence, delaying the ripening process, retaining the green colour and firmness of the fruits for 1-2 weeks is of utmost importance for safe transportation and to retain the quality of fruits.

There are several factors which account for postharvest losses of which, rapid ripening of fruits is a major challenge hampering a postharvest loss of about 15% (Jogdand *et al*., 2017). Research on appropriate methods to extend the shelf life of bananas to maintain fruit quality for long distance and domestic markets is vital (Kudachikar *et al*., 2011). For long distant transport and domestic storage, green life is a major factor whereas for retailers it is important that bananas arrive at a ripening stage that produces a marketable product. Therefore, the success in marketing of banana needs control over the ripening process through modifying storage conditions, use of pretreatments and application of ripening retardants (Kader, 2002).

Postharvest treatments can affect physiological activities in fruits including the biosynthesis of ethylene and thereby play an important role in delaying natural ripening process which helps to extend the green life of banana. Therefore, it is necessary to develop cost efficient postharvest treatments to minimize postharvest losses so as to ensure better farm income.

As Nendran banana is highly perishable under tropical conditions, standardisation of postharvest treatments to delay the senescence and to maintain the fruits for a longer period in normal storage condition is needed. Hence the present study entitled 'Postharvest quality management in banana cv. Nendran (*Musa* spp.)' with the objective to standardize the postharvest management for delayed ripening and extended shelf life of banana cv. Nendran with minimum nutritional loss through postharvest handling practices had been conducted in Department of Postharvest Technology, at College of Agriculture, Vellayani, Kerala Agricultural University.

Review of literature

2. REVIEW OF LITERATURE

Banana (*Musa* spp.) holds second position amongst the important fruit crops in India, next to mango (NHB, 2018). Banana originally belong to the lowlands of the humid tropics and most of the edible cultivated species are either derived from its wild race *Musa acuminata* (2n=22) or by the hybridization between *Musa acuminata* and *Musa balbisiana* (2n= 22) (Seymour and Tucker,1993). More than 50 different cultivars are grown and among them 'Nendran' (*Musa* AAB), the plantain cultivar, is the most popular variety of Kerala.

Nendran banana is a climacteric fruit and shows highest respiration and ethylene evolution rate during ripening. Being a climacteric fruit, banana shows high physiological changes during ripening (Stover and Simmonds, 1987). It continues its metabolic activities like respiration, transpiration, ripening and remains biologically active leading to high perishability. Hence it is necessary to reduce the rate of these changes through management practices in order to improve shelf life and quality of fruits. Harvested bananas have short shelf life and are highly perishable leading to postharvest losses in the range of 20-50% which could be due to quality deterioration and poor handling practices (Ajayi and Mbah, 2007; Zewter *et al.*, 2012). Research on appropriate methods to extend the shelf life of banana is vital to maintain the fruit quality for long distance and domestic markets (Kudachikar *et al*., 2011).

Nendran banana fruits are normally harvested at mature green stage, transported to markets, and ripened at the time of retail marketing. Hence extension of green life is an important aspect to improve the shelf life of Nendran banana fruits. Several research works are being conducted on different postharvest treatments in banana with a view to delay the process of ripening to increase the shelf life. A review of postharvest treatments in banana as well as other related fruits to extend the shelf life is described in this chapter.

2.1. CALCIUM CHLORIDE

Calcium plays an important role in a number of physiological activities of plants and inhibits senescence in many fruits and vegetables (Jones and Lunt, 1967).Calcium

chloride is commercially used as a firming agent for both fresh cut and whole products in fruit and vegetable industry. Shear(1975) reported thatvacuum infiltration of calcium chloride into pears and Cavendish banana at 20 ^{0}C delayed the process of ripening and increased the shelf life of the fruits by 40%.In this study, the ripening time was extended to 15 days for pear fruits infiltrated with 12% $CaC1_2$ as compared to 11 days in control fruits. Wills and Tirmazi (1982) studied the ripening behavior of intact avocado fruit infiltrated with 4% $CaC1_2$ under reduced pressure and observed that infiltration helped in delaying the ripening of avocado and the effect was higher at 20°C storage temperature. Embul banana infiltrated with 4% $CaCl_2$ recorded higher firmness retention and better quality than control fruits (Pereraand Karunaratne, 2002). The use of 4% $CaC1_2$ in avocado improved optimal uptake of calcium resulted in extended storage life 50% greater than the untreated fruits. It was also effective in enhancing firmness and retained crispness of minimally processed fruits (Chardonnet *et al*., 2003).

Anjum and Ali (2004) assessed green mature fruits of mango cv. SS-1 (Kala Chausa) which were immersed for 10 minutes in 5% calcium chloride solution and were subsequently ripened at ambient temperature (25 ± 3 ^{0}C). Calcium chloride treatment delayed the ripening of fruits for 4 days and resulted in better skin and pulp colour as against 10 minutes fresh water dipping of the fruits as control. Saif and Hashinaga (2004) revealed that banana fruits cv. Cavendish treated with hot water along with $CaCl_2$ (4 %) resulted in better retention of firmness (1.15 kg cm^{-2}), less weight loss (0.49 %) and increment in shelf life to 18 days as compared to 7 days in control. Aghofack and Yambou (2005) evaluated the bananafruits cv. William treated with calcium chloride 100mg L^{-1} for their rate of ripening, pigment quality, total lipid content and water content and reported that calcium chloride treatment inhibited the water loss from banana peel, prevented shrinkage of fruits and extended the shelf life. $CaCl_2$ 4 % treatment of Njalipoovan and Chengalikodan banana resulted inextended shelf life and superior quality of fruits (Sheela and Reni, 2005). Rajkumar and Manivannan (2007) found that treatment of CO- 2 papaya variety with $CaCl_2$ as postharvest dip at 2 % showed extended shelf life of 9 days without affecting its

physiological, biochemical and organoleptic attributes. Esguerra *et al*. (2008) reported that in banana, 4% calcium chloride delayed the onset of ripening and finger drop by 2 to 4 days hence an extension of shelf life.

Attiq *et al*. (2010) studied the effectiveness of 3 % Calcium chloride treatment as dipping for 2 minutes on storage behavior rand quality of loquat cv. Surkh, and reported that $CaCl_2$ treatment retained ascorbic acid, TSS, firmness and also reduced the browning index, and weight loss up to a storage period of 4-5 weeks.Custard apple fruits treated with $CaCl_2$ at 2 % for 5 minutes and stored at ambient conditions exhibited the lowest spoilage, highest organoleptic scores and shelf life due to delayed ripening and senescence of fruits (Nagaraja *et al.*, 2011).

Shirzadeh *et al*. (2011) assessed the effects of application of $CaC1_2$ 2% as postharvest application on the shelf life and quality of *Malus domestica* cv. 'Jonagold' apple in cold storage (2°C) upto 5 months. The results showed considerable reduction in loss of fruit weight in calcium treatments in comparison to controland increase in fruit firmness, catalase activity, and total acidity while decreased pH, sugar acid ratio and peroxidase activity. Irfan *et al*. (2013) assessed the application of fruit hardening agents after the harvest on fig cv. Poona and reported that calcium chloride (4%) showed the highest quality in terms of maintenance of fruit colour, texture and enhanced ascorbic acid accumulation as compared to untreated fig fruits and reduced the microbial spoilage.

Gol *et al*. (2013) evaluated calcium chloride (1.5%) treated strawberry fruits cv. Camarosa in combination with chitosan and evaluated the postharvest quality of fruits stored at 34 ± 1°C and 70–75% relative humidity. The calcium chloride treatment decreased the percentage of weight loss, fruit decay, total soluble solids, titratable acidity, pH, sugar accumulation, ascorbic acid content, pigment degradation and thereby prolonged the shelf life as compared to untreated fruits.

Khaliq *et al*. (2015) studied the effect of 3% calcium chloride on the physiological and biochemical changes in mango (*Mangifera indica* L. cv. Choke Anan) when stored at 6 ± 1 °C with RH 90 ± 3 % for 28 days and then transferred to 25 ± 2 °C

for 5 days. Calcium chloride treatment significantly reduced physiological loss in weight, TSS, color, respiration rate, ethylene production and maintained high titratable acidity, ascorbic acid and firmness.

Sahay e*t al.* (2015) reported that treating banana cv. Robusta with 4 % $CaCl_2$ improved the shelf life by 16 days with higher mean score for organoleptic qualities and maximum soluble sugars indicating the consumer acceptance. Papaya cv. Red Lady treated with $CaCl_2$ at 4 % exhibited the lowest physiological weight loss, disease occurrence, decay percentage with highest organoleptic scores, ascorbic acid content, fruit firmness, acidity and increased the shelf (Dasu *et al*., 2016).

Pitangas treated with $CaCl_2$ (1 or 2 %) was found to maintain quality of fruits up to nine days as against six days in control and retained pulp firmness, solids content, ascorbic acid,phenolic contents with lower weight loss (Sanches *et al.,* 2017). Postharvest treatment of jamun fruits with $CaCl_2$ at 1.5 % had significantly declined physiological weight loss, shriveling of fruits, spoilage loss, and good firmness which increased the marketability (Dalvadi *et al*., 2018). Postharvest treatment of Barhi dates with calcium chloride (2%) increased the total soluble solid content and reduced the weight loss as well as fruit decay. It was also efficient in restricting the fruit color changes and loss of firmness as against control fruits (Atia *et al*., 2018).

Eugene *et al*. (2019) evaluated the effect of $CaCl_2$ 150 mg L^{-1} on banana fruits and found an enhancement in overall quality of fruits in terms of firmness and low chlorophyll degradation. Sajid *et al.* (2019) noticed that pear fruits treated with calcium chloride (2%), subsequently stored at 20°C with relative humidity 65-70% resulted in an increasing trend in total soluble solids and non-reducing sugar, while the ascorbic acid content, titratable acidity and reducing sugar decreased with extended storability of25 days. Seleshi *et al.* (2019) assessed the effect of postharvest treatment of nectarine fruits with 4.5% $CaCl_2$ and noticed an extension in shelf life and improved fruit quality. Calcium chloride (1%) spray on guava fruits reduced physiological weight loss, rot incidence and increased the calcium content in fruits and ascorbic acid by 40 % was reported by Ribeiro *et al.* (2020).

2.2. GIBBERELLIC ACID

Gibberellins are growth promoting substances that are known to reduce the process of ripening as well as senescence of fruits. GA_3 helps in preventing chlorophyll disintegration, fruit softening, and helps in maintaining, sugar acid ratio, and sugar accumulation in fruits like mango and banana (Osman and Abu-Goukh, 2020).

The treatment of bananas (*Musa paradisica* L. cv. Dwarf Cavendish) with gibberellic acid, retarded ripening which wasindicated by higher values for starch, cellulose, hemicellulose and firmness (Desai and Deshpande, 1978). GA_3 treatment on banana cv. Tellachakkarakeli showed positive effects on shelf life and ripening (Raju, 1989). Khader (1992) found that postharvest application of gibberellic acid (200 mgL^{-1}) on mango cv. Mallika showed considerable delay in ripening when stored at a temperature of 37 ± 2°. The degradation of ascorbic acid and chlorophyll in the peel was significantly retarded, and also there appeared a reduction in rate of loss of weight and peroxidase activity during storage and storage life was extended upto 20 days when stored at 15°C.

Dipping treatment of Dwarf Cavendish banana fruits in aqueous solution of gibberellic acid (500 ppm), and ripened in cabinets maintained at 20 ± 1 °C and relative humidity 85-90 %, delayed the ripening process which was manifested in terms of delayed colour development and internal ripening changes and prolonged pre-climacteric respiration by two to three days as compared to untreated fruits (Ahmed and Tingwa,1995).

Hiwale and Singh (2003) revealed that GA_3 treated guava fruits packed in polyethylene bags had effectively retained physico-chemical properties of fruit, reduced acidity and prolonged shelf life up to 6 days. The treated fruits also exhibited reduced postharvest loss and enhanced the marketability. Gautam and Chundawat (2005) reported that sapota cv. Kalipatti treated with GA_3 (300 ppm) retarded the process of ripening by declining respiration and transpiration rate significantly, and in turn extended the shelf life. Kadu and Gajipara (2009) found that there was a gradual rise in total sugar, reducing sugar, and TSS, whereas a reduction in ascorbic acid content and

titratable acidity in sapota fruits treated with gibberellic acid (200 mg L^{-1}) and were stored up to eight days.

Gibberellic Acid at 100 ppm wasfoundto be efficientas a protective coating on banana fruits for retaining the quality attributes during the storage and extended the shelf life (17.25 days) and was reported as environmentally friendly, good handling procedure to enhance long distant marketing of banana as well as export (Gol and Rao, 2011). GA_3(150 ppm, 15^oC) treatment increased the shelf life of banana cv. Grand Naine (Rammohan, 2011). Vargas and Lopez (2011) reported that postharvest application of gibberellic acid (1000 mg kg^{-1}) as spray on green banana fruit cv. Cavendish delayed its maturation by 10.6 days compared to control fruits. Gibberellic acid spray at 200 ppm resulted in highest bunch weight (6.37 kg) and superior quality of banana fruits cv. Nanjangudu Rasabale (Kumar *et al*., 2011).

Duguma *et al.* (2014) found that Giant Cavendish banana fruits treated with GA_3 300ppm exhibited delayed ripening in comparison to control fruits and exhibited a positive effect on pulp/peel ratio and total soluble solids. It was also reported that GA_3at a higher concentration, delayed ethylene production, peel color changes, weight loss, CO_2 production and total sugar content. Zomo *et al*. (2014) reported that gibberellic acid (150 ppm) treatment in Sabri banana stored at 15°C revealed the best storage quality in terms of lower titratable acidity (0.49 %) and total sugar content (20.13 %) and the longest shelf life (14.56 days) against 8.20 days in control fruits.

Application of GA_3 at 500 ppm and 750 ppm in Kathali (*Musa* spp.) fruits delayed peel colour development, total sugar synthesis, total soluble solids accumulation and decreased the pH and total weight loss during storage as compared to fruits in control without the treatment and also extended the shelf life by 4 and 5 days as against control fruits (Archana and Sivachandiran, 2015). El-Boray *et al*. (2015) reported that postharvest treatment of gibberellic acid in bananacv. Williams recorded lower PLW (13.38) as against 25.97 % in control fruits. Mulagund *et al*. (2015) reported that postharvest dipping of bananas in 150 ppm GA_3 improved storage life of fruits with good firmness and quality.

Banana fruits cv. Berangan treated with GA_3 150 mg L^{-1} recorded reduction in weight loss (0.25 %), TSS (9.5 %) and the highest shelf life of 16 days as against only 10 days in control fruits (Sembok *et al*., 2016).

Bains *et al*. (2017) evaluated the result of GA_3 at 150 ppm as postharvest treatment on matured banana fruits and reported that a maximum titratable acidity of 0.41%, TSS (24.76 ^{0} Brix) and less reduction of ascorbic acid (39.65 %). Dates cv. Barhi treated with GA_3 (150 ppm) reduced the percentage of weight loss and fruit decay, with a controlled increment in total soluble solids (0.015 %) as against 22.5 %in control. Moreover, GA_3 treatment was efficient in restricting the changes in texture and fruit color of the treated fruits in comparison to the fruits in control (Atia *et al.*, 2018). Thokchom and Mandal (2018) evaluated the effect of gibberellic acid (100 ppm) on the post harvest life of Aonla cv. Chakaiya and observed that there was a significant increase in TSS (12. 46 ^{0} Brix), ascorbic acid retention (413.13 mg 100 g^{-1}), and total sugar (8.62 %) with the advancement of storage life.

Effect of of gibberellic acid (100 ppm) as postharvest treatment on lime fruits stored at 18 ± 1 ^{0}C and 85% – 90% relative humidity was studied by Abdallah and Abu- Goukh (2019) and reported that there was a decrease in rate of respiration, fruit softening and total soluble solids accumulation and also delayed peel colour development and increased ascorbic acid retention with significant reduction in weight loss (25 %) as against 36 % in control fruits. Abu- Goukh and Mohamed- Nour (2019) reported that application of GA_3 as postharvest treatment in guava delayed the onset of ripening by 3-5 days and maintained quality and exhibited reduced respiration rate, PLW, fruit softening, TSS, titratable acidity and delayed peel colour development and maximum vitamin C retention. Al-Qurashi and Awad (2019) reported that application of GA3 at 150 mg L^{-1} in banana cv. Grand Naine retained more peel green colour, firmness but lowered TSS, sugar: acid ratio and browning as compared to control. Application of gibberellic acid (100 ppm) in banana fruits cv. Dwarf Cavendish revealed thatGA_3application could retain the quality attributes of banana, TSS accumulation, peel colour development, fruit softening, weight loss and improved the

shelf life by delaying the climacteric peak of respiration during storage (Osman and Abu- Goukh, 2020).

2.3. OXALIC ACID

Oxalic acid (OA) is a natural antioxidant in plants and act as anti-senescence and anti-browning agent (Zheng andTian, 2006) withresistance against various diseases (Tian *et al*., 2007)and delays fruit ripening (Zheng *et al*., 2012).

Oxalic acid (5%)treatmentwas foundto be a potent anti-browning agent in longan fruit cv. Dawand and it also reduced the postharvest decay and pericarp browning as compared with other acids (Whangchai *et al*., 2005). Storage of Litchi fruit cv. Huaizhi, at room temperature after with 4 mM oxalic acid treatment prevented pericarp browning, increased membrane integrity, inhibited anthocyanin degradation, reduced oxidation, and maintained relatively low peroxidase activity during storage was reported by Zheng and Tian (2006).Mango fruits (*Mangifera indica* L. cv. Zill) dipped in 5 mM oxalic acid solution for 10 min at 25°C, reduced ripening and decay incidence during storage at room temperature (Zheng *et al*., 2007).Wang *et al*. (2009) revealed that oxalic acid application on jujube fruits at a concentration of 5 mM delayed the process of senescence by reducing ethylene production, alcohol content and suppressing fruit reddening. Wu*et al*. (2011) concluded that the application of oxalic acid 5 mM for 3 min reduced ethylene production and delayed softening of plum fruit cv. Damili packed in polyethylene bags and recorded a shelf life of 12 days when kept at 25 °C.

Huang *et al*. (2013) revealed that banana fruits cv. Brazil subjected to oxalic acid (20 mM) as a dipping solution and subsequently stored at room temperature delayed change in fruit colour, browning of peel and maximum chlorophyll fluorescence and fruit firmness (8.26 ± 1.36 N) by maintaining a smooth surface. Razzaq *et al*. (2015) reported that mango fruits cv. Samar Bahisht Chaunsa dipped in oxalic acid (5 mM) and stored at room temperature and cold storage reduced the rate of ethylene production, tissue softening, respiration rate and exo-polygalacturonase enzyme activity with better fruit firmness and activity of pectin esterase.

The exogenous application of oxalic acid at 20 mM as a coating on 'Williams' banana for 10 minutes and stored at room temperature ensured a smooth surface by reducing the browning of peel in long term storage. It also induced a reduction in cell membrane degrading enzymes such as cellulose, lipoxygenase and pectinase and browning enzymes like and phenylalanine ammonia-lyase and polyphenol oxidase (Lo'ay and Dawood, 2017). Ravi and Pareek (2018) reported that postharvest treatment of ber fruit cv. Bela with oxalic acid 10 mM was found to be beneficial in extending the shelf life upto 9 days at room temperature, and reduced physiological and enzymatic activity of fruits, thereby retaining its quality. A spray of 5 mM oxalic acid on kiwi fruit cv. Bruno delayed the increase in soluble solids and decreased titratable acidity of fruits with an increased content of ascorbic acid (45.86 mg 100 g^{-1}) was also observed during storage (Ali *et al*., 2019). Pomegranate fruits cv. Hicaznar treated with oxalic acid at a concentration of 6 mM exhibited higher titratable acidity, antioxidant property, and total phenols in comparison with control fruits (Koyuncu *et al*., 2019).

2.4. SALICYLIC ACID

Salicylic Acid (SA) is a non-toxic, effective inhibitor of ethylene biosynthesis and delays fruit ripening by inhibiting the conversion of 1-aminocyclopropane-1-carboxylic acid to ethylene and maintains postharvest quality of fruits (Leslie and Romani, 1986; Srivastava and Dwivedi, 2000). Salicylic Acid is an endogenous signal molecule, playing pivotal roles in regulating stress. The postharvest losses can be effectively controlled through application of Salicylic Acid (Babalar *et al*., 2007 and Cao *et al*., 2013). Salicylic acid treatment could delay the rise in reducing sugars, maintain texture and improve the level of biologically active compounds which provide health benefits to human beings and is recognized as Generally Recommended As Safe (GRAS) for postharvest application of fruits and vegetables (Supapvanich and Promyou, 2013).

Application of salicylic acid as post harvest spray had been found to delay the ripening process in banana, which is expressed in terms of delayed softening of fruits, reduced pulp to peel ratio, reducing sugar, respiration rate and invertase activity as

compared to control fruits. The major cell wall degrading enzymes *viz*., polygalacturonase, xylanase, and cellulose and major antioxidants (catalase, peroxidase) were also found to be reduced in presence of salicylic acid during ripening (Srivastava and Dwivedi, 2000). Joyce *et al*. (2001) found that 'Kensington Pride' mango fruits when treated with salicylic acid at concentration of 2000 mgL^{-1}as dip and vacuum infiltration, the skin colour and firmness changes were significantly slowed down, attributing to prevention of mango fruit ripening and senescence. During the ripening and softening of kiwifruit cv. Bruno at 20.8°C, a positive correlation was found to exist between change in Salicylic Acid levels in the fruit tissues and the extent of fruit ripening and softening (Zhang *et al*., 2003).

Huang *et al*. (2008) studied the postharvest attributes of antioxidant compounds in 'Cara Cara' navel orange (*Citrus sinensis* L. Osbeck) fruit in relation to the application of SA and reported that the treatment increased carotenoid content, ascorbic acid, total phenolics and flavonoid content in the pulp and peel during storage. Aghdam *et al.* (2009) harvested kiwifruit (*Actinidia deliciosa* 'Hayward') at commercial maturity and exposed it to 32 µl SA vapor at 20 °C for 16 h. The study reported that the treatment resulted in considerable reduction of ethylene production, softening of fruit flesh and ascorbic acid content of fruit during the storage while maintaining the firmness andthe overall quality of fruits was improved during the storage.

Gholami *et al*. (2009) assessed the anthocyanin, total acidity and stem and flesh freshness of Mashhad sweet cherry (*Prunus avium*) treated with 3 mM Salicylic Acid and found that the treatment was effective in decreasing ethylene production and prolonging stem green colour while retaining the fruit quality. Pomegranate fruits treated with Salicylic Acid at 2 mM and stored at 2°C effectively reduced chilling injury and electrolyte leakage in the husk of pomegranate as well as loss of ascorbic acid as compared to control fruits (Sayyari *et al*., 2009).

The application of SA as pre and postharvest dip at 5 mM for 15 minutes was effective in shelf life extension of pineapple up to 20 days and prevented internal browning (Lu *et al*., 2010).The fruit quality of strawberry cv. Camarosa increased

considerably when given a postharvest treatment of salicylic acid (2 mM) in 25 °C or 45 °C water which reduced the physiological loss in weight(0.77 %), decay and redness and with higher firmness and hue angle than control fruits (Shafiee *et al.*, 2010).Luo *et al*. (2011) conducted studies on effect salicylic acid at 2mM concentration on plum fruits and observed an inhibition in ethylene production and delay in ripening. Sweet cherry fruits treated with salicylic acid at 1 mM delayed fruit ripening and reduced weight loss and acidity with maximum retention of antioxidant activity and ascorbic acid with a shelf life of 20 days (Valero *et al*., 2011). Tareen *et al.* (2012) evaluated the effect of SA (2 Mm) on peach fruit cv. Florida King and noticed reduction in PLW, increased fruit firmness, TSS, vitamin C content and an extended shelf life of five weeks. Harvested clusters of Gizel Uzum grapes when subjected to salicylic acid treatment at 2 mM L^{-1} concentration helped to retain its soluble solid content, total phenolic content, antioxidant and catalase activity with an increased storability and quality (Asghari *et al.*, 2013).

Salicylic acid applied Cornelian cherry fruits stored at 4°C for 21 days had resulted in an increment in ascorbic acid content and postharvest antioxidant potential which may bedue to activation of PAL enzyme and hence triggering the phenylpropanoid-flavonoids pathway (Dokhanieh *et al.,* 2013). Kumar *et al*. (2013) observed a rise in ascorbic acid content and delay in pericarp browning and ripening in litchi fruit cv. Rose Scented when treated with salicylic acid (0.5 %) as postharvest treatment. Salicylic acid treatment on mangosteen fruits have shown to delay the process of ripening (Mathew, 2013). Brar *et al.* (2014) observed that pre and postharvest application of SA treatments decreased the weight loss of peach fruits as against the fruits in control.

A postharvest dip of ‘Kaek Dam’ papaya fruit in salicylic acid at 2 mM significantlydelayed the fruit ripening and retained fruit firmness during refrigerated storage by hindering the levels of EL and, EDTA and Na_2CO_3 soluble pectin components and the treatment also enhanced scavenging activity of fruits (Promyou and Supapvanich, 2014). Jaishankar and Kukanoor, (2016) concluded that salicylic acid

treatment (0.01%) on sapota cv. Kalipatti for 5 minutes recorded reduced physiological weight loss, TSS (23.45 ^{0}Brix), respiration rate, reduced decay percentage and increased shelf life for 9.67 days. Mandal *et al*. (2016) noticed that postharvest handling of banana cv. Grand Naine with SA at 4 mM resulted in good physico- chemical attributes such as reduced level of titratable acidity (0.22%), sugar: acid ratio, total sugar (13.42%) and high ascorbic acid level (11.53 mg 100g-1) which shows the efficiency of salicylic acid in delaying ripening. It also resulted in an increased shelf life of 14.85 days. Postharvest application of SA (0.05 Mm) in cherry cv. Sweet Heart exhibited maximum fruit firmness, TSS, colour index, and antioxidant activity with maximum retention of nutrients (Gimenez *et al*., 2017).

SA application (4 mM) in grapes cv. Superior Seedless experienced better berry firmness, decreased PLW, carotenoids content and an extended shelf life of 4 days (Lo'ay, 2017). Increased fruit firmness, carotenoids, ascorbic acid and total antioxidant activity with reduced rate of PLW was observed in 'Holland' papaya treated with SA 2 mM during storage (30±2ºC) (Supapvanich and Promyou, 2017).SA treatment at 1 mM in nectarines recorded reduced weight loss, and softening, increased shelf life with higher overall fruit quality (Bal, 2018).

Mandal *et al*. (2018) evaluated the effect of SA, at 0.5-3.0 mM as exogenous postharvest treatment on banana cv. Grand Naine and reported that the fruits subjected to treatment SA 2 mM caused reduced weight loss (21.08%) with sugar: acid ratio (41.57) and high retention of ascorbic acid (19.60 mg 100g-1) with extended shelf life (20.25 days) compared to 15.35 days in control. An improved shelf life of 15.75 days and good biochemical attributes like minimum TSS content (24.40 ^{0} Brix), acidity (0.47 %) and higher retention of ascorbic acid content (9.84 mg 100 g^{-1}) was reported for banana cv. Nendran treated with Salicylic Acid at 2 mM and stored at ambient temperature (Nair, 2018).

Application of Salicylic Acid 200 mM improved the anthocyanin content, antioxidant activity and phenol content in grape berries (Oraei *et al*., 2019). Banana fruits cv. Cavendish treated with salicylic acid (1 mM) exhibited better retention of

firmness, antioxidant activity, phenol content, more weight loss control, and inhibition of polyphenol oxidase enzyme activity in comparison to the control fruits (Khademi *et al*., 2019). Ennab *et al*. (2020) reported that SA treatment of Murcott mandarin at a concentration of 400 ppm led to retention of firmness, TSS, ascorbic acid, acidity andsugar acid ratio during storage with minimum weight loss and decay.

Materials and Methods

3. MATERIALS AND METHODS

The experiment entitled "Postharvest quality management in banana cv. Nendran (*Musa* spp.)" was conducted with the objective to standardize the postharvest management for delayed ripening and extended shelf life of banana cv. Nendran with minimum nutritional loss through postharvest handling practices. The materials and methodologies used for the investigation have been described in this chapter.

3.1 DETAILS OF EXPERIMENT

3.1.1. **Experimental site**

The experiment was undertaken at PG research lab of Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, during the year 2018 - 2020.

3.1.2. Selection of banana fruits

Nendran banana bunches of uniform maturity, size, weight, shape, colour, quality, without any pests, diseases, and other damages were procured from the progressive farmers of Farmer Producer Organisation, Sanghamaithri, at Kalliyoor, Thiruvananthapuram.

3.1.3. Postharvest treatments

The dehanded Nendran banana of uniform maturity were washed, and sanitized by ozonation (2 ppm) for 10 minutes. The sanitized Nendran banana hands were subjected to the following postharvest treatments by dipping for 10 minutes along with control as Nendran fruits without any postharvest treatments.

T_1: Calcium chloride (4%)

T_2: Gibberellic Acid (150 ppm)

T_3: Oxalic Acid (20 mM)

T_4: Salicylic acid (2 mM)

3.1.3.1 Preparation of Calcium chloride solution

Calcium chloride solution of 4 per cent was made by adding 4 g calcium chloride to 100 ml of distilled water and Tween 80 as wetting agent.

3.1.3.2 Preparation of Gibberellic Acid solution

Gibberellic Acid solution of 100 ppm was prepared by dissolving 100 mg of GA_3 in 10 mL of ethanol, and was then added to 1000ml of distilled water.

3.1.3.3 Preparation of Oxalic Acid solution

Oxalic acid solution of 20 mM was prepared by dissolving 1.8g of oxalic acid in 1000ml of distilled water and Tween 80 as wetting agent was also added.

3.1.3.4 Preparation of Salicylic Acid solution

Salicylic acid solution of 2 mM was made by adding the required quantity of salicylic acid in 1L of distilled water along with 0.1 percent Tween 80 as wetting agent.

3.1.4. Storage

After the postharvest treatments, Nendran banana fruits were air dried and stored in Corrugated Fibre Board boxes under room temperature (30± 2 ^{0} C and 80-85% RH) and were analysed for physiological, biochemical, physical and sensory characters during storage.

3.2 TREATMENT DETAILS

T_1: Calcium chloride (4%) (Dipping for 10 minutes)

T_2: Gibberellic Acid (150 ppm) (Dipping for 10 minutes)

T_3: Oxalic Acid (20 mM) (Dipping for 10 minutes)

T_4: Salicylic acid (2 mM) (Dipping for 10 minutes)

T_5: Control (without any treatment)

Experimental design: Completely randomized Design (CRD)

Number of treatments: 5

Number of replication: 4 (10 fruits in each replication)

Ozonation (2 ppm)

Postharvest treatment

Stored in CFB

At the end of shelf life

Plate 1. Postharvest treatment of Nendran banana

3.3. OBSERVATIONS RECORDED

Physiological, biochemical, physical, and sensory parameters of postharvest treated Nendran banana fruits during storage at room temperature were analysed at an interval of three days till the end of storage life.

3.3.1. Physiological parameters

Different physiological parameters like physiological loss in weight and respiration rate of the treated Nendran banana fruits were recorded.

3.3.1.1. Physiological Loss in Weight (PLW)

Physiological loss in weight was determined by recording the initial fruit weight and fruit weight during storage at intervals. The cumulative physiological loss in weight was calculated by subtracting the fruit weight on particular storage day from the initial fruit weight. The weight was taken at an interval of three days till the end of shelf life and physiological weight loss was calculated and expressed in percentage.

$$PLW\ (\%) = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

3.3.1.2. Respiration rate (mL CO_2 $kg^{-1}h^{-1}$)

The respiration rate of Nendran banana fruits was determined based on the CO_2concentrations as per the procedure described by Kader and Saltveit (2003) using Checkpoint Portable Gas Analyzer. The respiration rate was expressed in mL CO_2 $kg^{-1}h^{-1}$.

3.3.2. Biochemical parameters

Biochemical properties like moisture content, starch, total sugar, reducing sugar, total soluble solids (TSS), acidity, carotenoids, ascorbic acid and antioxidant activity of Nendran banana after postharvest treatments were analysed at 3 days interval.

3.3.2.1. Moisture content (%)

Moisture analyser (Essae, AND MAX 50) was used to estimate the moisture content of banana pulp. It consists of a halogen lamp which dries the sample and

expresses the moisture content in percentage on the basis of principle of gravimetric analysis.

3.3.2.2. Starch (%)

Starch content of Nendran banana fruits was analysed as per the procedure described by Ranganna (1986) and expressed as percentage. To 5 g of sample, a little quantity of distilled water was added and was heated to 60^0C to obtain a solution of starch. To this, 100 mL of 95% alcohol was added and centrifuged till precipitate settled at the bottom. Then it was filtered and the residue was mixed with alcohol (50 %) until the filtrate gave no test for sugars.

The residue was then transferred into a conical flask and added about 100 mL distilled water and 20 mL conc. HCl and digested for 2h in a water bath at 100°C. Then it was cooled and 40% NaOH was added until the solution was neutral and the neutralization completed by adding sodium carbonate. It was then filtered to a 250 ml standard flask and made the solution to the mark. The solution was then taken in a burette and mixture of 5 mL Fehling solution A & 5 mL Fehling solution B was taken in a conical flask. Then 50 mL of distilled water was added and mixed well, to which 0.5 mL methylene blue indicator was added and heated for one minute and titrated. The endpoint was determined by the disappearance of the blue colour and appearance of a brick red colour. The starch content of the fruits was expressed in percentage:

$$\text{Starch (\%)} = \frac{\text{Total volume made up} \times 0.05 \times 0.09 \times 100}{V \times W}$$

V = Titre value

W = Weight of sample

3.3.2.3. Total sugar (%)

The total sugar content of Nendran banana fruits was analysed and expressed in percentage according to Ranganna (1986). Twenty five gram of banana fruit pulp was grinded using a mortar and pestle and 100 ml distilled water was poured to it and made up to 100 mL with distilled water. Neutralization was done with 1 N NaOH and neutral

lead acetate (2 mL) was added and kept for 10 minutes after shaking. Excess lead acetate was removed by addition of 2 mL potassium oxalate and the solution was then filtered and made up to required volume to produce a clarified solution. Twenty five mL clarified sample solution was pipetted into 250mL conical flask to which distilled water 50 mL and citric acid (5 g) were added. The solution was boiled for 10 minutes to complete the inversion, cooled, and neutralized with 1N NaOH using phenolphthalein indicator and was made up to required volume. Fehling's solutions A and B, 5 mL each were pipetted and 50 mL water was added and boiled vigorously. The burette was filled with clarified fruit sample and added to the boiling Fehling solution drop by drop until the blue colour faded. When the blue colour of the solution changed, 3 drops of methylene blue indicator was added and the titration was continued till the indicator was completely discoloured and a brick red colour developed.

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total vol. made up (mL) x Vol. made up after inversion (mL) x 100}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (mL)}}$$

3.3.2.4. Reducing sugar (%)

Estimation of reducing sugar was done by using Lane and Eynon method as suggested by Ranganna (1986). Twenty five gram of banana fruit pulp was ground using a mortar and pestle and 100 mL distilled water was added to it and made up to 100 mL with distilled water. Neutralization was done with 1 N NaOH and 2 mL neutral lead acetate was added and kept for 10 minutes after shaking. 2 mL potassium oxalate was added to remove excess lead acetate and the solution was then filtered and made up to required volume to produce a clarified solution.

Fehling's A and B solution 5 mL each were pipetted out and 50 mL of distilled water was transferred into a 250 mL conical flask. The burette was filled with the clarified sample and was then added drop by drop to the Fehling's solution. When the blue colour of the Fehling's solution changed, three drops of methylene blue indicator

was added and the titration was continued till a brick red colour formed. The reducing sugar percentage was estimated according to the given formula

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Eq. (0.005) x Total volume made up (mL) x 100}}{\text{Titre value (mL) x Weight of pulp (g)}}$$

3.3.2.5. Total Soluble Solids (^{o} Brix)

Total soluble solids (TSS) of banana fruit pulp was assessed by using digital refractometer (Atago- 0 to 53%) and expressed in degree brix (^{o}Brix).

3.3.2.6. Acidity (%)

The titratable acidity of banana fruit pulp was recorded by the method described by Ranganna (1986) and expressed percentage of citric acid equivalent using following formula:

$$\text{Acidity (\%)} = \frac{\text{Titre value x Normality of NaOH (0.1N) x volume made up (100 mL) x Equivalent weight of acid (0.064) x100}}{\text{Volume of aliquot (25 mL) x weight / volume of the sample (5 g)}}$$

3.3.2.7. Carotenoids (mg 100g^{-1})

The method suggested by Saini *et al*. (2001) was used to measure the carotenoids of Nendran banana fruits and expressed in mg 100g$^{-1.}$

Five gram of banana fruit was taken and ground using motor and pestle with 10 mL of 80% acetone to get a thin paste. The pulp was filtered and the extract was centrifuged (5000 rpm for 5 minutes) and the supernatant was transferred to 100 mL volumetric flask. The residue was again extracted with 80% acetone and made up to 100 mL. The absorbance was read at 480nm and 510 nm against solvent (80%) blank. Total carotenoid content was calculated as follows:

$$\text{Carotenoids (mg 100 g}^{-1}\text{)} = \frac{7.6 \times OD_{480} - 1.49 \times OD_{510} \times V}{W \times 1000}$$

3.3.2.8. Ascorbic acid (mg 100g^{-1})

DCPIP (2, 6-dichlorophenol indophenol) dye method suggested by Ranganna (1986) was used to estimate the ascorbic acid content of Nendran banana fruit and expressed as mg 100g$^{-1.}$

Five gram of Nendran banana fruit was made into pulp with 4% oxalic acid and made up to a known volume (100mL) and centrifuged. The supernatant was collected and 5mL of the aliquot was pipetted into a conical flask to which 10 mL of 4% oxalic acid was added. This was titrated against 2,6-dichlorophenol indophenol dye solution, until the end point of pink colour (V_2) was attained, which persisted for a few minutes. The ascorbic acid content was estimated as follows:

$$\text{Ascorbic acid (mg 100g}^{-1}\text{)} = \frac{\text{Titre value } (V_2 \text{ mL}) \times \text{dye factor} \times \text{volume made up (mL)} \times 100}{\text{Aliquot of extract taken (mL)} \times \text{wt. of sample (g)}}$$

Dye factor = 0.5 / V_1 mL

3.3.2.9. *Antioxidant activity (DPPH assay) %*

DPPH radical scavenging assay was used to measure the antioxidant activity using 2, 2 – diphenyl -1- picryhydrazyl and the scavenging effect on free radical was estimated according to the procedure put forth by Sharma and Bhat (2009).

The fruit sample extract (1mL) was added to 2 mL 0.1 mM DPPH solution, mixed thoroughly and left for 30 minutes at room temperature. The absorbance was read at 517 nm. The scavenging effect was shown as per cent inhibition of DPPH as conveyed in the below equation.

$$\% \text{ inhibition of DPPH} = \frac{\{A_{blank} - A_{sample}\} \times 100}{A_{blank}}$$

Where,

A_{blank} – Absorbance of DPPH solution without sample, read against ethanol blank

A_{Sample} – Absorbance of test sample after 30 Minutes

3.3.3. Physical parameters

The Nendran banana fruits after postharvest treatment were analysed for its physical attributes *viz*., peel percentage, pulp percentage, pulp to peel ratio, colour and fruit firmness (texture) at an interval of 3 days during storage.

3.3.3.1 Pulp %

The pulp percentage was calculated by measuring the whole fruit weight and pulp weight and expressed as percentage.

$$\text{Pulp \%} = \frac{\text{Pulp Weight}}{\text{Whole fruit weight}} \times 100$$

3.3.3.2. Peel %

The peel percentage was estimated by recording the whole fruit weight at an interval of three days, using the following formula and expressed in percentage.

$$\text{Peel \%} = \frac{\text{Peel Weight}}{\text{Whole fruit weight}} \times 100$$

3.3.3.3. Pulp to peel ratio

Pulp to peel ratio of treated Nendran banana was calculated using the following formula after measuring the pulp and peel weight during the storage.

$$\text{Pulp to peel ratio} = \frac{\text{Pulp Weight}}{\text{Peel weight}}$$

3.3.3.4. Colour

The standard banana ripening chart by the USDA (2001) was used to analyze the external fruit colour of treated Nendran banana fruits during storage. Each sample was given a numerical value from stage 1 (I) to stage 7 (VII) based on the peel colour using following scores.

Dark Green – 1

Light Green- 2

More Green than Yellow- 3

More Yellow than Green- 4

Yellow with Green tips- 5

Full Yellow- 6

Yellow with Brown Spots- 7

3.3.3.5. *Texture (fruit firmness) (N)*

Measurement of firmness of the treated Nendran banana fruit was done using texture analyser TA.HD plus (stable Microsystems, England) using compression mode. The machine was calibrated as following.

Test mode- Measure force in compression

Pre-test speed- 1.5 mm s^{-1}

Test speed- 2 mm s^{-1}

Posttest speed- 10 mm s^{-1}

Distance- 25 mm

Trigger force- 0.049 N

Data acquisition rate- 200 pps

After calibration, the Nendran banana fruit was placed on the platform and the test was conducted at three equidistant points on the fruit. A 2 mm cylindrical stainless steel (p/2 dia-cylinder stainless steel) probe was used to carry out the compression test and to plot a corresponding force deformation curve. The maximum force obtained during probe travel was used as a measure of texture as fruit firmness and expressed in Newton (N).

3.3.4. Sensory analysis

Nendran banana fruits were subjected to sensory analysis after ripening and assessed for sensory attributes such as appearance, colour, flavor, taste, texture and overall acceptability by a 30member semi-trained panel. The panel was formed with the staff members and research scholars of College of Agriculture, Vellayani. They were asked to score the Nendran banana fruits for the sensory qualities on a numerical scoring method using nine-point hedonic scale in the order of preference as shown below.

Like extremely	- 9
Like very much	- 8
Like moderately	- 7
Like slightly	- 6
Neither like nor dislike	- 5
Dislike slightly	- 4
Dislike moderately	- 3

Dislike very much - 2

Dislike extremely - 1

The samples were scored and statistically analysed using the Kruskall-Wallis test (chi-sqaure value).

3.3.5. Shelf life (days)

The shelf life of Nendran banana fruits was expressed in days and the end of shelf life was determined when10% of the fruit surface showed discoloration.

3.4. STATISTICAL ANALYSIS

The data recorded from the experiments were statistically analysed using Completely Randomized Design (CRD). Sensory parameters were statistically analysed using Kruskall-Wallis Chi-sqaure test.

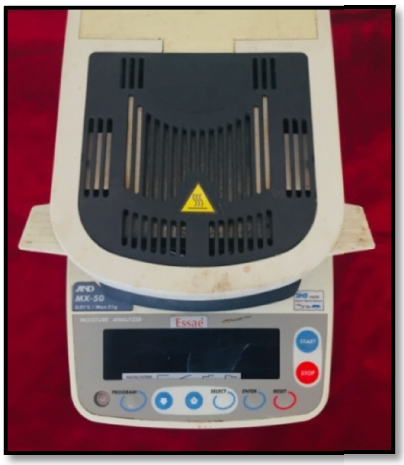

Plate 2. Moisture Analyzer

Plate 3. Gas Analyzer

Plate 4. Texture Analyzer

Results

4. RESULTS

The data obtained from the present study on "Postharvest quality management in banana cv. Nendran (*Musa* spp.)" were analyzed statistically and the results are described in this chapter.

Nendran banana fruits were subjected to sanitization treatment with ozone at 2ppm and were then subjected to different postharvest treatment *viz*., Calcium chloride ($CaCl_2$) (4%), Gibberellic Acid (GA_3) (150 ppm), Oxalic Acid (OA) (20 mM), Salicylic acid (SA) (2 mM) as against fruits without any treatment as control. The treated fruits after the removal of excess moisture were stored under ambient condition (30 ± 2 ^{0}C, RH 80- 85%) and the effectiveness of the treatments was analysed based on physiological, biochemical, physical and sensory parameters at 3 days interval till the end of shelf life.

4.1. PHYSIOLOGICAL PARAMETERS

4.1.1. Physiological Loss in Weight (PLW) (%)

Effect of postharvest treatments on Physiological Loss in Weight (PLW) of Nendran banana during storage is described in Table 1. The PLW of Nendran banana fruits increased from 3.16% to 11.21 % after 12 days of storage at room temperature. The untreated fruits (T_5- control) recorded the highest PLW of 9.48 % whereas T_4 (SA 2 mM) recorded the least Physiological Loss in Weight (5.61 %) at the end of 12 days of storage.

When the interaction effects between the postharvest treatments and days of storage were considered, the lowest PLW (2.63 %) was recorded by T_4 (SA 2 mM) and the highest PLW (3.93%) was recorded for the fruits without any treatment T_5 (control) after 3 days of storage. The lowest PLW was recorded by the SA 2 mM (T_4) treatment throughout the storage period and recorded weight loss of 3.59%, 6.66%, and 9.57% after 6th, 9thand 12th day of storage respectively. After 12th day, Nendran fruits without any postharvest treatment T_5 (control) recorded the highest PLW of 15.21 % followed

byT_1 ($CaCl_2$ 4%) with 11.81 % and the lowest PLW (9.57 %) was observed in (SA 2 mM) which was on par with T_2 (GA_3 150 ppm) with a PLW of 9.58%. The fruits without any postharvest treatments (control) were discarded due to spoilage after 12 days of storage.

The lowest Physiological Loss in Weight (13.43%) was recorded for T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) (14.3 %) and the highest PLW of (16.14 %) was recorded for the fruits treated (T_1) with $CaCl_2$ 4 % after 15 days of storage.

4.1.2. Respiration rate (mL CO_2 kg^{-1} h^{-1})

The effect of postharvest treatments on respiration rate during storage of Nendran banana is depicted in Table 2. The respiration rate of Nendran banana increased during storage and from 29.32 mL CO_2 kg^{-1} h^{-1}at the time of storage to 109.59 mL CO_2 kg^{-1} h^{-1}after 12 days of storage. The salicylic acid treatment T_4 (SA 2 mM) recorded the lowest mean respiration rate of 61.44 mL CO_2 kg^{-1} h^{-1} followed by T_2 (GA_3 150 ppm) with 71.51 mL CO_2 kg^{-1} h^{-1} and T_5 (control) recorded the highest mean respiration rate of 89.69 mL CO_2 kg^{-1} h^{-1} after 12 days of storage.

When the interaction effects were studied, the pretreated banana fruits inT_4 (SA 2 mM) showed the lowest respiration rate of 41.88 mL CO_2 kg^{-1} h^{-1} and the highest respiration rate was noticed in T_5 (control) with 66.51 mL CO_2 kg^{-1} h^{-1}, after 3rd day of storage. After 6th day of storage, the highest rate of respiration was noticed in fruits without any treatment T_5 (control) (99.18 mL CO_2 kg^{-1} h^{-1}) and the lowest in T_4 (SA 2 mM) with 63.40 mL CO_2 kg^{-1} h^{-1}.

The Salicylic Acid treatment at 2mM (T_4) recorded the lowest rate of respiration of 82.12 mL CO_2 kg^{-1} h^{-1} followed by T_2 (GA_3 150 ppm) with 96.76 mL CO_2 kg^{-1} $h^{-1}$and the highest rate of respiration was recorded in untreated Nendran fruits (T_5-control) with 118.34 mL CO_2 kg^{-1} h^{-1} after 9 days of storage. Respiration rate recorded was the lowest (91.27 mL CO_2 kg^{-1} h^{-1}) in T_4 (SA 2 mM) followed by GA_3 150 ppm (T_2) with 105.95 mL CO_2 kg^{-1} h^{-1} which significantly differed from other treatments and the highest respiration rate of 129.58 mL CO_2 kg^{-1} h^{-1} was recorded by T_5 (control), after 12th day of storage.

Table 1. Effect of postharvest treatments on Physiological Loss in Weight (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)				Treatment mean(T)	15
	3	6	9	12		
T_1 ($CaCl_2$ 4%)	3.33 (2.08)**	5.28 (2.50)	7.67 (2.94)	11.81 (3.57)	7.02 (2.78)	16.14 (4.14)
T_2 (GA_3 150 ppm)	2.80 (1.96)	3.68 (2.16)	7.25 (2.87)	9.58 (3.28)	5.83 (2.57)	14.30 (3.91)
T_3 (OA 20 mM)	3.11 (2.03)	5.10 (2.48)	7.42 (2.90)	9.89 (3.29)	6.38 (2.68)	15.14 (4.01)
T_4 (SA 2 mM)	2.63 (1.90)	3.59 (2.14)	6.66 (2.76)	9.57 (3.25)	5.61 (2.51)	13.43 (3.80)
T_5 (Control)	3.93 (2.22)	8.24 (3.04)	10.52 (3.39)	15.21*(4.02)	9.48 (3.17)	-
Days (D) mean	3.16 (2.03)	5.18 (2.46)	7.90 (3.97)	11.21 (3.48)		

	SE ± (m)	CD (0.05)
Treatment (T)	0.003	0.010
Days (D)	0.003	0.009
Treatment (T) X Days (D)	0.007	0.019

SE ± (m) 0.016
CD (0.05) 0.058

*Banana fruits were discarded due to spoilage

** Values in parenthesis indicate square root transformation

Table 2. Effect of postharvest treatments on respiration rate (mL CO_2 kg^{-1} h^{-1}) of banana cv. Nendran during storage `

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	27.42	54.55	114.19	99.31	111.70	74.65	114.19
T_2 (GA_3 150 ppm)	28.41	50.37	112.38	96.76	105.95	71.51	112.38
T_3 (OA 20 mM)	27.41	54.30	112.763	98.55	109.45	73.04	112.763
T_4 (SA 2 mM)	28.50	41.88	102.70	82.12	91.27	61.44	102.70
T_5 (Control)	34.84	66.51	99.18	118.34	129.58*	89.69	-
Days (D) mean	29.32	53.52	79.42	99.02	109.59		

	SE ± (m)	CD (0.05)	
Treatment (T)	0.107	0.304	SE ± (m) 0.094
Days (D)	0.107	0.304	CD (0.05) 0.292
Treatment (T) X Days (D)	0.239	0.68	

*Banana fruits were discarded due to spoilage

The salicylic acid 2 mM (T_4) treatment recorded the lowest respiration rate of 102.70 mL CO_2 kg^{-1} h^{-1} followed byT_2 (GA_3 150 ppm) with 112.38 mL CO_2 kg^{-1} h^{-1} andthe highest respiration rate was observed in T_1 ($CaCl_2$ 4%) with a respiration rate of 114.19 mL CO_2 kg^{-1} h^{-1}after a storage period of 15 days.

4.2. BIOCHEMICAL PARAMETERS

4.2.1. Moisture content (%)

The moisture content (%) of Nendran banana fruits during storage after the postharvest treatments is described in Table 3.The moisture content of Nendran banana fruits increased during storage from 54.72 % to 61.52 % after 12 days of storage. The maximum moisture content of 63.40 % was noticed in the untreated fruits, T_5 (control) and minimum value of 59.77 % recorded for T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with a moisture content of 60.99 % after 12 days of storage.

The moisture content of Nendran banana fruits at the time of storage, after different postharvest treatments were on par and it ranged from 58.04% to 59.26 % at the time of storage.

On studying the interaction effects, the fruits without postharvest treatments, T_5 (control), recorded the highest moisture content (57.38 %) and a moisture content of 56.80 % by T_4 (SA 2 mM), after 3 days of storage. After 6^{th} day of storage, minimum moisture content of 57.30 % was recorded by T_4 (SA 2 mM) and T_5 (control) recorded maximum moisture content of 59.13 %. The highest moisture content was recorded by the untreated control fruits (T_5)with 61.71 %, and 63.40 % after 9^{th} and 12^{th} days of storage respectively. The fruits treated with SA at 2 mM recorded the lowest moisture content of 58.26 % at the end of 9 days and 59.77 % after 12 days of storage.The SA application 2 mM (T_4) was followed by T_2 (GA_3 150 ppm) with 60.99 % moisture content which did not differ significantly with T_3 (OA 20 mM).

After 15 days of storage, Nendran banana fruits treated with T_4 (SA 2 mM) recorded the lowest moisture content (61.27 %) followed by T_2 (GA_3 150 ppm) with 61.81 % and the highest moisture content (62.46%) was recorded for 4% $CaCl_2$ (T_1) treated fruits.

4.2.2. Starch (%)

The effect of postharvest treatments on starch content (%) of Nendran banana during storage is depicted in Table 4. The starch content of banana fruits was 21.5 % and decreased to 9.49 % after 12 days of storage. The starch content significantly reduced among the treatments during storage and recorded a lowest of 13.61 % in fruits without any treatment (control) and the highest starch content of 15.22 % in treatmentT_4 (SA 2 mM) at the end of 12 days of storage.

The starch percentage of Nendran banana at the time of storage showed significant difference and it ranged from 21.54% to 21.37%. After 3rd day of storage, treatment T_4 (SA 2 mM) recorded the highest starch content of 18.25% and the lowest starch content was recorded in T_5 (control) with a starch content of 16.47 %. After 12th day of storage, treatment T_4 (SA- 2 mM) recorded the maximum starch content of 10.44 % followed by 9.74 % in treatment T_2 (GA_3 150 ppm) which showed no significant difference with T_3 (OA 20 mM). The banana fruits without any treatment (control) showed minimum starch content of 9.05 % and were discarded after 12 days of storage due to spoilage. After 15days of storage, treatment T_4 (SA 2 mM) recorded the highest starch content of 10.19 % followed byT_2 (GA_3 150 ppm) with starch content of 9.38 % and the lowest starch content by T_1 ($CaCl_2$ 4%) with 8.25%.

4.2.3. Total sugar (%)

The total sugar content (%) of banana cv. Nendran during storage at room temperature is depicted in Table 5. Total sugar content of Nendran banana fruits at the time of storage after different postharvest treatments was on par and it ranged from 10.25 % to10.48 %. The total sugar content of fruits was 10.37 % at the time of storage which increased to 21.27 % after 12 days of storage. The total sugar content increased in all the treatments during storage and the highest sugar content of 16.77 % was recorded in fruits stored without any treatment (T_5-control) and the lowest total sugar content of 14.26 % was observed for the treatment T_4 (SA 2 mM) after 12 days of storage.

Table3. Effect of postharvest treatments on moisture content (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	54.55	57.37	58.16	60.94	61.98	58.60	62.46
T_2 (GA_3 150 ppm)	54.92	56.64	58.37	59.26	60.99	58.04	61.81
T_3 (OA 20 mM)	54.84	56.55	58.38	60.32	61.47	58.31	62.28
T_4 (SA 2 mM)	54.60	56.80	57.30	58.26	59.77	57.35	61.27
T_5 (Control)	54.69	57.38	59.13	61.71	63.40*	59.26	-
Days (D) mean	54.72	56.95	58.27	60.10	61.52		SE ± (m) 0.442
		SE ± (m)	CD (0.05)				CD (0.05) NS
Treatment (T)		0.087	0.249				
Days (D)		0.083	0.249				
Treatment (T) X Days (D)		0.195	0.556				

*Banana fruits were discarded due to spoilage

Table4. Effect of postharvest treatments on starch (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	21.54 (4.74)**	16.5 (4.18)	12.9 (3.73)	10.04 (3.32)	9.07 (3.17)	14.01 (3.83)	8.25 (3.04)
T_2 (GA_3 150 ppm)	21.62 (4.75)	17.87 (4.34)	13.58 (3.82)	11.06 (3.47)	9.74 (3.28)	14.77 (3.92)	9.38 (3.22)
T_3 (OA 20 mM)	21.48 (4.74)	17.3 (4.28)	13.14 (3.76)	10.3 (3.37)	9.16 (3.18)	14.27 (3.86)	8.90 (3.15)
T_4 (SA 2 mM)	21.49 (4.74)	18.25 (4.38)	14.35 (3.92)	11.58 (3.54)	10.44 (3.38)	15.22 (4.06)	10.19 (3.35)
T_5 (Control)	21.37 (4.73)	16.47 (4.41)	11.77 (3.57)	9.37 (3.21)	9.05 (3.17)*	13.61 (3.72)	-
Days (D) mean	21.50 (4.74)	17.27 (4.3)	13.14 (3.83)	10.47 (3.45)	9.49 (3.27)		SE ±(m) 0.012 CD(0.05) 0.037

	SE± (m)	CD (0.05)
Treatment (T)	0.006	0.016
Days (D)	0.006	0.016
Treatment (T) X Days (D)	0.012	0.035

*Banana fruits were discarded due to spoilage

** Values in parenthesis indicate square root transformation

Table 5. Effect of postharvest treatments on total sugar (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	10.35	12.72	17.41	18.34	21.66	16.10	22.04
T_2 (GA_3 150 ppm)	10.47	11.64	15.72	17.43	20.95	15.24	21.05
T_3 (OA 20 mM)	10.25	12.07	16.18	17.94	21.27	15.54	21.61
T_4 (SA 2 mM)	10.29	11.00	14.60	15.62	19.81	14.26	20.21
T_5 (Control)	10.48	13.61	17.61	19.47	22.66*	16.77	-
Days (D) mean	10.37	12.20	16.30	17.76	21.27		SE ± (m) 0.188 CD (0.05) 0.586

	SE ± (m)	CD (0.05)
Treatment (T)	0.068	0.194
Days (D)	0.068	0.194
Treatment (T) X Days (D)	0.152	0.44

*Banana fruits were discarded due to spoilage

Table 6. Effect of postharvest treatments on reducing sugar (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	9.23	11.73	15.51	16.57	18.61	14.33	19.50
T_2 (GA_3 150 ppm)	9.21	10.52	12.20	14.90	17.11	12.78	17.80
T_3 (OA 20 mM)	9.15	10.84	12.57	15.84	17.56	13.24	17.92
T_4 (SA 2 mM)	9.24	10.27	11.53	14.58	16.72	12.47	17.34
T_5 (Control)	9.18	13.39	16.40	18.81	20.37*	15.63	-
Days (D) mean	9.20	11.35	13.69	16.14	18.07		SE± (m) 0.205 CD (0.05) 0.64

	SE ± (m)	CD (0.05)
Treatment (T)	0.058	0.165
Days (D)	0.058	0.165
Treatment (T) X Days (D)	0.129	0.368

*Banana fruits were discarded due to spoilage

In the interaction effects between the postharvest treatments and days of storage were considered, after 3rdday of storage, the lowest total sugar content (11 %) was recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with a total sugar content of 11.64 % and the highest total sugar content of 13.61 %was observed for the treatment T_5 (control). After 12th day of storage, Nendran fruits without any postharvest treatment T_5 (control) recorded the highest total sugar content of 22.66 % followed by T_1 ($CaCl_2$ 4%) with 21.66% and the lowest total sugar content of 19.81 % was reported in SA 2 mM treatment (T_4)followed by T_2 (GA_3 150 ppm) with 20.95 %. The fruits without any postharvest treatments (control) were removed due to spoilage after 12 days of storage.

After 15th day of storage, the minimum total sugar content of 20.21% was recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) (21.05 %) and the maximum total sugar contentof 22.04 % was observed for T_1 ($CaCl_2$ 4%) which showed no significant difference with T_2 (OA 20 mM).

4.2.4. Reducing sugar (%)

Effect of postharvest treatments on reducing sugar content (%) of banana cv. Nendran is depicted in Table 6. The reducing sugar content of fruits was 9.20 % at the time of storage which increased to 18.07% after 12 days of storage. The reducing sugar gradually increased during storage in all the treatments and recorded the highest reducing sugar content of 15.63 % in fruits stored without any treatment (T_5) (control) and the lowest reducing sugar content of 12.47 % was observed for the treatment T_4 (SA 2 mM) after 12 days of storage.

When the interaction effects were considered, after 3rd day of storage, the minimum reducing sugar content (10.27 %) was recorded by Nendran banana fruits subjected to T_4 (SA 2 mM) treatment followed by T_2 (GA_3 150 ppm) with a reducing sugar content of 10.52 % and the highest reducing content(13.39 %) was observed for the fruits without any postharvest treatment T_5 (control). The minimum reducing sugar content of 11.53% was noticed in T_4 (SA 2 mM) and maximum reducing sugar content (16.40 %) was recorded for T_5 (Control), after 6 days of storage.

Nendran fruits treated with SA 2 mM (T_4) recorded the lowest reducing sugar content (14.58%) and a highest reducing sugar content (18.81 %) was noticed for T_5 (control), after 9 days of storage. After 12th day of storage, Nendran fruits without any postharvest treatment T_5 (control) recorded the highest reducing sugar content of 20.37 % followed by T_1 ($CaCl_2$ 4%) and the lowest reducing sugar content (16.72 %) was observed in SA 2 mM (T_4) followed by T_2 (GA_3 150 ppm with 17.11 %. The fruits without any postharvest treatments (control) were removed due to spoilage after 12 days of storage.

After 15th day of storage, the minimum reducing sugar content of 17.34 % was recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with 17.80 % and the maximum reducing sugar content (19.50 %) was obtained for the fruits treated with $CaCl_2$ 4% (T_1).

4.2.5. Total Soluble Solids(TSS) (^{0} Brix)

The changes in Total Soluble Solids of Nendran banana during storage is depicted in Table 7. Total Soluble Solids of Nendran banana fruits at the time of storage after different postharvest treatments showed no significant difference among the treatments and ranged from 2.71 ^{0} Brix to 2.79 ^{0} Brix. The TSS content of fruits was 2.75 ^{0} Brix at the time of storage which increased to 23.84 ^{0} Brix after 12 days of storage. The TSS increased during storage in all the treatments and recorded the highest value of 16.20 ^{0} Brix in fruits stored without any treatment (T_5) (control) and the lowest TSS of 10.74 ^{0} Brix was observed for the treatment T_4 (SA 2 mM) after 12 days of storage.

When the interaction effects between the postharvest treatments and days of storage were considered, after 3rd day of storage, the minimum TSS of 4.47 ^{0} Brixwas recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with a TSS of 5.29 ^{0} Brix and the highest TSS (7.27 ^{0} Brix) was observed for the treatment T_5 (control). After 12th day of storage, Nendran fruits without any postharvest treatment T_5 (control) recorded the highest TSS of 27.56 ^{0} Brix followed by T_1 ($CaCl_2$ 4%) (23.59 ^{0} Brix) which showed no

Table 7. Effect of postharvest treatments on TSS (^{0}Brix) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	2.73	6.65	9.72	20.24	23.59	12.59	25.57
T_2 (GA_3 150 ppm)	2.71	5.29	8.62	18.54	22.48	11.53	25.03
T_3 (OA 20 mM)	2.78	5.70	9.14	19.56	23.38	12.11	25.43
T_4 (SA 2 mM)	2.75	4.47	7.69	16.57	22.20	10.74	24.60
T_5 (Control)	2.79	7.27	18.74	24.65	27.56*	16.20	-
Days (D) mean	2.75	5.88	10.78	19.91	23.84		

	SE ±(m)	CD (0.05)
Treatment (T)	0.067	0.192
Days (D)	0.067	0.192
Treatment (T) X Days (D)	0.154	0.431

SE ± (m) 0.145
CD (0.05) 0.453

*Banana fruits were discarded due to spoilage

Table 8. Effect of postharvest treatments on acidity (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	0.18	0.25	0.35	0.42	0.49	0.34	0.51
T_2 (GA_3 150 ppm)	0.17	0.24	0.30	0.37	0.43	0.30	0.45
T_3 (OA 20 mM)	0.17	0.23	0.32	0.35	0.44	0.30	0.46
T_4 (SA 2 mM)	0.18	0.23	0.25	0.33	0.42	0.28	0.45
T_5 (Control)	0.18	0.34	0.42	0.49	0.51*	0.39	-
Days (D) mean	0.18	0.26	0.33	0.39	0.46		SE± (m) 0.003
			SE ± (m)	CD (0.05)			CD (0.05) 0.011
Treatment (T)			0.002	0.006			
Days (D)			0.002	0.006			
Treatment (T) X Days (D)			0.005	0.013			

*Banana fruits were discarded due to spoilage

significant difference with T_3 (OA 20 mM)and the lowest TSS (22.20 ^{0} Brix) was recorded by the treatment T_4 (SA 2 mM). The fruits without any postharvest treatments (control) were spoiled and were removed after storage for 12 days.

After 15th day of storage, the lowest TSS of 24.60 ^{0} Brix was recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with 25.03 ^{0} Brix and the highest TSS of 25.57^0 Brix was obtained for T_1 ($CaCl_2$ 4%) which showed no significant difference with T_3 (OA 20 mM).

4.2.6. Acidity (%)

The effect of postharvest treatments on titratable acidity during storage of Nendran banana is depicted in Table 8. The acidity of Nendran banana fruits subjected to postharvest treatments increased significantly during storage. The titratable acidity of Nendran banana increased from 0.18 % at the time of storage to 0.46%after12 days of storage. The treatment T_4 (SA 2 mM) recorded the lowest titratable acidity of 0.28 % followed by T_2 (GA_3 150 ppm) with 0.30 % and T_5 (control) recorded the highest acidity of 0.39 % after 12 days of storage.

When the interaction effects were studied, T_4 (SA 2 mM) recorded the lowest titratable acidity of 0.23 % which was statistically on par with T_3 (OA 20 mM) and the highest titratable acidity of 0.34 % was noticed in T_5 (control), after 3rd day of storage. After 6th day of storage, a maximum titratable acidity (0.42 %) was observed in fruits without any treatment T_5 (control) and the lowest was in T_4 (SA 2 mM) with 0.25% titratable acidity.

The banana fruits treated with Salicylic acid 2 mM(T_4) exhibited the lowest titratable acidity of 0.33 % followed by 0.37 % in T_2 (GA_3 150 ppm) and the highest titratable acidity was recorded in T_5 (control) with 0.49 % after 9 days of storage. Titratable acidity was the lowest (0.42 %) in T_4 (SA 2 mM) followed by 0.43 % in T_2 (GA_3 150 ppm) which differed significantly from other treatments and the highest acidity of 0.51 % was noticed in T_5 (control), after 12th day of storage.

After 15 days of storage T_4 (SA 2 mM) recorded the lowest titratable acidity of 0.45 %, which is statistically on par with T_2 (GA_3 150 ppm) and the highest titratable acidity of 0.51 % was recorded for $CaCl_2$ 4% treated fruits (T_1).

4.2.7. Carotenoids (mg $100g^{-1}$)

The effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) during storage of Nendran banana is depicted in the Table 9. The carotenoid content of postharvest treated banana fruits increased during storage in all the treatments and it was 0.13 mg $100g^{-1}$ at the time of storage which increased to 0.31mg $100g^{-1}$ after 12 days of storage.

The treatment T_4 (SA 2 mM) recorded the lowest carotenoid content of 0.19mg $100g^{-1}$ followed byT_2 (GA_3 150 ppm) with 0.21 mg $100g^{-1}$ which showed significant difference with other treatments and the highest carotenoid content (0.25 mg $100g^{-1}$) was noticed in fruits without any treatment T_5 (control) after 12 days of storage.

On studying the interaction effects, it was observed that after 3 days of storage the banana fruits subjected to T_4 (SA 2 mM) recorded the lowest carotenoid content of 0.15 mg $100g^{-1}$ and the fruits without any treatment T_5 (control) recorded the highest content (0.19 mg $100g^{-1}$).

After 12^{th} day of storage, the lowest carotenoid content (0.25 mg $100g^{-1}$) was noticed in T_4 (SA 2 mM) followed by 0.30 mg $100g^{-1}$ in T_2 (GA_3 150 ppm) and the highest was recorded in T_5 (control) with 0.35mg $100g^{-1}$.The fruits without any treatments T_5 (control) were removed after storage for 12 days due to spoilage.

The postharvest treatment with SA 2 mM (T_4) recorded the minimum carotenoid content of 0.29 mg $100g^{-1}$ followed by T_2 (GA_3 150 ppm) and T_3(OA 20 mM) with 0.32 mg $100g^{-1}$ and the maximum carotenoid content of 0.33mg $100g^{-1}$was recorded by T_1 ($CaCl_2$ 4%) after 15 days of storage.

4.2.8. Ascorbic acid (mg $100g^{-1}$)

The effect of postharvest treatments on ascorbic acid (mg $100g^{-1}$) content of Nendran banana during storage is depicted in the Table 10. The postharvest treatment with salicylic acid2 mM (T_4) recorded the maximum ascorbic acid content (15. 17mg$100g^{-1}$)

Table 9. Effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	0.13	0.18	0.21	0.27	0.32	0.22	0.33
T_2 (GA_3 150 ppm)	0.13	0.16	0.19	0.26	0.30	0.21	0.32
T_3 (OA 20 mM)	0.14	0.17	0.20	0.26	0.31	0.22	0.32
T_4 (SA 2 mM)	0.13	0.15	0.17	0.23	0.25	0.19	0.29
T_5 (Control)	0.14	0.19	0.26	0.31	0.35*	0.25	-
Days (D) mean	0.13	0.17	0.21	0.27	0.31		SE± (m) 0.005
		SE ± (m)		CD(0.05)			CD (0.05) 0.014
Treatment (T)		0.020		0.006			
Days (D)		0.020		0.006			
Treatment (T) X Days (D)		0.005		0.014			

*Banana fruits were discarded due to spoilage

Table 10. Effect of postharvest treatments on ascorbic acid (mg $100g^{-1}$) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	18.26	14.11	12.40	10.44	7.55	12.55	7.48
T_2 (GA_3 150 ppm)	18.41	16.69	14.40	12.5	10.20	14.44	8.59
T_3 (OA 20 mM)	18.46	16.58	13.46	12.39	9.54	14.09	8.03
T_4 (SA 2 mM)	18.32	17.54	15.59	13.60	10.81	15.17	9.30
T_5 (Control)	18.62	13.43	11.45	10.43	6.55*	12.10	-
Days (D) mean	18.41	15.67	13.46	11.87	8.93		SE ± (m) 0.157 CD (0.05) 0.488
		SE± (m)		CD (0.05)			
Treatment (T)		0.081		0.23			
Days (D)		0.081		0.23			
Treatment (T) X Days (D)		0.18		0.513			

*Banana fruits were discarded due to spoilage

followed byT_2 (GA_3 150 ppm) with 14.44 mg $100g^{-1}$ which showed significant difference with other treatments and the lowest ascorbic acid content (12.10 mg $100g^{-1)}$ was noticed in fruits without any treatment (T_5 - control).

The ascorbic acid content of postharvest treated fruits decreased significantly during storage and it ranged from18.41 mg $100g^{-1}$on the initial day of storage to 8.93 mg $100g^{-1}$ at the end of 12 days of storage.

On studying the interaction effects, after 3 days of storage the banana fruits subjected to SA 2 mM (T_4) recorded the highest ascorbic acid content of 17.54 mg $100g^{-1}$ and the lowest content 13.43 mg $100g^{-1}$ was recorded by T_5 (control). Similar trend was observed after 6^{th} and 9^{th} days after the storage where SA 2mM retained highest ascorbic acid.

After 12^{th} day of storage, the highest content of ascorbic acid (10.81 mg $100g^{-1}$) was noticed in T_4 (SA 2 mM) followed by 10.20 mg $100g^{-1}$ in T_2 (GA_3 150 ppm) and the minimum was recorded in T_5 (control) with 6.55 mg $100g^{-1}$. The fruits without any treatments were removed after storage for 12 days due to spoilage.

The treatment, T_4 (SA 2 mM) recorded the maximum ascorbic acid content of 9.30 mg $100g^{-1}$ followed by T_2 (GA_3 150 ppm) (8.59 mg $100g^{-1}$) and the minimum ascorbic acid content (7.48 mg 100 g^{-1}) was exhibited by T_1 ($CaCl_2$ 4%) after 15 days of storage of Nendran fruits.

4.2.9. Antioxidant activity (%)

The effect of postharvest treatments on antioxidant activity (%) of Nendran banana fruits during storage is described in Table 11.The antioxidant activity of Nendran banana fruits after different postharvest treatments ranged from 90.27 % to 90.50 % at the time of storage. The antioxidant activity decreased among the treatments and recorded a maximum of 85.23 % in T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) with an antioxidant activity of 83.57% and a minimum of 80.06 % was observed in T_5 (control), after12 days of storage. The antioxidant activity of Nendran banana fruits decreased with storage from 90.38 % after 3^{rd} day of storage to 74.39 % after 12^{th} day of storage.

When the interaction effects were analysed, the treatment T_4 (SA 2 mM) showed the maximum retention of antioxidant activity of 88.78 % and the minimum antioxidant activity of 82.67% was recorded by T_5 (control), after storage of 3 days. After 6^{th} day of storage, a maximum of 85.05 % was recorded by T_4 (SA 2 mM) and T_5 (control) recorded minimum antioxidant value of 79.34 %.

The untreated fruits, T_5 (control) recorded the lowest antioxidant activity of77.44 % and70.41 % after 9 and 12 days of storage respectively whereas the treatment, T_4 (SA 2 mM) recorded the highest antioxidant activity of 83.45 % after 9 days and 78.39 % after 12 days of storage. The untreated fruits were spoiled and were removed after storage for 12 days.

After 15 days of storage, banana fruits treated with SA 2 mM (T_4) recorded the highest antioxidant activity of 75.52 % followed by T_2 (GA_3 150 ppm) with 74.31 % which showed significant difference with other treatments and the lowest antioxidant activity of 71.37 % was recorded for fruits treated with $CaCl_2$ 4% (T_1).

4.3. PHYSICAL PARAMETERS

4.3.1. Pulp (%)

Effect of postharvest treatments of Nendran banana on pulp (%) during storage is depicted in Table 12. The pulp % increased during storage from 63.56 % at the time of storage to 67.38 %, 69.18 %, 71.46 % and 72.37 % on 3^{th}, 6^{th}, 9^{th} and 12^{th} day of storage respectively. The treatment T_4 (SA 2 mM) recorded the minimum pulp percentage of66.89 % followed by T_2 (GA_3 150 ppm) with 68.20 % and the maximum pulp percentage (70.72 %) was recorded by T_5 (control), after 12 days of storage.

Nendran banana fruits subjected to postharvest treatments with SA 2 mM (T_4) recorded the lowest of pulp percentage (65.76 %) and the highest pulp percentage of 69.50% was recorded by T_5 (control) after 3 days of storage. After 6^{th} day of storage, T_5 (control) fruits observed the maximum pulp percentage (71.38 %) and a minimum pulp percentage (67.31 %) was noticed in T_4 (SA 2mM).

The highest pulp percentage of 73.77 % was recorded by T_5 (control) after 9 days of storage and the lowest pulp percentage (68.39 %)in fruits treated with SA 2 mM (T_4).

Table 11.Effect of postharvest treatments on antioxidant activity (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	90.27	84.40	81.58	79.26	73.49	81.80	71.37
T_2 (GA_3 150 ppm)	90.32	86.41	84.23	81.64	75.23	83.57	74.31
T_3 (OA 20 mM)	90.36	83.90	82.27	80.39	74.44	82.27	72.94
T_4 (SA 2 mM)	90.50	88.78	85.05	83.45	78.39	85.23	75.52
T_5 (Control)	90.45	82.67	79.34	77.44	70.41*	80.06	-
Days (D) mean	90.38	85.23	82.49	80.44	74.39		SE ± (m) 0.246 CD (0.05) 0.760

	SE± (m)	CD (0.05
Treatment (T)	0.111	0.315
Days (D)	0.111	0.315
Treatment (T) X Days (D)	0.247	0.705

*Banana fruits were discarded due to spoilage

Table 12. Effect of postharvest treatments on pulp (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	63.74	67.55	70.22	72.16	73.16	69.36	73.94
T_2 (GA_3 150 ppm)	63.63	66.47	68.16	71.17	71.60	68.20	73.32
T_3 (OA 20 mM)	63.11	67.62	68.84	71.84	72.46	68.78	73.78
T_4 (SA 2 mM)	63.43	65.76	67.31	68.38	69.59	66.89	70.60
T_5 (Control)	63.91	69.50	71.38	73.77	75.03*	70.72	-
Days (D) mean	63.56	67.38	69.18	71.46	72.37		SE± (m) 0.179 CD (0.05) 0.558

	SE± (m)	CD (0.05)
Treatment (T)	0.126	0.358
Days (D)	0.126	0.358
Treatment (T) X Days (D)	0.281	0.800

*Banana fruits were discarded due to spoilage

After 12th day of storage, Nendran fruits without any postharvest treatmentsT_5 (control) recorded the highest pulp percentage of 75.03 % and the lowest pulp percentage of 69.59 % was recorded byT_4 (SA 2mM). The fruits without any postharvest treatments T_5 (control) were discarded due to spoilage after 12 days of storage.

After 15th day of storage, the maximum fruit pulp percentage of 73.94 % was recorded by T_1 ($CaCl_2$ 4%) and the minimum pulp percentage (70.60 %) was in fruits treated with SA 2 mM (T_4).

4.3.2. Peel (%)

Effect of postharvest treatments of Nendran banana on peel (%) during storage is depicted in Table 13. The treatment T_4 (SA 2 mM) recorded the maximum peel percentage of 33.10 % and the minimum pulp percentage of 29.28 % was recorded by T_5 (control), after 12 days of storage. The peel % decreased during the storage period of 12 days from 36.44% on the initial day to 32.61 %, 30.81 %, 28.53 % and 27.65 % on 3rd, 6th, 9th, and 12th day of storage respectively.

Peel percentage of Nendran banana fruits subjected to postharvest treatment with SA 2 mM (T_4) recorded the highest value of 34.24 % and the lowest peel percentage (30.49 %) was for T_5 (control) after 3 days of storage. The fruits subjected to treatment with T_4 (SA 2 mM) observed the maximum peel percentage (32.69 %) and a minimum peel percentage (28.62 %) was noticed in T_5 (control) at the end of 6 days of storage.

The highest peel percentage of 31.61% and 30.41% were recorded for SA 2mM (T_4) treated fruits after 9 and 12 days of storage respectively and the lowest peel percentage of26.23 % after 9th day and 24.97% after 12th day was recorded by fruits without any treatment T_5 (control). The fruits without any postharvest treatments T_5 (control) were spoiled and were removed after storage for 12 days.

After 15th day of storage, the minimum fruit peel percentage of (26.05%) was recorded by T_1 ($CaCl_2$ 4 %) and the maximum peel percentage of 29.39 % was for fruits treated with SA 2 mM (T_4).

4.3.3. Pulp to Peel ratio

Effect of postharvest treatments of Nendran banana on pulp to peel ratio during storage is depicted in Table 14. The pulp to peel ratio of Nendran banana fruits at the time of storage after different postharvest treatments ranged from 1.71to 1.77. The pulp to peel ratio of fruits was 1.74 at the time of storage which increased to 2.63 after 12 days of storage. The treatment T_4 (SA 2mM) recorded the lowest pulp to peel ratio of 2.03 followed by T_2 (GA_3 150 ppm) with 2.17 and the highest pulp to peel ratio (2.47) was recorded by T_5 (control), after 12 days of storage.

The pulp to peel ratio was 2.28 for Nendran banana fruits subjected to postharvest treatment with SA 2 mM (T_4) and the highest pulp to peel ratio (1.92) was recorded by T_5 (control) at the end of 3rd day of storage. After 6th day of storage, fruits without any postharvest treatment T_5 (control) observed the maximum pulp to peel ratio of 2.49 and a minimum pulp to peel ratio (2.06) was noticed in T_4 (SA 2mM).

The highest pulp to peel ratio of 2.81 after 9 days and 3.01 after 12 days of storage was recorded by T_5 (control) and the lowest pulp to peel ratio was recorded by T_4 (SA 2 mM) with a value of 2.16and 2.29 after 9th and 12th day of storage respectively. The fruits without any postharvest treatments T_5 (control) were spoiled and were removed after storage for 12 days.

After 15th day of storage, the highest fruit pulp to peel ratio of 2.83 was recorded by T_1 ($CaCl_2$ 4%) and the lowest pulp to peel ratio (2.40) was for fruits treated with SA 2 mM (T_4).

4.3.4. Colour

Effect of postharvest treatments on peel colour of Nendran banana is depicted in Table 15. The colour of banana fruits changed significantly during storage and it ranged from dark green colour(Stage I), light green colour (Stage II), more green than yellow (Stage III), more yellow than green (Stage IV), yellow with green tip (Stage V), full yellow (Stage VI) and yellow with brown spots (Stage VII).

.Table 13. Effect of postharvest treatments on peel (%) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	36.26	32.45	29.78	27.84	26.94	30.64	26.05
T_2 (GA_3 150 ppm)	36.37	33.53	31.84	28.83	28.40	31.79	26.68
T_3 (OA 20 mM)	36.89	32.38	31.15	28.16	27.54	31.22	26.21
T_4 (SA 2 mM)	36.57	34.24	32.69	31.61	30.41	33.10	29.39
T_5 (Control)	36.09	30.49	28.62	26.23	24.97*	29.28	-
Days (D) mean	36.44	32.61	30.81	28.53	27.65		SE ± (m) 0.179 CD(0.05) 0.558

	SE ± (m)	CD (0.05)
Treatment (T)	0.126	0.358
Days (D)	0.126	0.358
Treatment (T) X Days(D)	0.3281	0.800

*Banana fruits were discarded due to spoilage

Table 14. Effect of postharvest treatments on pulp to peel ratio of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	1.76	2.08	2.36	2.59	2.73	2.30	2.83
T_2 (GA_3 150 ppm)	1.75	1.98	2.14	2.47	2.52	2.17	2.75
T_3 (OA 20 mM)	1.71	2.09	2.22	2.55	2.63	2.34	2.81
T_4 (SA 2 mM)	1.73	1.92	2.06	2.16	2.29	2.03	2.40
T_5 (Control)	1.77	2.28	2.49	2.81	3.01*	2.47	-
Days (D) mean	1.74	2.07	2.25	2.52	2.63		

	SE ±(m)	CD (0.05)
Treatment (T)	0.014	0.039
Days (D)	0.014	0.039
Treatment (T) X Days (D)	0.030	0.087

SE± (m) 0.024

CD (0.05) 0.076

*Banana fruits were discarded due to spoilage

Table 15. Effect of postharvest treatments on colour of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					
	0	3	6	9	12	15
T_1 ($CaCl_2$ 4%)	I	II	IV	VI	VII	VII
T_2 (GA_3 150 ppm)	I	II	IV	V	VI	VII
T_3 (OA 20 mM)	I	II	IV	V	VI	VII
T_4 (SA 2 mM)	I	I	II	IV	VI	VII
T_5 (Control)	I	III	V	VI	VII	-

*Banana fruits were discarded due to spoilage

Table 16. Effect of postharvest treatments on texture (fruit firmness) (N) of banana cv. Nendran during storage

Postharvest treatments	Days after storage (D)					Treatment mean(T)	15
	0	3	6	9	12		
T_1 ($CaCl_2$ 4%)	25.28	23.37	20.48	17.41	13.05	19.92	11.88
T_2 (GA_3 150 ppm)	25.01	21.69	18.43	14.94	11.14	18.24	8.73
T_3 (OA 20 mM)	25.42	22.28	17.28	14.41	11.35	18.15	8.11
T_4 (SA 2 mM)	25.16	23.45	21.65	16.58	12.26	19.82	10.13
T_5 (Control)	25.52	19.31	14.61	10.25	6.78*	15.29	-
Days (D) mean	25.27	22.02	18.49	14.71	10.91		SE $\pm$ (m) 0.167 CD (0.05) 0.522

*Banana fruits were discarded due to spoilage

After 3 days of storage the fruits treated with T_4 (SA 2mM) showed dark green colour (Stage I) as against light green colour (Stage II) in T_2 (GA_3 150 ppm), T_3 (OA 20 mM) and T_1 ($CaCl_2$ 4%) and more green than yellow (Stage III) in T_5 (control). Banana fruits dipped in Salicylic Acid 2 mM (T_4) recorded light green colour (Stage II) whereas T_2 (GA_3 150 ppm), T_3 (OA 20 mM) and T_1 ($CaCl_2$ 4%) recorded more yellow than green (Stage IV) and T_5 (control) recorded yellow with green tip (Stage V) at the end of 6th day of storage.

After 9 days of storage, peel colour of fruits in control (T_5) and T_1 ($CaCl_2$ 4%) recorded full yellow (Stage VI) and T_4 (SA 2mM) recorded a peel colour of yellow with green tip (Stage V). At the end of 12 days of storage, fruits in control (T_5) and T_1 ($CaCl_2$ 4%) recorded yellow with brown spots (Stage VII) and full yellow (Stage VI) was recorded in T_2 (GA_3 150 ppm), T_3 (OA 20 mM), and T_4 (SA 2 mM). The fruits without any treatment T_5 (control) were removed due to spoilage.

After 15 days of storage fruits subjected to treatment with T_2 (GA_3 150 ppm), T_3 (OA 20 mM), T_1 ($CaCl_2$ 4%) and T_4 (SA 2mM) were reached Stage VII, fruits are yellow with brown spot.

4.3.5. Texture (Fruit firmness) (N)

Effect of postharvest treatments on texture (fruit firmness) of Nendran banana is described in Table 16. The treatment T_1 ($CaCl_2$ 4%) recorded the maximum fruit firmness of 19.92 N which was statistically on par withT_4 (SA 2 mM) (19.82 N) and the minimum fruit firmness of 15.29 N was recorded by fruits without any treatment T_5 (control). The texture of postharvest treated fruits decreased significantly during storage and it ranged from 25.27 N to 10.91 N during 12 days of storage.

When the effects between the postharvest treatments and days of storage were considered, after 3rd of storage, the maximum firmness of 23.45 N was recorded by T_4 (SA 2 mM) which showed no significant difference with $CaCl_2$ 4% (T_1)and the minimum firmness (19.31 N) was observed for the treatment T_5 (control). After 12th day of storage, Nendran fruits without any postharvest treatment T_5 (control) recorded the lowest firmness of 6.78 N and the maximum firmness of 13.05 N was recorded by fruits

treated with T_1 ($CaCl_2$ 4%) followed by T_4 (SA 2 mM). The fruits without any postharvest treatments (control) were removed due to spoilage after 12 days of storage.

After 15th day of storage, the minimum fruit firmness of (8.11 N) was recorded by T_3 (OA 20 Mm) followed by T_2 (GA_3 150 ppm) and the maximum firmness (11.88 N) was observed for T_1 ($CaCl_2$ 4%) followed by T_4 (SA 2 mM) with 10.13 N fruit firmness.

4.4. SENSORY ANALYSIS

Effect of postharvest treatments on sensory (organoleptic) parameters after ripening of Nendran banana fruits was statistically evaluated using Kruskall- Wallis chi square test. The appearance, colour, flavor, taste, texture and overall acceptability of fruits subjected to different postharvest treatments showed significant difference among the treatments after 9 days of storage (Table 17). The fruits untreated fruits (T_5- control) recorded the highest mean score for appearance (8.26), flesh colour (8.56), flavor (8.53), taste (8.60), texture (8.60) and overall acceptability (8.7). The lowest mean score for appearance (8.18), flesh colour (8.05), flavor (7.95), taste (7.90), overall acceptability. The lowest mean score for appearance (8.18), flesh colour (8.05), flavor (7.95), taste (7.90), overall acceptability (8.00) was recorded in T_4 (SA 2 mM) and lowest mean score for appearance (8.16) was observed in T_1 ($CaCl_2$ 4%).

After 12th day of ripening, the highest mean score for appearance (8.9), flesh colour (8.86), flavor (8.83), taste (8.83), texture (8.6) and overall acceptability (8.8) was observed inT_4 (SA 2 mM) (Table 18). The fruits treatmentT_5 (control) recorded the lowest mean score for appearance (7.86), flesh colour (7.56), flavor (7.53), taste (7.6), texture (7.6) and overall acceptability (7.4).

After 15 days of storage, lowest mean score for appearance (7.73), flesh colour (8.33), flavor (7.56), taste (7.63), texture (7.83) and overall acceptability (7.56) was recorded in T_1 ($CaCl_2$ 4%). The Nendran fruits treated with SA 2 mM recorded the highest mean score for appearance (8.86), flesh colour (8.86), flavor (8.83), taste (8.83), texture (8.6) and overall acceptability (8.8) after 15 days of storage (Table 19).

Table 17. Effect of postharvest treatments on sensory parameters of banana cv. Nendran after 9th day of storage

Postharvest treatments	Appearance	Flesh colour	Flavor	Taste	Texture	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 ($CaCl_2$ 4%)	8.16	8.18	8.06	8.13	8.2	8.14
T_2 (GA_3 150 ppm)	8.18	8.16	8.13	8.06	8.25	8.16
T_3 (OA 20 mM)	8.23	8.14	8.13	8.05	8.21	8.10
T_4 (SA 2 mM)	8.18	8.05	7.95	7.90	8.00	7.90
T_5 (Control)	8.26	8.56	8.53	8.60	8.60	8.70
K W value	52.50**	60.90**	64.09**	68**	73.20**	71.40**
χ^2 (0.05)	9.48					

Scores

Like extremely -9 Like very much -8 Like moderately -7 Like slightly -6 Neither like nor dislike – 5

Dislike slightly -4 Dislike moderately – 3 Dislike very much – 2 Dislike extremely -1

** Significant

Table 18. Effect of postharvest treatments on sensory parameters of banana cv. Nendran after 12th day of storage

Postharvest treatments	Appearance	Flesh colour	Flavor	Taste	Texture	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 ($CaCl_2$ 4%)	8.9	8.73	8.6	8.63	8.83	8.89
T_2 (GA_3 150 ppm)	8.8	8.76	8.76	8.76	8.73	8.60
T_3 (OA 20 mM)	8.73	8.76	8.73	8.63	8.56	8.60
T_4 (SA 2 mM)	8.9	8.86	8.83	8.83	8.6	8.80
T_5 (Control)	7.86	7.56	7.53	7.6	7.4	7.40
K W value	53.51**	76.44**	71.61**	65.63**	73.42**	73.26**
χ^2 (0.05)	9.48					

Scores

Like extremely -9 Like very much -8 Like moderately -7 Like slightly -6 Neither like nor dislike – 5

Dislike slightly -4 Dislike moderately – 3 Dislike very much – 2 Dislike extremely -1

** Significant

4.5. SHELF LIFE (Days)

Effect of postharvest treatments on shelf life of Nendran banana during storage is depicted in Table 20. The longest shelf life of 15.67 days was recorded for banana fruits cv. Nendran treated with Salicylic Acid 2mM (T_4) followed by 14.30 days for fruits treated with GA_3 150 ppm(T_2). The banana fruits treated with T_3 (OA 20 mM) resulted in a shelf life of 13.65 days and the fruits treated with $CaCl_2$ 4% (T_1) recorded a shelf life of 12.3 days as against 11.13 days in fruits without any postharvest treatment T_5 (control).

Table 19. Effect of postharvest treatments on sensory parameters of banana cv. Nendran after 15th day of storage

Postharvest treatments	Appearance	Flesh colour	Flavor	Taste	Texture	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 ($CaCl_2$ 4%)	7.73	8.33	7.56	7.63	7.83	7.56
T_2 (GA_3 150 ppm)	8.8	8.73	8.73	8.76	8.73	8.70
T_3 (OA 20 mM)	8.76	8.66	8.73	8.63	8.56	8.66
T_4 (SA 2 mM)	8.86	8.86	8.83	8.83	8.6	8.80
T_5 (Control)	-	-	-	-	-	-
K W value	54.04**	69.53**	67.64**	66.99**	73.42**	70.77**
χ^2 (0.05)	9.48					

Scores

Like extremely -9 Like very much -8 Like moderately -7 Like slightly -6 Neither like nor dislike – 5

Dislike slightly -4 Dislike moderately – 3 Dislike very much – 2 Dislike extremely -1

** Significant

Table 20. Effect of postharvest treatments on shelf life (days) of banana cv. Nendran during storage.

Postharvest Treatments (T)	Shelf life (Days)
T_1 ($CaCl_2$ 4%)	12.30
T_2 (GA_3 150 ppm)	14.30
T_3 (OA 20 mM)	13.65
T_4 (SA 2 mM)	15.67
T_5 (Control)	11.13
SE $\pm$ (m) 0.198 CD(0.05) 0.594	

Discussion

5. DISCUSSION

The results obtained from the experiment on "Postharvest quality management in banana cv. Nendran (*Musa* spp.)" are discussed in this chapter.

Nendran banana fruits after sanitization (ozonation 2 ppm) were subjected to postharvest treatments with Calcium Chloride ($CaCl_2$), Gibberellic Acid (GA), Oxalic Acid (OA) and Salicylic Acid (SA) as against fruits without postharvest treatment as control. The fruits after the postharvest treatments were stored in Corrugated Fibre Board boxes at room temperature (30±2 ^{0}C, RH 85-90 %). Effectiveness of the treatments was analyzed on the basis of physical, physiological, biochemical and sensory parameters at an interval of 3 days till the end of shelf life.

5.1. PHYSIOLOGICAL PARAMETERS

5.1.1. Physiological Loss in Weight

Physiological loss in weight (PLW) is of utmost importance in post harvest life of fruits and affects sensory quality of fruits and thereby makes a negative impact on its marketability (Scriven *et al*., 1989).The PLW of fruits during storage is the result of loss of moisture and reserve food materials by evapo-transpiration and respiration (Siddiqui *et al*., 1991) leading to shrinkage and wilting, eventually making the fruits unusable. The loss in weight also led to deterioration of the fruit by reducing its tissue turgor (Sothornvit and Rodsamran, 2008).

The PLW of Nendran banana fruits increased during storage for both treated and untreated fruits but the postharvest treatments helped in reducing the loss in weight considerably. Among the different postharvest treatments, Salicylic Acid (2 mM) treatment recorded the lowest weight loss (13.43%) during the entire storage period of 15 days. Siddiqui *et al*. (1991) noticed that PLW of fruits increases with storage period and the postharvest treatments of banana fruits resulted in a reduced rate of increment inPLW as compared to absolute control. The postharvest treatment with SA 2 mM recorded the lowest PLW of 9.57 % which showed no significant difference to GA_3 150 ppm with 9.58 % as against the highest PLW (15.21 %) for fruits without any postharvest treatment at the end of 12 days of storage (Fig. 1). The results are in

agreement with the findings of research on the effect of postharvest treatments on mango (Singh and Singh, 1992) and similar conclusions were also made by Patel *et al*. (2010); Hakim *et al*. (2013); Tapas(2016) and Khademi *et al*. (2019) in banana cv. Grand Naine.

The type of postharvest treatments influenced the rate of PLW in Nendran banana and SA 2 mM recorded the lowest PLW (13.43 %) followed by the fruits treated with GA_3 150 ppm (14.3%) after 15 days of storage. Among the postharvest treatments, SA 2 mM was found to be most effective in decreasing the PLW which might be due to the reduction in rate of transpirationand respiration (Manthe *et al*., 1992) as well as delay in the appearance of climacteric peak (Srivastava and Dwivedi, 2000) by salicylic acid. SA is found to interfere in the formation and action of the plant hormone ethylene, thereby retard the ripening process. Shafiee *et al*. (2010) revealed that SA helps in reducing PLW by producing free radicals, which in turn inhibits the normal respiration.

Salicylic acid treatment reduced the PLW in mandarin oranges (Zheng and Zhang, 2004) and strawberry (Shafiee *et al*., 2010). Kazemi *et al*. (2011) reported that apple fruits treated with salicylic acid as postharvest treatment recorded the lowest weight loss as against the highest in control fruits. Sahithya *et al*. (2015) evaluated the effect of salicylic acid (100µM) on banana fruits cv. Grand Naine and found that there was a significant reduction in weight loss of 8.27% during storage. Mandal *et al.* (2016) reported that banana cv. Grand Naine treated with SA (2 mM) showed reduced weight loss (12.25%) as compared to the untreated fruits. Similar result was also observed by Alali *et al*. (2018) in banana cv. Grand Naine and Nair (2018) in banana cv. Nendran.

Postharvest treatment with GA_3 (150 ppm) also reduced the weight loss significantly. This is in tune with the conclusions of Randhawa *et al.* (2002) in plum fruits. This reduction in PLW may be due the anti-senescence action of GA_3 (Sudha *et al*., 2007). Similar results were also observed in several cultivars of banana by Patel *et al*. (2010) in cv. Grand Naine, Macwan *et al.* (2012) in cv. Robusta and Mulagund *et al.* (2015) in cv. Grand Naine. This could possibly be due to the ability of gibberellic acid

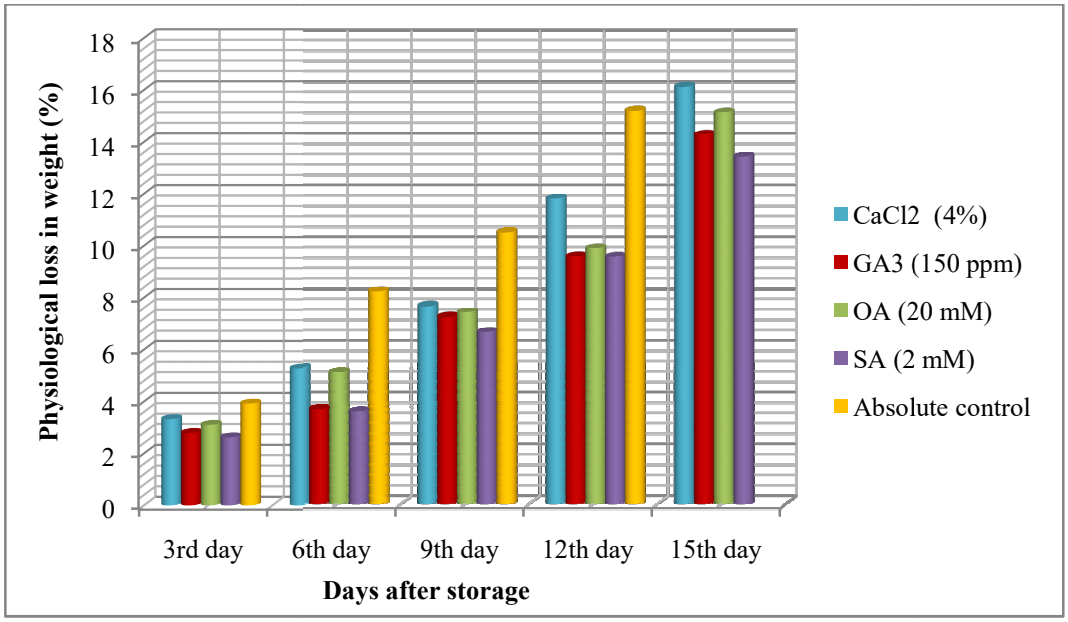

Fig. 1. Effect of postharvest treatments on Physiological loss in weight (%) of banana cv. Nendran during storage

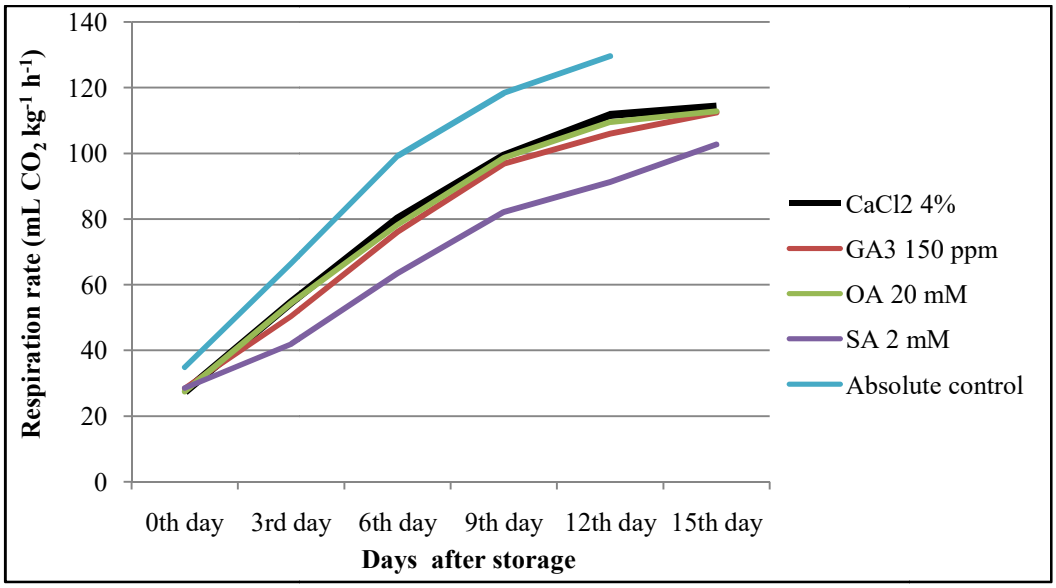

Fig. 2. Effect of postharvest treatments on respiration rate (mL CO_2 kg^{-1} h^{-1}) of banana cv. Nendran during storage

in inhibiting respiration and transpiration, restricting ethylene accumulation and production in fruits during ripening (Bhusan *et al.,* 2018).

5.1.2. Respiration rate (mL CO_2 kg^{-1} h^{-1})

Respiration plays an important role in postharvest ripening. The respiration rate has been found to increase with the process of ripening in all climacteric fruits (Srivastava and Dwivedi, 2000) and the rate of respiration is proportional to the rate of deterioration in harvested commodities (Irtwange, 2006). Being a climacteric fruit, banana has high respiration rate which leads to a shorter storage life (Gonge *et al*., 2013).

Respiration is a catabolic process in which organic materials like proteins, fats and carbohydrates are broken down into simple products with a release of energy (Hailu *et al*., 2013). The respiration rate of Nendran banana fruits increased in storage irrespective of the treatments. However, application of postharvest treatments resulted in reducing the respiration rate. Salicylic acid (2 mM) was found as the most effective treatment in reducing the respiration rate. The lowest respiration rate (91.27 mL CO_2 kg^{-1} h^{-1}) was observed in fruits treated with SA 2 mM, followed by GA_3 150 ppm (105.95 mL CO_2 kg^{-1} h^{-1}) and the highest respiration rate (129.58 mL CO_2 kg^{-1} h^{-1}) was observed in untreated fruits after 12 days of storage (Fig. 2). After 15 days of storage, SA 2 mM recorded the lowest respiration rate (102.70 mL CO_2 kg^{-1} h^{-1}) followed by GA_3 150 ppm with a respiration rate of 112.38 mL CO_2 kg^{-1} h^{-1}. This could be due to the effect of salicylic acid in reducing the respiration rate by inhibiting the ethylene biosynthesis or ethylene action (Srivastava and Dwivedi, 2000). Salicylic acid also acts as an electron donor and releases free radical which in turn retards the normal process of respiration (Wolucka *et al*., 2005).

The result is in confirmation with the findings of Mo *et al*. (2008) on the research of application of SA as postharvest treatment in sugar apple and (Nair, 2018) in banana cv. Nendran.

5.2. BIOCHEMICAL PARAMETERS

Changes in biochemical parameters such as moisture content, TSS, acidity starch, total sugar, reducing sugar, ascorbic acid, carotenoid and antioxidant activity of banana plays an important role in its nutritional quality. The present postharvest treatments slowed down the biochemical changes associated with ripening.

5.2.1. Moisture content (%)

Moisture content of the Nendran banana fruit pulp increased during storage period irrespective of the treatments. Significant variation was found in moisture content among the treatments. The Nendran banana fruits treated with SA 2 Mm recorded a gradual increase in moisture content from 54.6 % to 61.27 % during the period of 15 days of storage followed by GA_3 150 ppm. The fruits without postharvest treatment recorded the highest moisture content (63.40 %) after 12 days of storage and were discarded due to spoilage. The increase in moisture content might be attributed to the withdrawal of water through osmosis from banana peel to pulp and complete breakdown of starch to water and carbon dioxide (Hakim *et al*., 2013). Similar conclusions were also reported by Jomo *et al*. (2014) in banana cv. Sabri.

The moisture content of control fruit increased rapidly, while the banana fruits subjected to different post harvest treatments experienced a slower increase during 15 days of storage period. This could be due to the suppression of ACC oxidase ativity and reduction of ethylene production by salicylic acid, which in turn decreased the moisture content in fruits (Bal and Celik, 2010).

5.2.2. Starch (%)

Starch forms about 20 to 25% of the fresh weight of the pulp of unripe bananas (Hailu *et al*., 2013). During ripening, banana fruits cv. Nendran experienced a decrease in starch content irrespective of the postharvest treatments but the rate of decrease in starch content was lower in the treated fruits as compared to untreated fruits. Banana fruits treated with SA 2 mM recorded the highest starch content (10.44 %) followed by fruits treated with GA_3 150 ppm (9.74 %) and the lowest starch content (9.05 %) was recorded by untreated fruits at the end of 12 days of storage (Fig. 3).

Afshar- Mohammadian and Rahimi- Koldeh (2010) reported that during ripening, starch is degraded into simple soluble sugars which results in the accumulation of sucrose, glucose and fructose. Degradation of starch during ripening also provides flavor forming volatile compounds and carbon for the synthesis of sucrose (Saraiva *et al*., 2013). The highest retention of starch content (10.19 %) was recorded in fruits treated with SA 2 mM followed by GA_3 150 ppm (9.38 %) at the end of 15 days of storage. This is in agreement with the findings of Srivastava and Dwivedi (2000) that SA 2 mM restricted the activity of invertase in banana fruits, which in turn delayed the starch conversion into sugars and also fruit softening. This indicates the delay in ripening, as salicylic acid reduces the breakdown of starch into sugar by hindering the activity of amylase enzyme (Hu *et al*., 2009).

The fruits treated with GA_3 also experienced more retention of starch content during storage. Desai and Deshpande (1978) reported that a significant increase in firmness, starch, cellulose and hemicellulose contents were observed in banana fruits treated with gibberellic acid which may be due to the retardation of banana ripening. This is in agreement with the research on postharvest dipping of banana fruits in GA_3 (Rao and Chundawat, 1988) which delayed the hydrolysis of starch to sugars and reduced the ethylene production.

5.2.3. Total sugar (%)

During the process of ripening, accumulation of sugar is one of the main changes occurring in fruit composition (Li *et al*., 2011). The total sugar content of Nendran banana fruits exhibited an increment irrespective of the postharvest treatments. However, the rate of change varied among the treatments. This is in accordance with the findings of Tapre and Jain (2012) who concluded that a progressive rise in total sugar was noticed in banana during ripening. The total sugar content increased from 10.37 % at the time of storage to 21.27 % during the process of Nendran ripening at the end of 12 days of storage.

The increase in total sugar content could be due to the hydrolysis of starch into sugar during ripening (Marriott and Palmer 1980 and Terra *et al*.,1983) and also the

increased activity of enzymes related to the process of ripening like starch phosphorylase, α- amylase and β-amylase resulting in enhanced TSS and sugars (Mulagund *et al*., 2015).

Nendran banana fruits treated with SA 2 Mm recorded the lowest total sugar (20.21 %) content followed by fruits treated with GA_3 150 ppm (21.05 %) at the end of 15 days of storage. This is in conformity with the results of Prompyou and Supavanich (2014) in papaya.

GA_3 application reduced the total sugar content during the ripening process of banana cv. Nendran. This could be due to the ability of gibberellic acid in delaying the hydrolysis of starch to sugars by inhibiting the activity of enzymes related to ripening and retaining the level of organic acid that results in reduced sugar content in fruits at ripening (Mulagund *et al*., 2015).

5.2.4. Reducing sugar (%)

The reducing sugar of Nendran banana fruits increased during the storage and ripening irrespective of treatments. But the application of postharvest treatments efficiently reduced the rate of change during the storage. The lowest concentration of reducing sugar (16.72 %) was noticed in Nendran banana fruits treated with salicylic acid 2 mM followed by $GA_3$150 ppm (17.11 %) and the highest reducing sugar content was recorded in control fruits (20.37 %) after 12 days of storage which is in agreement with the findings of Li *et al*. (2011) in banana.

An increase in reducing sugar could be attributed to the increased breakdown of starch to soluble sugars (Beaudry *et al*., 1987) such as sucrose, fructose and glucose(Seymour and Tucker, 1993) and also due to the inversion of non reducing sugar to reducing sugar (Gol and Rao, 2011). Amongst the sugars, sucrose is the predominant sugar and its synthesis starts before the formation of glucose and fructose.

Each postharvest treatment had a different effect on the reducing sugar content of the treated fruits treated with salicylic acid 2 mM recorded the lowest sugar content (17.34 %) followed by GA_3 150 ppm with 17.80 % after 15 days of storage. This clearly

shows that postharvest treatments has a significant role in reducing the rate of biochemical changes related to starch sugar conversion during ripening.

Salicylic Acid inhibited the rise in reducing sugar content in fruits as it has a depressing effect on the activity of invertase which in turn delays the conversion of starch into soluble sugar in banana (Srivastava and Dwivedi, 2000). Khademi and Ershadi (2013) reported that salicylic acid reduces ethylene production in fruits which may result in lowered enzyme activity, leading to a decrease in the formation of sucrose synthesis. This was supported by the findings of Mohamed *et al.* (2012) in navel oranges.

Nendran banana fruits treated with GA_3 also recorded a decrease in reducing sugar content and similar result was reported by Hoa and Ducamp (2008) in mango and Gol and Rao (2011) in banana.

5.2.5. Total Soluble Solids (TSS) (^{0} Brix)

Total Soluble Solids (TSS) content of Nendran fruits is considered as an index of ripening in fruits. An increase in TSS of fruits was observed during the process of ripening. But the rate of increase was in a controlled manner in postharvest treated fruits. The Total Soluble Solid content increased from 2.75 ^{0}Brixto 23.84^0 Brixduring 12 days of storage. Similar result was also noticed by Tripathi *et al*. (1981), Abdullah *et al*. (1985) and Munasque and Mendoza (1990) in banana fruits.

An increase in TSS is due to the conversion of starch (Fisk 2006) and other form of polysaccharides into soluble sugar (Zomo *et al*., 2014) .The lowest concentration of TSS (24.60 ^{0} Brix) was noticed in Nendran banana fruits treated with salicylic acid 2 mM followed by $GA_3$150 ppm (25.03 ^{0}Brix) at the end of 15 days of storage. This could be due to the action of salicylic acid in decreasing the rate of breakdown of starch to sugar in banana which lowered the accumulation of soluble sugar (Hu *et al*., 2009). Salicylic acid treatment suppresses ethylene formationby inhibiting ACC synthase and ACC oxidase activities (Asghari and Aghdam, 2010). Similar result of gradual increase in TSS of fruits during storage and ripening was reported by Asghari (2006)in strawberry, Asghari and Aghdam (2010) and Bal and Celik (2010) in kiwi fruits, Fattahi

et al. (2010), Kazemi *et al*. (2011) in apple, Davarynejad *et al*. (2015) in plum and Nair (2018) in Nendran banana.The TSS of banana fruits treated with GA3 also experienced a slower increase during the storage which is supported by various research workers and similar result was reported by Alali *et al.* (2018) in banana fruits cv. Grand Naine.

5.2.6. Acidity (%)

Banana generally shows an increase in acidity during ripening and the main organic acid present in banana are malic, citric and oxalic acid (Palmer, 1971).Mean values of titratable acidity in banana showed a gradual increase during storage due to production of organic acids such malic acid and citric acid as during ripening(Yap *et al*., 2017).

During ripening, Nendran banana fruits treated with SA 2 mM and GA_3 150 ppm recorded the lowest titratable acidity (0.45 %) after 15 days of storage. This could be because salicylic acid has an antagonistic effect on the activity of malic synthase that corresponds to decarboxylation of malic acid in banana (Mandal *et al.*, 2016).

Similar resultwas obtained in orange (Aminifard *et al*., 2013) strawberry (Salari *et al*., 2013) and mango by Barman (2013). Gibberellic Acid was also found to delay the acid development during ripening of banana and is supported by Pinaki *et al.*(1997) in banana. This could be due to the general preservative effect of GA_3 that can possibly reduce respiration and oxidation processes by modifying the internal atmosphere of fruits (Maqbool *et al.,* 2011).

5.2.7. Carotenoids (mg $100g^{-1}$)

During ripening, the carotenoid content gradually increased in all the treatments but the rate of change decreased by the postharvest treatments. The highest carotenoids content (0.35 mg $100g^{-1}$) was observed in Nendran banana fruits kept in control without postharvest treatment while carotenoids content was the lowest (0.25 mg $100g^{-1}$) in fruits treated with SA 2 mM followed by fruits treated with GA_3 150 ppm (0.30mg $100g^{-1}$) at the end of 12 days of storage. This clearly shows that the postharvest treatments with SA and GA_3were efficient enough to delay ripening so that biochemical changes associated with carotenoid development is also influenced. This was in tune

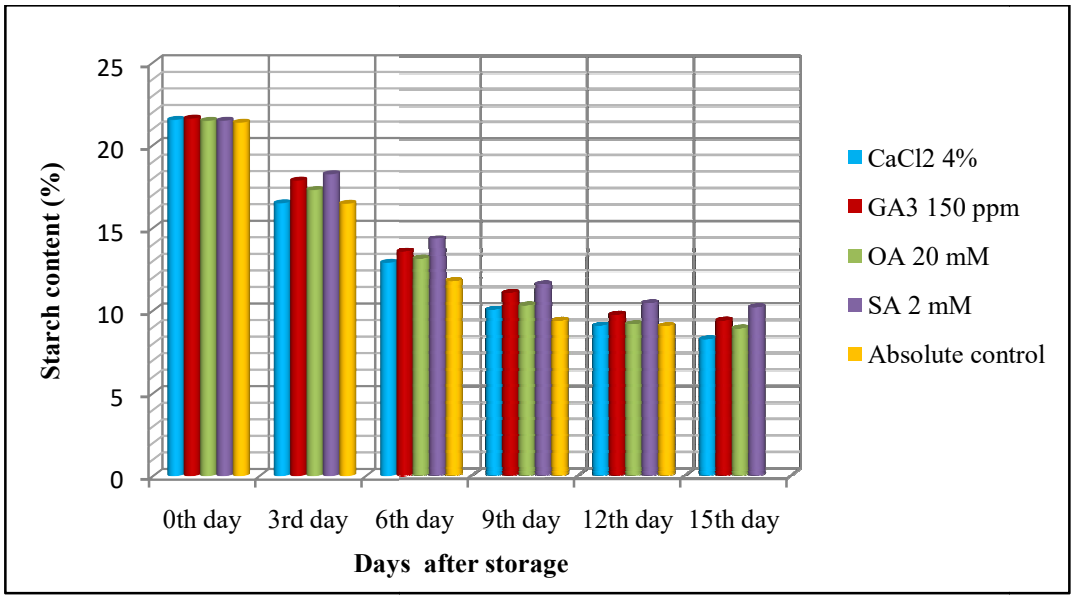

Fig. 3. Effect of postharvest treatments on starch content (%) of banana cv. Nendran during storage

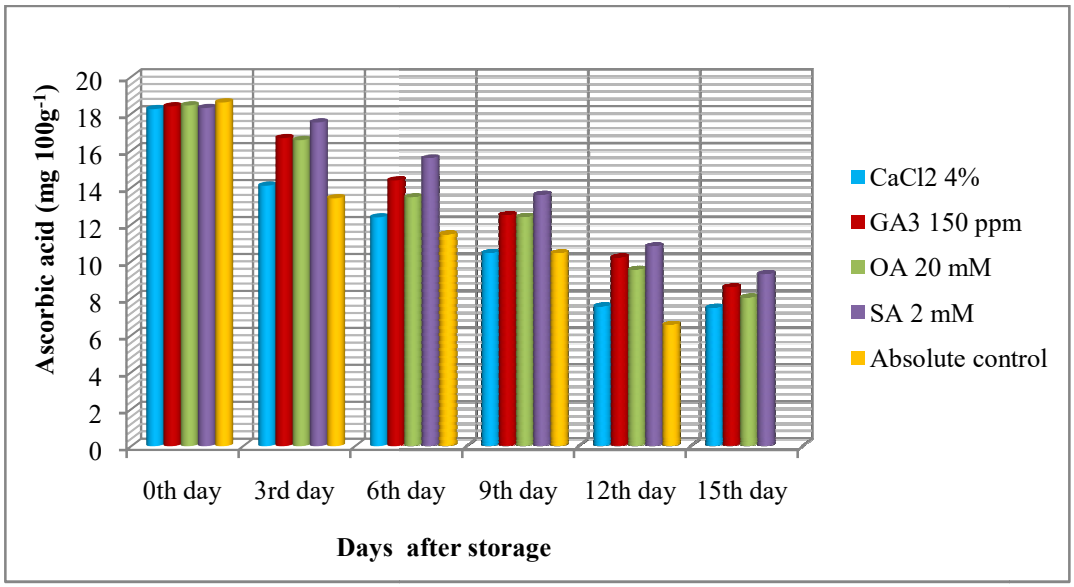

Fig. 4. Effect of postharvest treatments on ascorbic acid (mg $100g^{-1}$) of banana cv. Nendran during storage

with the findings of Gross and Flugel (1982) in banana and Pila *et al*. (2010) and Supapvanich and Promyou (2017) in papaya during ripening.

The postharvest treatment with GA_3 reduces the Mg-dechelatase and chlorophyllase activity which results in the degradation of chlorophyll (Ramma *et al*., 1999). The inhibition of chlorophyll degradation could have caused delaying carotenoids formation in banana and is supported by the studies of Rajkumar *et al*. (2005) in papaya, Deepak and Kathiyar (2008) and Patel and Padhiar (2010) in banana.

5.2.8. Ascorbic acid (mg $100g^{-1}$)

The ascorbic acid content of Nendran banana fruits subjected to postharvest treatments decreased with ripening. However, the postharvest treatments had an upper hand in the retention of ascorbic acid content. At the end of 12 days of storage, banana fruits treated with salicylic acid 2 mM recorded the highest retention of ascorbic acid content (10.81 mg $100g^{-1}$) followed by GA_3 150 ppm (10.20 mg $100g^{-1}$) whereas the untreated fruits recorded the least retention of ascorbic acid (6.55 mg $100g^{-1}$) (Fig. 4). The drop in the content of ascorbic acid can be attributed to the oxidation of ascorbic acid by oxidizing enzymes like ascorbic acid oxidase, catalase, polyphenol oxidase and peroxidase (Singh and Rao, 2005).

The fruits treated with SA 2 mM recorded the highest ascorbic acid content (9.30 mg $100g^{-1}$) followed by GA_3 150 ppm (8.59 mg $100g^{-1}$) after 15 days of storage also. The higher retention of ascorbic acid by Salicylic could be attributed to the activation of ascorbate peroxidase by salicylic acid, which in turn increased the antioxidant ability and ascorbic acid content in fruits (Wang *et al.*, 2006).

Rise in antioxidant activity and anti-stress power of fruits induced by SA, helps `in preventing the degradation of ascorbic acid (Wisniewska and Chelcowski, 1999). It is in tune with the findings of Sayyari *et al*. (2009) who reported that SA 2 mM was most effective for maintaining ascorbic acid content of pomegranate.

Similar findings were reported by Wang *et al.* (2006) in peach fruits; Kazemi *et al*. (2011) in apple; Akhtar *et al*. (2011) in loquat and Gunasekara *et al*. (2015) in banana fruits cv. Embul.

GA_3 treated fruits also recorded better ascorbic acid retention which could be attributed to the reduced oxidization of ascorbic acid into dehydro ascorbicacid and also alteration in the synthesis of carbohydrate and glucose which is considered to be the precursor of ascorbic acid. This is supported by the findings of Bhalerao *et al*. (2011) in banana.

5.2.9. Antioxidant activity (%)

Antioxidant activity of Nendran banana fruits decreased significantly with storage irrespective of treatments. However, a reduced rate of loss was observed in fruits stored after postharvest treatments. Nendran banana fruits treated with salicylic acid 2 mM recorded better retention of antioxidant activity (78.39 %) followed by GA_3 150 ppm (75.23 %) while the lowest (70.41 %) was recorded for untreated fruits at the end of 12 days of storage (Fig. 5).

The reduction in antioxidant activity may be due to the degradation of phenol and ascorbic acid during ripening process. Postharvest application of SA significantly helped in retention of antioxidant activity which may be attributed to the increase in total phenolics and DPPH radical scavenging activity and total phenolics are positively correlated with the antioxidant activity (Khademi and Ershadi, 2013).

Salicylic acid is also considered to stimulate the synthesis of antioxidant enzymes (Qin *et al*., 2003; Yao and Tian, 2005) and the application of 2 mM SA effectively maintained antioxidant activity in strawberry (Asghari, 2006), sugar apples (Mo *et al*., 2008), and cherry cv. Cornelian (Dokhanieh *et al*., 2013) and Kinnow mandarin (Haider *et al*., 2020).

Application of GA_3 as dipping also helped in retention of antioxidant activity in Nendran banana fruits. It is in tune with the findings of Addai *et al*.(2013) in papaya; Khaliqa *et al*. (2015) in mango and Nair (2018) in Nendran banana.

5.3 PHYSICAL PARAMETERS

The pulp and peel percentage, pulp to peel ratio, peel colour, and fruit firmness are considered to be the main physical indices in ripening of banana. All these factors

are correlated to ripening and senescence which in turn determine the quality and shelf life of banana.

There was significant increase in pulp percentage in all the treatments with storage which is negatively correlated with the peel percentage, which is the characteristic feature of banana ripening. However, postharvest treatments on banana fruits influenced the rate of change of pulp and peel percentage. Nendran banana fruits treated with SA 2 mM showed the minimum pulp percentage (70.61 %) followed by GA_3 150 ppm (73.32 %) at the end of 15 days of storage, while untreated fruits had the maximum pulp percentage (75.03 %) at the end of 12 days of storage which indicate the early ripening of fruits stored without postharvest treatments. The peel percentage decreased with the increase in pulp percentage, which could be attributed to increase in moisture content of the pulp, obtained from carbohydrates used in osmotic transfer from the peel to the pulp and respiration (Adao and Gloria, 2005).

After 15 days of storage, peel percentage of Nendran banana fruits treated with SA 2 mM was 29.39 % and the fruits without treatment recorded a minimum peel percentage of 24.97 % after12 days of storage. It is supported by the result obtained by Nair (2018) in banana. The reduction in peel percentage could be accounted to the osmotic transfer of water from the peel to the pulp with the rise in sugar content in pulp (Tapre and Jain, 2012).

Lizada and Esguerra (1990) reported that water is withdrawn from the peel to the pulp, gradually leading to reduction in peel thickness in banana during ripening. Patil and Shanmugasundaram (2015) concluded that cell wall undergoes modification with loss of firmness and ultimately resulted in void space causing reduction in peel percentage.

Pulp to peel ratio can be considered as a coefficient of ripeness in banana (Loesecke, 1950) and it generally decreases with ripening. Nendran banana fruits treated with SA 2 mM showed the minimum pulp to peel ratio (2.40) followed by GA_3 150 ppm (2.75) at the end of 15 days of storage indicating the delayed ripening, while untreated fruits had the maximum pulp to peel ratio (3.01) at the end of 12 days of

storage. This could probably be due to the difference in sugar concentration in the tissues of pulp and peel. The sugars in the pulp rapidly increases during ripening as compared to that in the peel resulted in a difference in osmotic pressure and consequently water is withdrawn from the peel to pulp (Asghari and Aghdam, 2010).

The result is in conformity with the findings of Adao and Gloria (2005),Jomo*et al*. (2014),Valérie Passo Tsamo *et al.* (2014), Mandal *et al*. (2016) and Muthal *et al*. (2019) in banana. This could be because SA affects the activities of different senescence related enzymes and lowers the rate of respiration and transpiration which in turn may be involved in controlling the weight loss from fruit peel and pulp (Haider *et al*., 2020).

Peel colour is considered as the index for ripening and senescence of banana. It is the main access to better market value as the right peel colour is usually all that is necessary for a choice to purchase the commodity by the consumer (Salvador *et al*., 2007).

The peel colour normally changes with storage and ripening of banana fruits. However, the rate of colour change was more pronounced in the untreated fruits (control) as against the fruits stored after postharvest treatments.

Optimum ripening colour (Stage VI-full yellow colour) was obtained after 9 days of storage in untreated Nendran banana fruits whereas it was developed only after 12 days of storage in fruits treated with SA 2 mM and GA_3 150 ppm. The increase in yellowness and degradation of greenness may occur due to the increased activity of chlorophyllase, peroxidase and chlorophyll oxidase (Jin and Park, 2001) which may result in the degradation of chlorophyll in the peel tissue (Tapre and Jain, 2012).

The slower rate of change in the salicylic acid treated fruits may be due to the suppression of ethylene production and consequently decreased degeneration of chlorophyll and biosynthesis of carotenoids, in the peel (Reddy *et al*., 2016). It is in agreement with the findings of Cheng *et al*. (2009) in mango cv. Kensingten Pride and Zaharah and Singh (2011) in banana.

Nendran banana fruits treated with GA_3 150 ppm also retained the optimum peel colour till12 days of storage. This could probably be due to the ability of GA_3in

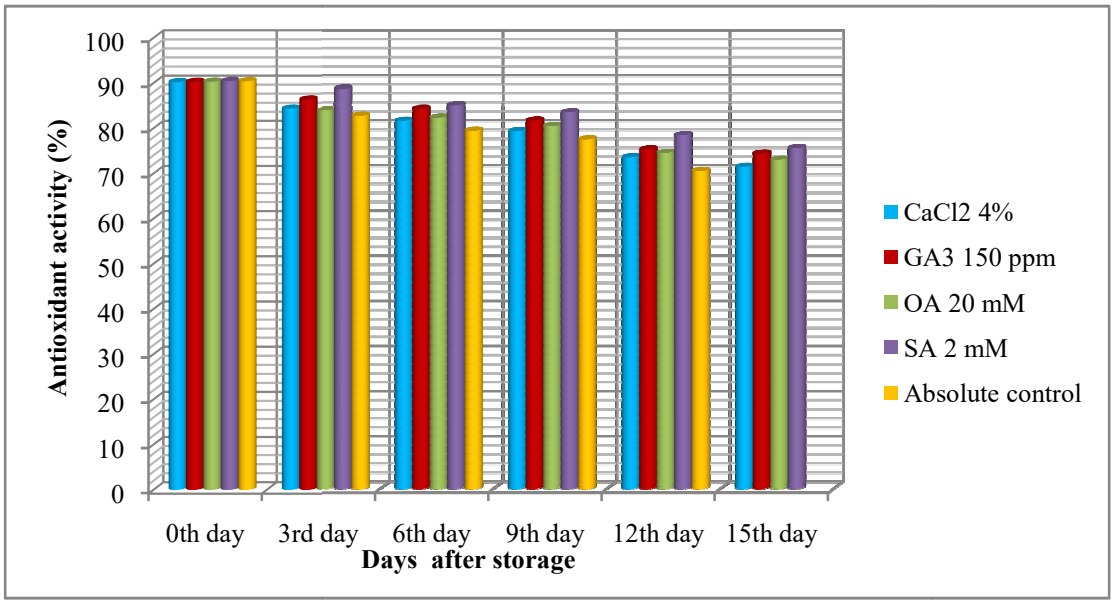

Fig. 5.Effect of postharvest treatments on antioxidant activity (%) of banana cv. Nendran during storage

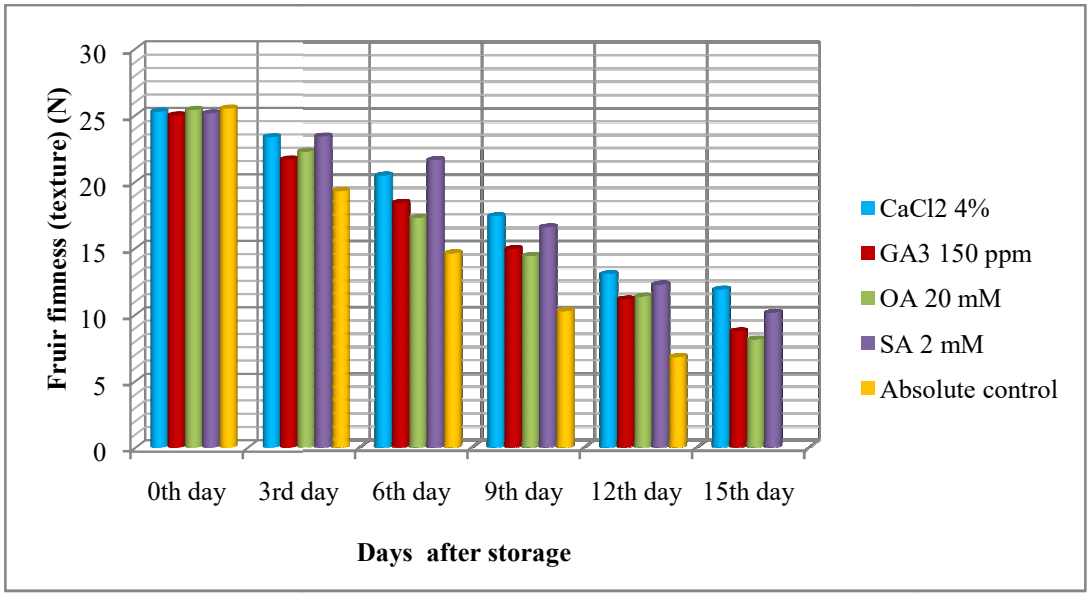

Fig.6. Effect of postharvest treatments on texture (fruit firmness) (N) of banana cv. Nendran during storage

regulating proteins and nucleic acid synthesis and thus retaining the chlorophyll moiety (Fletchner and Osborne, 1965). It is supported by the findings of Vendrell (1970) in banana and reported delayed chlorophyll degradation in banana and Khader (1992) in mango.

Fruit firmness is an excellent criterion for determining the shelf life (Hailu *et al*., 2013), ripeness and edible quality of bananas (Xiao*et al.*, 2018). The fruit firmness was found to decrease during storage of Nendran banana fruits irrespective of the treatments. But the fruits subjected to postharvest treatments recorded better retention of fruit firmness as compared to untreated fruits. Among them banana fruits treated with $CaCl_2$ 4% recorded the maximum retention of fruit firmness (11.88 N) followed by SA 2 mM (10.13 N) at the end of 15 days of storage. The minimum retention of fruit firmness (6.78 N) was observed in untreated fruits at the end of 12 days of storage (Fig.6).

The coordinated degradation of hemicellulosic, pectic polysaccharides in the cell wall and starch are considered to be the main reason for banana fruit softening (Mbeguie-A-Mbeguie *et al.*, 2009; Shiga *et al*., 2011).

The better retention of fruit firmness by $CaCl_2$ might be attributed to accumulation of calcium in the cell wall resulting in cross linking of pectic polymers which in turn increases the wall strength and wall cohesion (White and Broadley, 2003). This is in concordance with the findings of Ishaq *et al*. (2009) in apricot, Zhi *et al*. (2017) in peach.

Salicylic acid application decreased ethylene production and inactivates cell wall and membrane destroying enzymes such as lipoxygenase, polygalacturonase, pectinemethylesterase and cellulase leading to decreased rate of fruit softening (Srivastavaand Dwivedi, 2000). Salicylic Acid also affects cell swelling which results in higher firmness of fruits (Zhang *et al*., 2003). It is supported by the report of Wang *et al*. (2006) in banana, Shafiee *et al*. (2010) in strawberry, Soltani *et al*. (2011) in banana, Reddy *et al*. (2016) in mango cv. Amrapali and Nair (2018) in banana.

5.4. SENSORY PARAMETERS

The sensory attributes (organoleptic) such as appearance, colour, flavor, taste, texture and overall acceptability of banana fruits has a positive impact on the marketability and consumer acceptability. The scores assigned for these attributes increased up to optimum ripening stage (Macrae *et al*., 1989) and thereafter it declined (Brito and Narain, 2002).The Nendran banana fruits dipped in Salicylic Acid 2 mM followed by GA_3 150 ppm exhibited the maximum mean scores for all attributes after12^{th} and 15^{th} day of storage. The untreated fruits showed the maximum mean score till 9^{th} day of storage and thereafter dropped drastically indicating the senescence. Salicylic Acid retards ethylene production in climacteric fruit by inhibiting ACC oxidase production and thereby delays ripening (Supapvanich and Promyou, 2013).

Salicylic Acid treatment retained overall quality in strawberry cv. Selva (Babalar *et al.*, 2007), and in Kiwi fruits (Fattahi *et al*., 2010).The exogenous application of SA 2 mM as dipping improved the visual appearance, TSS, fruit firmness and colour of papaya cv. Holland (Supavanich and Promyou, 2017) and banana (Nair, 2018).

5.5. SHELF LIFE (DAYS)

The shelf life of banana fruits cv. Nendran was extended by the postharvest treatments by regulating the changes associated with physiological, biochemical, physical and sensory parameters.

The fruits treated with SA 2 mM recorded the longest shelf life (15.67 days) followed by GA_3 150 ppm (14.30 days) and the shortest shelf life was recorded by untreated fruits (11.13 days). Delay in fruit ripening and extended shelf life after SA treatment was also reported by Leslie and Romani (1986) and Zainuri *et al*. (2001) in pear, Srivastava and Dwivedi (2000) and Mandal *et al*. (2016) in banana.

Postharvest application of GA_3 was also efficient in increasing the shelf life as it hinders ethylene biosynthesis by its anti-senescent action (Mulagund *et al*., 2015). GA_3 application helps in reduction of permeability of tissue, thereby decreasing water loss rate leading to delayed fruit ripening (Nirupama *et al*., 2010). The findings are in

conformity with the reports of Khader (1992) in mango, Greany *et al*. (1994) in citrus and Osman and Abu- Goukh (2020) in Dwarf Cavendish banana.

Summary

SUMMARY

The experiment entitled "Postharvest quality management in banana cv. Nendran (*Musa* spp.)" was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, during the year 2018-2020, with the objective to standardize the postharvest management for delayed ripening and extended shelf life of banana cv. Nendran with minimum nutritional loss through postharvest handling practices. The major findings of the experiment are summarized below.

Good quality banana fruits (cv. Nendran) of uniform size and maturity were procured from the progressive farmers of Farmer Producer Organisation, Kalliyoor, Thiruvananthapuram. The de-handed fruits were washed and sanitized by ozonation (2 ppm) for 10 minutes. The sanitized Nendran banana hands were subjected to postharvest treatments*viz.* Calcium chloride ($CaCl_2$ 4 %), Gibberellic Acid (GA_3 150 ppm), Oxalic Acid (OA 20 mM) and Salicylic Acid (SA 2 mM) by dipping for 10 minutes along with Nendran fruits without any postharvest treatments as control. The treated fruits after the removal of excess moisture were stored in Corrugated Fibre Board boxes at room temperature (30±2 ^{0}C, RH 85-90 %). Effectiveness of the treatments was analysed based on the changes in physiological, biochemical, physical and sensory parameters during storage which were analysed at an interval of 3 days till the end of shelf life.

Physiological changes during storage of Nendran banana were influenced by the postharvest treatments. The least Physiological Loss in Weight (13.43%) was recorded for Nendran banana fruits dipped in SA 2 mM (T_4) followed by T_2 (GA_3 150 ppm) with 14.3 % after 15 days of storage at room temperature. The fruits without postharvest treatment (control), recorded the highest PLW of 15.21 % at the end of shelf life of 12 days.

The respiration rate of Nendran banana fruits increased during storage and the postharvest treatments helped in reducing the respiration rate. Fruits treated with salicylic acid 2 mM (T_4) treatment recorded the lowest respiration rate of 102.70 mL CO_2 kg^{-1} h^{-1} followed byT_2 (GA_3 150 ppm) with 112.38 mL CO_2 kg^{-1} h^{-1} after 15 days of

storage at room temperature. But during storage, Nendran banana without postharvest treatments exhibited the highest respiration rate of 129.58 mL CO_2 kg^{-1} h^{-1}after a storage period of 12 days. The postharvest treatments of Nendran banana helped in reducing the physiological activity of fruits during storage and thus delayed the ripening process.

The moisture content and biochemical parameters *viz.,* starch, total sugar, reducing sugar, TSS, acidity, carotenoids, ascorbic acid, antioxidant activity were assessed during the storage of fruits. The moisture content increased with the storage period and a lower rate of change was observed in fruits with postharvest treatments. Nendran banana fruits treated with SA 2 mM recorded the lowest moisture content (61.27 %) followed by GA_3 150 ppm with 61.81 % after 15 days of storage and the highest moisture content of 63.40 % was observed in untreated fruits after 12 days of storage. Starch content exhibited a decreasing trend on ripening and the fruits with SA 2 mM treatment recorded the maximum starch content of 10.19 % followed by GA_3 150 ppm with 9.38 % and the fruits without postharvest treatment (control) showed minimum starch content of 9.05 % after 12 days of storage.

The total sugar content increased during storage period reaching a maximum of 22.66 % in fruits without any treatment (control), at the end of 12 days of storage. The lowest total sugar content of 20.21% was recorded the treatment SA 2 mM followed by GA_3 150 ppm (21.05 %), at the end of 15 days of storage. Similarly, reducing sugar content of 17.34 % and 17.80 %was recorded for SA 2 mM and GA_3 150 ppm treated fruits respectively after 15 days of storage and 20.37 % reducing sugar content was recorded in fruits without any postharvest treatment at the end of 12 days of storage.

The TSS content of Nendran banana fruits increased with ripening and the highest TSS of 27.56 ^{0} Brix was recorded in fruitswithout any postharvest treatment (control) after12 days of storage and it was 24.60 ^{0} Brixfor SA 2 mM treatment followed by GA_3 150 ppm with 25.03 ^{0} Brix after 15 days of storage. The increase in titratable acidity with advancement in ripening is a characteristic feature of banana ripening. The acidity of Nendran banana fruits increased and reached the highest

content of 0.51 % in control fruits after 12th day of storage.However, the application postharvest treatments lowered the rate of change and the fruits treated with SA 2 mM and GA_3 150 ppm recorded the lowest titratable acidity.

The carotenoids content increased during the ripening of Nendran banana and the postharvest treatment with SA 2 recorded the lowest rate of change and recorded 0.29 mg 100g^{-1} content of carotenoid after 15 days of storage and the fruits without postharvest treatment recorded 0.35 mg 100g^{-1} after 12 days of storage. The ascorbic acid content decreased during ripening and the maximum retention of ascorbic acid (9.30 mg 100g^{-1}) was observed in fruits treated with SA 2 mM followed by GA_3 150 ppm (8.59 mg 100g^{-1}) after 15 days of storage. The fruits without any treatment (control) recorded the lowest ascorbic content of 6.55mg 100g^{-1} after 12 days of storage.The antioxidant activity of banana fruits treated with SA 2 mM recorded the highest antioxidant activity of 75.52 % followed by GA_3 150 ppm with 74.31 %, at the end of 15 days of storage and 78.39 % of antioxidant activity of was observed in fruits without any treatment (control) after 12 days of storage.

The physical attributes of Nendran banana such as pulp percentage, peel percentage, pulp to peel ratio, colour and texture (fruit firmness) were assessed during storage. The pulp percentage increased with the advancement of ripening and 75.03% of pulp was recorded by the fruits without any treatment (control) after 12 days of storage and it was 70.60% for fruits treated with SA 2 mM. The process of ripening was shown to be negatively correlated with peel percentage and SA 2 mM recorded 29.39 % after 15 days of storage. But the untreated fruits exhibited the minimum peel percentage of 24.97 % after 12th day of storage at room temperature.

The postharvest treatments with SA 2 mM recorded a pulp to peel ratio of 2.40 followed by GA_3 150 ppm with 2.75 after 15 days of storage and it was 3.01 after 12 days of storage. Peel colour of full yellow (Stage VI) was recorded for fruits treated with GA_3 150 ppm, OA 20 mM, and SA 2 mM after 12 days of storage and the fruits without any treatment (control) recorded yellow with brown spot (Stage VII) after 12 days of storage and were discarded due to spoilage. The highest retention of fruit

firmness (11.88 N) was recorded in fruits treated $CaCl_2$ 4% followed by SA 2 mM with 10.13 N after 15 days of storage.

The sensory qualities *viz*. appearance, flesh colour, flavor, taste, texture and overall acceptability were best maintained by dipping the Nendran banana fruits in SA 2 mM which exhibited the least sensory score on 9^{th} day and later highest score for all sensory attributes on 12^{th} and 15^{th} day of storage. But the untreated fruits (control) recorded the highest mean score of on 9^{th} day and it reduced with the advancement of storage. On analyzing the shelf life, banana fruits treated with SA 2mM recorded the longest shelf life of 15.67 days followed by 14.30 days for fruits treated with GA_3 150 ppm and the shortest shelf life of 11.13 days was recorded by fruits without any postharvest treatment.

On the basis of physiological, biochemical, physical and sensory analysis, postharvest treatment of banana fruits cv. Nendran treated with SA 2 mM as dipping for 10 minutes was standardized as the best treatment for delayed ripening and extended shelf life of 15.67 days with minimum nutritional loss for storage under room temperature.

FUTURE LINE OF WORK

The present study confirmed that the application of postharvest treatments could be used for delaying the ripening and extending the shelf life of Nendran banana. The technology developed can be commercialized after authenticating in the present marketing system as future line of work which will help farmers to get better returns and can reduce the postharvest loss.

References

7. REFERENCES

Abdallah, E. K. H. and Abu-Goukh, A. B. A. 2019.Effect of gibberellic acid and waxing on quality and storability of lime fruits. *Univ. of Khartoum J. Agric. Sci.* 18(3).

Abdullah, H., Zaipun, M. Z., and Rohaya, M. A. 1985.Maturity indices of banana (*Musa sapientum* cv. Berangan). *Res. Bull.* 2(2): 56-76.

Abu-Goukh, A. B. A. and Mohamed-Nour, I. A. 2019.Effect of Gibberellic Acid and Waxing onQuality and Shelf Life of Guava (Psidium guajava L.)Fruits. *Univ. Khartoum J. Agric. Sci.*25(2): 181-194.

Adao, R. C. and Glória, M. B. A. 2005.Bioactive amines and carbohydrate changes during ripening of Prata banana (*Musa acuminata* × *Musa balbisiana*). *Food Chem*. 90(4):705-711.

Addai, Z. R., Abdullah, A., Mutalib, S. A., and Musa, K. H. 2013.Effect of gum arabic on quality and antioxidant properties of papaya fruit during cold storage.*Int. J. Pharm. Tech. Res.* 5: 2854–2862.

Afshar-Mohammadian, M. and Rahimi-Koldeh, J. 2010.The comparison of carbohydrate and mineral changes in three cultivars of kiwifruit of Northern Iran during fruit development. *Aust. J. Crop Sci.* 4(1): 49.

Aghdam, M. S., Motallebiazar, A., Mostofi, Y., Moghaddam, J. F., and Ghasemnezhad, M. 2009. Effects of MeSA vapor treatment on the postharvest quality of Hayward kiwifruit. *Proceedings of the VI Int. Postharvest Symp.*8-12 April.2009, Antalya, Turkey: 43-748.

Aghofack, J. N. and Yambou, T. N. 2005.Effects of Calcium chloride and magnesium sulphate treatments on the shelf-life of climacteric banana and non-climacteric pineapple fruits. *Cameroon J.Exp.Biol.* 1(1): 34-38.

Ahmed, O. K. and Tingwa, P. O. 1995. Effect of gibberellic acid on several parameters of ripening banana fruits (*Musa* sp. cv. Dwarf cavendish). *Univ. of Khartoum J. Sci*. 21(2): 76-84.

Ajayi, A. R. and Mbah, G. O. 2007. Identification of indigenous ripening technologies of banana and plantain fruits among women-marketers in southeastern Nigeria. *Agric. Sci*. 6(2): 60-66.

Akhtar, M., Chan, P., Safriani, N., Murray, B., and Clayton, G. 2011.Concentration of apple juice using spinning disc reactor technology. *J. Food Processing Technol. 2*: 2.

Alali, A. A., Awad, M. A., Al-Qurashi, A. D., and Mohamed, S. A. 2018. Postharvest gum Arabic and salicylic acid dipping affect quality and biochemical changes of Grand Naine bananas during shelf life. *Sci. Hortic.* 237: 51-58.

Ali, M., Liu, M. M., Wang, Z. E., Li, S. E., Jiang, T. J., and Zheng, X. L. 2019. Pre-harvest spraying of oxalic acid improves postharvest quality associated with increase in ascorbic acid and regulation of ethanol fermentation in kiwifruit cv. Bruno during storage. *J. Integrative Agric.* 18(11): 2514-2520.

Al-Qurashi, A. D. and Awad, M. A. 2019. Postharvest gibberellic acid, 6-benzylaminopurine and calcium chloride dipping affect quality, antioxidant compounds, radical scavenging capacity and enzymes activities of Grand Naine bananas during shelf life. *Sci. Hortic.*253: 187-194.

Aminifard, M. H., Mohammadi, S., and Fatemi, H. 2013. Inhibition of green mould in blood orange (*Citrus sinensis* var. Moro) with salicylic acid treatment. *Arch. Phytopathol. Plant Prot.* 46(6): 695-703.

Anjum, M. A. and Ali, H. 2004. Effect of various calcium salts on ripening of mango fruits. *J. Res. Sci.* 15(1): 45-52.

Archana, U. and Sivachandiran, S. 2015. Effect of application of gibberellic acid (GA_3) on shelf-life of banana.*Int. J. Res. Agric. Food Sci*. 3(1): 2311-2476.

Asghari, M. 2006. Effects of salicylic acid on Selva strawberry fruit, antioxidant activity, ethylene production and senescence, fungal contamination and some other quality attributes. *J.Tehran Univ.* 23: 14-15.

Asghari, M. and Aghdam, M. S. 2010.Impact of salicylic acid on postharvest physiology of horticultural crops.*Trends Food Sci. Technol*. 21: 502-509.

Asghari, M., Ahadi, L., and Riaie, S. 2013. Effect of salicylic acid and edible coating based aloe vera gel treatment on storage life and postharvest quality of grape (*Vitis vinifera* L. cv. Gizel Uzum). *Int. J. Agric. Crop Sci.*5(23): 2890-2898.

Atia, A., Abdelkarim, D., Younis, M., and Alhamdan, A. 2018. Effects of Gibberellic Acid (GA_3) and Salicylic Acid (SA) postharvest treatments on the quality of fresh Barhi dates at different ripening levels in the Khalal maturity stage during controlled atmosphere storage. *Int. J. Agric. Biol. Eng.* 11(3): 211-219.

Attiq, A., Abbasi, N. A., and Azhar, H. 2010. Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. *Pakist. J. Bot.* 42(1): 181-188.

Babalar, M., Asghari, M., Talaei, A., and Khosroshahi, A. 2007.Effect of pre- and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of Selva strawberry fruit.*Adv. Hort. Sci*. 30(3): 183-192.

Bains, B. K., Sharma, M., and Singh, S. K. 2017.Quality regulation in banana through post-harvest treatment with ethylene and ethylene inhibitors. *Res. Crops*. 18(4): 656-661.

Bal, E. 2018. Combined Treatment of Modified Atmosphere Packaging and Salicylic Acid Improves Postharvest Quality of Nect arine (*Prunus persica* L.)Fruit. *Plant Physiol*. 65(2): 218-225.

Bal, E. and Celik, S. 2010. The effects of postharvest treatments of salicylic acid and potassium permanganate on the storage of kiwifruit. *Bulgarian J. Agric. Sci*. 16(2): 576-584.

Barman, K. 2013. Biologically safe approaches to control sap burn, chilling injury and postharvest diseases of mango. Ph.D. thesis, IARI, New Delhi, India. 142p.

Barman, K. and Asrey, R. 2014. Salicylic acid pre-treatment alleviates chilling injury, preserves bioactive compounds and enhances shelf life of mango fruit during cold storage. *J. Sci. Ind. Res*. 73(11): 713-718.

Beaudry, R. M., Paz, N., Black, C. C., and Kays, S. J. 1987. Banana ripening: implications of changes in internal ethylene and CO2 concentrations, pulp fructose 2, 6-bisphosphate concentration, and activity of some glycolytic enzymes. *Plant physiol*. 85(1): 277-282.

Bhalerao, P.B., Parmar, B. V., Padhiar, R. R., and S. B. Parmar. 2011. Effect of growth regulators on postharvest life of banana cv. Grand Naine. *Asian J. Hort.* 6(2): 283-287.

Bhusan, L. P., Das, A. K., Dash, D. K., Dash, S. N., Swain, S., and Pradhan, B. 2018. Influence of post-harvest application of GA and Ca on shelf-life of banana (*Musa* spp.) cv. grand naine. *J. Pharmacog. Phytochem.* 7(2): 3132-3135.

Brar, J. S., Gupta, N., and Gill, M. S. 2014. Effect of pre and post-harvest treatments of salicylic acid on quality characteristics of peach (*Prunus persica* L.) fruits during storage. *Prog.Hortic.* 46(2): 217-221.

Brito, E. S. D. and Narain, N. 2002. Physical and chemical characteristics of sapota fruit at different stages of maturation. *Pesquisa Agropecuária Brasileira*. 37(4): 567-572.

Cao, S., Hu, Z., Zheng, Y., and Lu, B. 2013.Synergistic effect of heat treatment and salicylic acid on alleviating internal browning in cold-stored peach fruit. *Postharvest Biol. Technol.* 58(2): 93-97.

Chardonnet, C. O., Charron, C. S., Sams, C. E., and Conway, W. S. 2003. Chemical changes in the cortical tissue and cell walls of calcium-infiltrated 'Golden Delicious' apples during storage. *Postharvest Biol. Technol.* 28(1): 97-111.

Cheng, G., Yang, E., Lu, W., Jia, Y., Jiang, Y., and Duan, X. 2009. Effect of nitric oxide on ethylene synthesis and softening of banana fruit slice during ripening.*J. Agri. Food Chem.* 57: 5799-5804.

Dalvadi, A. C., Dodiya, K. D., Bhad, D. M., Chaudhari, T., and Trambadiya, R. 2018.Effect of chemicals on shelf life of (*Syzygium cuminii* Skeels) cv. Local. *Agric. Sci. Digest-A Res. J.* 38(1): 68-70.

Dasu, R., Kumar, B. P., Rajasekhar, M., and Suneetha, S. 2016.Effect of growth regulators on post harvest shelf life and quality of papaya (*Carica papaya* L.) cv. Red Lady.*Environ. Ecol*. 34 (3): 1037-1040.

Davarynejad, G. H., Zarei, M., Nasrabadi, M. E., and Ardakani, E. 2015.Effects of salicylic acid and putrescine on storability, quality attributes and antioxidant activity of plum cv. Santa Rosa. *J. Food Sci. Technol*. 52(4): 2053-2062.

Deepak P. N. and Kathiyar J. P. 2008. Effect of post-harvest chemical treatments onshelf life of physico chemical quality of banana cv. Harichal.*Asian J. Hortic*. 3: 386-388.

Desai, B. B. and Deshpande, P. B. 1978.Chemical control of ripening in banana. *Physiol. Plant.* 44(3): 238-240.

Dokhanieh, A. Y., Aghdam, M. S., Fard, J. R., and Hassanpour, H. 2013. Postharvest salicylic acid treatment enhances antioxidant potential of cornelian cherry fruit. *Sci. Hortic.* 154: 31-36.

Duguma, T., Egigu, M. C., and Muthuswamy, M. 2014.The effects of gibberellic acid on quality and shelf life of banana (*Musa* spp.). *Int. J. Curr. Res. Rev.* 6(23): 63-69.

El-Boray, M. S., Mostafa, M. F., Hosam El-Deen, A. S., and Emam, M. F. 2015. Influence of pre-and post-harvest applications of some antioxidants and biochemicals on prolonging marketable life of Williams banana fruits. *J. Plant Prod.* 6(4): 423-446.

Esguerra, E. B., Hilario, D. C. R., and Absulio, W. L. 2008.Control of finger drop in'Latundan'banana (*Musa acuminata* AA group) with preharvest calcium spray.*Asia Pac. Symposium on Assuring Quality and Safety of Agri-Foods* 837: 167-170.

Eugene, P.T., Ovaric, K. J., and Jean, A. N. 2019.Effects of Calcium Chloride Treatment on the Photosynthetic Capacity and Intensity of Banana Fruit during Ripening. *J. Adv. Biol. Biotechnol.* 6(1):1-9.

Ennab, H. A., El-Shemy, M. A., and Alam-Eldein, S. M. 2020.Salicylic Acid and Putrescine to Reduce Post-Harvest Storage Problems and Maintain Quality of Murcott Mandarin Fruit. *Agron.*10(1): 115.

Fattahi, J., Fifall, R., and Babri, M. 2010. Postharvest quality of kiwifruit (*Actinidia deliciosa* cv. Hayward) affected by pre-storage application of salicylic acid. *S. West. J. Hortic. Biol. Environ*. 1(2): 175-186.

Fisk, C. L. 2006. Investigation of postharvest quality and storability of Hardy kiwifruit (*Actinidia arguta* 'Ananasnaya'). M. Sc. thesis, Oregon State University, USA, 230p.

Fletchner, R. A. and Osborne, D. J. 1965. Regulation of protein and nucleic acid synthesis by gibberellin during leaf senescence.*Nature.*207: 1176-1177.

Gautam, S. K. and Chundawat, B. S. 2005. Postharvest Changes in Sapota Cv.'Kalipatti': I-Effect of various postharvest treatments on biochemical changes. *Indian J. Hortic.*46(3): 310-315.

Giménez, M. J., Serrano, M., Valverde, J. M., Martínez-Romero, D., Castillo, S., Valero, D., and Guillén, F. 2017. Preharvest salicylic acid and acetylsalicylic acid treatments preserve quality and enhance antioxidant systems during postharvest storage of sweet cherry cultivars. *J. Sci. Food Agric.* 97(4): 1220-1228.

Gol, N. B., Patel, P. R., and Rao, T. R. 2013. Improvement of quality and shelf-life of strawberries with edible coatings enriched with chitosan. *Postharvest Biol. Technol.* 85: 185-195.

Gol, N. B. and Rao. T. V. R. 2011. Banana fruit ripening as influenced by edible coatings. *Int. J. Fruit Sci*. 11(2): 119-135.

Gonge, A. P., Patel, N. L., Ahlawat, T. R. and Patil, S. J. 2013.Effect of maturity and storage temperature on shelf-life and quality of banana cv. Grand Naine. *J. Hortic. Sci.* 8(1): 95-98.

Gholami, M., Sedighi, A., Ershadi, A., and Sarikhani, H. 2009.Effect of pre-and postharvest treatments of salicylic and gibberellic acid on ripening and some physicochemical properties of'mashhad'sweet cherry (Prunus avium L.) fruit.*XI International Symposium on Plant Bioregulators in Fruit Production.*884: 257-264.

Greany, P. D., Mc Donald, R. E., Schroeder, W. J., Shaw, P. E., Aluja, M., and Malavasi, A. 1994. Use of gibberellic acid to reduce citrus fruit susceptibility to fruit flies.*J. Food Sci*. 76: 234-239.

Gross, J. and Flugel, M. 1982. Pigment change in peel of the ripening banana (Cavendishl). *Pure Appl. Chem.* 47: 62-64.

Gunasekara, S. R. W., Hemamali, K. K. G. U., Dayananada, T. G., and Jayamanne, V. S. 2015. Post harvest quality analysis of Embul banana following artificial ripening techniques. *Int. J. Sci. Environ. Technol.* 4(6): 1625-1632.

Haider, S. A., Ahmad, S., Khan, A. S., Anjum, M. A., Nasir, M., and Naz, S. 2020. Effects of salicylic acid on postharvest fruit quality of “Kinnow” mandarin under cold storage. *Sci.Hortic.*259: 108843.

Hakim, K. A., Sarkar, M. A. R., Khan, M. Z. H., Rahman, S. M., Ibrahim, M., and Islam, M. K. 2013.Effect of post-harvest treatmnets on physico-chemical characters during storage of two banana (*Musa* spp. L.) cv. Sabri and Amritasagar.*Int. J. Biosci*. 3: 168-179.

Hiwale, S. S. and Singh, S. P. 2003. Prolonging shelf-life of guava (*Psidium guajava* L.). *Indian J. Hortic*. 60(1): 1-9.

Hoa, T. T. and Ducamp, M. 2008. Effects of different coatings on biochemical changes of 'cat Hoa loc' mangoes in storage.*Postharvest Biol. Technol*. 48:150–152.

Hailu, M., Workneh, T. S., and Belew, D. 2013. Review on postharvest technology of banana fruit. *Afr. J. Biotechnol*. 12(7): 53-65.

Hu, H. Mo, Y. Xie, J. Zhang, I. Gu, H., and Gong, D. 2009. Effect of salicylic acid on antioxidation capacity and preservation of post-harvested banana fruits.*Food Sci.* 2: 239-244.

Huang, H., Jing, G., Guo, L., Zhang, D., Yang, B., Duan, X., Ashraf, M., and Jiang, Y. 2013. Effect of oxalic acid on ripening attributes of banana fruit during storage. *Postharvest Biol. Technol.* 84: 22-27.

Huang, R., Xia, R., Lu, Y., Hu, L., and Xu, Y. 2008. Effect of pre-harvest salicylic acid spray treatment on post-harvest antioxidant in the pulp and peel of 'Cara cara' navel orange (*Citrus sinensis* L. Osbeck). *J. Sci. Food Agric*. 88(2): 229-236.

Irfan, P. K., Vanjakshi, V., Prakash, M. K., Ravi, R., and Kudachikar, V. B. 2013. Calcium chloride extends the keeping quality of fig fruit (*Ficus carica* L.) during storage and shelf-life. *Postharvest Biol. Technol.* 82: 70-75.

Irtwange, S.V. 2006.Application of modified atmosphere packaging and related technology in postharvest handling of fresh fruits and vegetables. *Agric. Eng. Int.*71(2): 121.

Ishaq, S., Rathrore, H. R. A., Masud, T., and Ali, S. 2009. Influence of post-harvest calcium chloride application, ethylene absorbent and modified atmosphere on quality characteristics and shelf-life of apricot (Prunus armeniaca L.) fruit during storage. *Pakst. J. Nutr.* 8:861–865.

Jaishankar, H. and Kukanoor, L. 2016. Effect of post harvest treatments on physiological changes of sapota cv. Kalipatti at ambient storage. *Adv. Agric*. 2942p.

Jin, C. Q. and Park, S. M. 2001. The fractal behavior of polyaniline–dodecyl benzene sulfonate salt and polyaniline–chlorophyll studied by small-angle X-ray scattering. *Synthetic metals*. 124(3): 443-447.

Jogdand, S., Bhat, S., Misra, K., Kshirsagar, A., and Lal, R. 2017. New promising molecules for ethylene management in fruit crops, 1-MCP and nitric oxide: a review. *Int. J. Chem. Stud.* 5(3): 434-441.

Jomo, S. A., Ismail, S. M., Shahjahan, M., Ali, S. H., Mahmud, M. A. A., and Hosain, M. T. 2014. Physical Changes And Shelf Life Of Banana As Influenced By Different Postharvest Treatments. *Adv. Agric*. *Biol.* 2(1): 13-17.

Jones, R. W. and Lunt, O. R. 1967.The function of calcium in plants. *Bot.Rev.* 33(4): 407-426.

Joyce, D. C., Wearing, H., Coates, L., and Terry, L. 2001.Effects of phosphonate and salicylic acid treatments on anthracnose disease development and ripening of Kensington Pride mango fruit. *Aust. J. Exp. Agric.* 41(6): 805-813.

Kader, A. A. 2002. Quality parameters of fresh-cut fruit and vegetable products. *Fresh-cut fruits and vegetables.*20-29pp.

Kader, A. A. and Saltveit, M. E. 2003. Respiration and gas exchange. *Postharvest physiol.Pathol. Veg.* 2: 7-29.

Kadu, R. V. and Gajipara, N. N. 2009.Effect of post harvest treatments on quality of Sapota. *BIOINFOLET- Q. J. Life Sci.* 6(3): 271-273.

Kazemi, M., Aran, M., and Zamani, S. 2011.Effect of salicylic acid treatments on quality characteristics of apple fruits during storage.*Am. J. Plant Physiol.* 6(2): 113-119.

Koyuncu, M. A., Erbas, D., Onursal, C. E., Secmen, T., Guneyli, A., and Uzumcu, S.S. 2019. Postharvest treatments of salicylic acid, oxalic acid and putrescine influences bioactive compounds and quality of pomegranate during controlled atmosphere storage. *J. Food Sci. Technol.* 56(1): 350-359.

Khader, S. E. S. A. 1992. Effect of gibberellic acid and vapor gard on ripening, amylase and peroxidase activities and quality of mango fruits during storage. *J. Hortic. Sci.* 67(6): 855-860.

Khaliq, G., Mohamed, M. T. M., Ali, A., Ding, P., and Ghazali, H. M. 2015. Effect of gum arabic coating combined with calcium chloride on physico-chemical and qualitative properties of mango (Mangifera indica L.) fruit during low temperature storage. *Sci. Hortic.* 190: 187-194.

Kudachikar, V. B., Kulkarni, S. G., and Prakash, M. K. 2011.Studies on physico-chemical changes during artificial ripening of banana (*Musa* sp.) variety 'Robusta'. *J. Food Sci. Technol.* 48(6): 730-734.

Kumar, D., Mishra, D. S., Chakraborty, B., and Kumar, P. 2013. Pericarp browning and quality management of litchi fruit by antioxidants and salicylic acid during ambient storage. *J. Food Sci. Technol.* 50(4): 797-802.

Kumar, C.N., Sathyanarayana, B.N., Naresh, P., and Lakshmipathy, M. 2011. Effect of certain pre harvest treatments in improving the yield and quality of banana cv. Nanjangudu Rasabale. *Plant Arch.* 11(2): 677-681.

Kazemi, M., Aran, M., and Zamani, S. 2011.Effect of salicylic acid treatments on quality characteristics of apple fruits during storage. *Am. J. Plant Physiol.* 6(2): 113-119.

Khademi, O., Ashtari, M., and Razavi, F., 2019. Effects of salicylic acid and ultrasound treatments on chilling injury control and quality preservation in banana fruit during cold storage. *Sci. Hortic*. 249*:* 334-339.

Khademi, Z. and Ershadi, A. 2013. Postharvest application of salicylic acid improves storability of peach (*Prunus persica* cv. Elberta) Fruits. *Int. J. Agric. Crop Sci.* 5(6): 651-655.

Leslie, C.A. and Romani, R.J. 1986. Salicylic acid: a new inhibitor of ethylene biosynthesis. *Plant Cell Rep*.5(2): 144-146.

Li, W., Shao, Y., Chen, W., and Jia, W. 2011.The effects of harvest maturity on storage quality and sucrose-metabolizing enzymes during banana ripening. *Food Bioprocess Technol.* 4(7): 1273-1280.

Lizada, M.C.C. and Esguerrra, E.B. 1990. The postharvest behaviour and quality of carabao mangoes subjected to vapor heat treatment. *Asian Food J.* 5(1): 6-11.

Loay, A. A. 2017. Preharvest salicylic acid and delay ripening of 'Superior Seedless' grapes. *Egypt. J. Basic Appl. Sci.* 4(3): 227-230.

Lo'ay, A.A. and Dawood, H.D. 2017. Minimize browning incidence of banana by postharvest active chitosan/PVA Combines with oxalic acid treatment to during shelf-life. *Sci. Hortic.* 226: 208-215.

Loesecke. 1950. Some aspects of physico-chemical changes in ripening bananas during ripening in storages. *Prog. Hort*. 14(1): 79-84.

Lu, X., Sun, D., Li, Y., Shi, W., and Sun, G. 2010. Pre and post- harvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit. *Sci. Hortic*. 130: 97-101.

Luo, Z., Chen, C., and Xie, J. 2011. Effect of salicylic acid treatment on alleviating postharvest chilling injury of Qingnai plum fruit. *Postharvest Biol. Technol.* 62(2): 115-120.

Macrae, E. A., Lallu, N., Searle, A. N., and Bowen, J. H. 1989. Changes in the softening and composition of kiwifruit (*Actinidia deliciosa*) affected by maturity at harvest and postharvest treatments. *J. Sci. Food Agric.* 49(4): 413-430.

Macwan, R. M., Vihol, N. J., and Patel, K. A. 2012.Effect of post harvest application of growth regulators, wax emulsion and packaging on physical characters and shelf life of banana cv. Robusta. *Asian J. Hortic.* 7(2): 541-545.

Mandal, D., Lalrindika, E., Hazarika, T. K., and Nautiyal, B. P. 2016. Postharvest application of salicylic acid enhanced Shelf life and maintained quality of banana cv. 'Grand Naine' at ambient storage. *The Bioscan.* 11(1): 265-270

Mandal, D., Pachuau, L., Hazarika, T.K., and Shukla, A.C. 2018. Post-harvest application of salicylic acid enhanced shelf life and maintained quality of local mango cv Rangkuai of Mizoram at ambient storage condition. *Environ. Ecol.* 36(4): 1057-1062.

Manthe .B., Schulz, M., and Schnabl, H. 1992. Effects of salicylic acid on growth and stomatal movements of *Vicia faba*. L. *J. Chem. Ecol.* 18(9): 1525-1539

Maqbool, M., Ali, A., Alderson, P.G., Zahid, N., and Siddiqui, Y., 2011. Effect of a novel edible composite coating based on gum arabic and chitosan on biochemical and physiological responses of banana fruits during cold storage. *J. Agric. food chem.* 59(10): 5474-5482.

Marriott, J. and Palmer, J.K., 1980. Bananas—physiology and biochemistry of storage and ripening for optimum quality. *Crit. Rev. Food Sci. Nutr.* 13(1): 41-88.

Mathew, A. 2013.Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.).MSc. (Hort) thesis, Kerala Agricultural University, Thrissur, 120p.

Mbéguié-A-Mbéguié, D., Hubert, O., Baurens, F.C., Matsumoto, T., Chillet, M., Fils-Lycaon, B., and Sidibé-Bocs, S. 2009. Expression patterns of cell wall-modifying genes from banana during fruit ripening and in relationship with finger drop. *J. Exp. Bot.* 60(7): 2021-2034.

Mohamed, M. A. A., El-Mehrat, H. G., and Salem, A. S. E. 2012. Effect of postharvest treatments with salicylic acid and chito-care on navel orange fruits quality and storability compared with the commercial postharvest fungicide treatment. *J.Plant Prod.* 3(12): 3069-3082.

Mo, Y., Gong, D., Liang, G., Han, R., Xie, J., and Li, W. 2008.Enhanced preservation effects of sugar apple fruits by salicylic acid treatment during post-harvest storage. *J. Sci. Food Agric.* 88(15): 2693-2699.

Mulagund, J., Porika, H., Soorianathasundaram, K., and Deepika, C. 2015. Influence of growth regulators combined with chemicals to improve post-harvest fruit quality in banana cv. Nendran (*Musa* AAB). *J. Food Processing Technol*. 6(3): 1.

Munasque, V.S. and Mendoza, D. B. 1990.Developmental physiology and ripening behaviour of Senorita banana (*Musa* sp. L.) fruits. *Asian Food J.* 5(4): 152-157.

Muthal, T., Harini, R., Sunil, C., and Chidanand, D. 2019.Effect of Artificial Ripening Techniques on Physico-Chemical Properties of Banana (*Musa* sp.)Variety 'Poovan'. *Int. J. Pure App. Biosci*. *7*(2): 482-489.

Nagaraja, K., Chandrappa, H., Ramappa, P., Kumar, B. M. A., and Sannathimappa, H. G. 2011.Effect of calcium chloride for enhancing shelf life of custard apple fruits (*Annona squamosa* L.) during storage. *Environ. Ecol.* 29(2): 487-493.

Nair, A. M. 2018. Postharvest treatments for delayed ripening in Nendran banana (*Musa* spp.)M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur, 125p.

Nirupama, P., Gol, N. B., and Rao, T. R. 2010.Effect of post harvest treatments on physicochemical characteristics and shelf life of tomato (*Lycopersicon esculentum* Mill.) fruits during storage. *Am.Eurasian J. Agric. Environ. Sci.* 9(5): 470-479.

NHB [National Horticultural Board]. 2018. Indian Horticultural Board [online]. Available:http://nhb.go.in.area-pro/database-2019.pdf. [25 April 2020].

Osman, H. E. and Abu-Goukh, A. B. A. 2020.Effect of polyethylene film lining and gibberellic acid on quality and shelf-life of banana fruits. *Univ. Khartoum J. Agric. Sci.* 16(2): 54-61.

Oraei, M., Panahirad, S., Zaare-Nahandi, F., and Gohari, G. 2019. Pre-véraison treatment of salicylic acid to enhance anthocyanin content of grape (*Vitis vinifera* L.) berries. *J. Sci. Food Agric.* 99(13): 5946-5952.

Palmer, J. K. 1971. *The biochemistry of fruits and their products*. Academic press, London, 11: 65-105pp.

Patel, N. I., Padiar, B. V., and Patel, N. B. 2010.Effect of postharvest treatments on storage life of banana cv. Grand Naine.*Asian J. Hortic*. 5(1): 80-84.

Patil, S.K. and Shanmugasundaram, S. 2015. Physicochemical changes during ripening of Monthan banana. *Int. J. Technol. Enhancements Emerging Eng. Res*. 3(2): 2347-4289.

Perera, A .N. and Karunaratne, A. M. 2002. Postharvest calcium chloride treatments do not help to increase shelf-life of bananas. *Fruits*.57(2): 87-94.

Pila, N., Neeta, B. Gol., and Rao, T. V. R. 2010.Effect of post harvest treatments on physicochemical characteristics and shelf life of tomato (*Lycopersiconesculentum mill*.)Fruits during storage.*Am.-Eurasian J. Agric. Environ. Sci*. 9 (5): 470-479.

Pinaki, A. K., Rajput, C. B. S., Acharya, P., and Kumar, D. 1997. Effect of gibberellic acid, calcium chloride and bavistin on the postharvest life of banana fruits (*Musaparadisica* L) cv. Dwarf Cavendish. *Recent.Hortic.* 4: 30-31.

Promyou, S. and Supapvanich, S. 2014. Effects of salicylic acid immersion on physicochemical quality of Thai papaya fruit 'Kaek Dam' during storage. *Acta Hortic.*105-112.

Qin, G. Z., Tian, S. P., Xu, Y., and Wan, Y. K. 2003. Enhancement of biocontrol efficacy of antagonistic yeasts by salicylic acid in sweet cherry fruit. *Physiol. Mol. Plant Pathol.* 62(3): 147-154.

Rajkumar, M., Karuppaiah, P., and Kandasamy, R. 2005.Effect of calcium and gibberellic acid on post-harvest behaviour of papaya cv. Co2. *Indian J. Hortic.*62(4): 327-331.

Rajkumar, M. and Manivannan, K. 2007.Effect of chemicals and growth regulator on storage behavior of papaya (*Carica papaya* cv. CO-2).*Acta Hortic.*740: 327-331.

Raju, V. K. 1989. Studies on postharvest storage life of banana cv. Tellachakkarakeli.M.Sc. thesis, Agricultural College, Bapatla, Andhra Pradesh. 142p.

Ramma, I., Beni Madhu, S. P., and Peerthum, S. 1999. Post-harvest quality improvement of banana. M.Sc. thesis, Food Agricultural Research Council, Reduit, Mauritius. 231p.

Rammohan, K. 2011. Postharvest studies in banana cv. Grand Naine. M.Sc.(Hort.) thesis, Andhra Pradesh Horticultural University, 152p.

Ranganna, S. 1986. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products.*Tata McGraw-Hill Publishing Company Limited. New Delhi. 182p.

Ravi, K. and Pareek, S. 2018. Effect of Oxalic Acid on Sensory Evaluation of Gola Ber (*Ziziphus mauritiana* Lamk.)Fruit during Storage. *Int. J. Curr. Microbiol. App. Sci*. 7(1): 347-354.

Razzaq, K., Khan, A.S., Malik, A.U., Shahid, M., and Ullah, S. 2015.Effect of oxalic acid application on Samar Bahisht Chaunsa mango during ripening and postharvest.*Food Sci. Technol.* 63(1): 152-160.

Reddy, S. V. R., Sharma, R. R., Srivastava, M., and Kaur, C. 2016.Effect of pre-harvest application of Salicylic acid on the postharvest behavior of Amrapali mango fruits during storage.*Indian J. Hort.* 73(3): 405-409.

Ribeiro, L. R., Leonel, S., Souza, J. M. A., Garcia, E. L., Leonel, M., Monteiro, L. N. H., de Souza Silva, M., and Ferreira, R. B. 2020. Improving the nutritional value and extending shelf life of red guava by adding calcium chloride. *LWT-Food Sci. Technol.* 109655.

Rao, D. V. R. and Chundawat, B. S. 1988. Post harvest behavior of banana bunches of cv. Basrai in response to certain chemical and packing treatment. *Gujrat Agric. Univ. Res. J. India.* 14(1): 42-48.

Sudha, R., Amutha, R., Muthulaksmi, S., Baby Rani, W., Indira, K., and Mareeswari, P. 2007. Influence of pre and post harvest chemical treatments on physical characteristics of sapota (*Achras sapota* L.) var. PKM 1. *Res. J. Agric. Biol. Sci.* 3(5): 450-452.

Sahay, S., Mishra, P. K., Rashmi, K., Ahmad, M. F., and Choudhary, A. K. 2015.Effect of post harvest application of chemicals and different packaging materials on shelf-life of banana (*Musa* spp.) cv. Robusta. *Indian J. Agric. Sci.* 85(8): 1042-1045.

Sahithya, B. R., Raju, B., Hipparagi, K., Manjunatha, G., and Sagar, B. S. 2015. Phytohormones and signal molecules for shelf life enhanacement of Grand Naine banana fruit. *The Bioscan.* 10(1): 141-145

Saif, M. M. and Hashinaga, F. 2004. Effect of heat, calcium chloride and modified atmosphere on the shelf life of banana fruits. *Food Preservation Sci.* 30(4): 179-184.

Saini, R. S., Sharma, K. D., Dhnakar, O. P., and Kaushik, R. A. 2001. *Laboratory manual of agro techniques in horticulture.Agrobios*, India, 135p.

Sajid, M., Basit, A., Ullah, I., Tareen, J., Asif, M., Khan, S., Ali, Q.S., Gilani, S.A.Q., Zeb, S., and Nawaz, M.K. 2019. Efficiency of calcium chloride ($CaCl_2$) treatment on post-harvest performance of pear (*Pyrus communis* L.). *Pure Appl. Biol.* 8(2): 1111-1125.

Salari, N., Bahraminejad, S., Afsharmanesh, G., and Khajehpour, G. 2013.Effect of salicylic caid on postharvest quantitavir and qualitative traits of strawberry cultivars.*Adv. Environ. Biol.* 4: 94-100.

Salvador, A., Sanz, T., and Fiszman, S. M. 2007.Changes in color and texture and their Relationship with eating quality during storage of different dessert bananas.*Postharvest Biol. Technol*. 43 (3): 319-325.

Sanches, A. G., da Silva, M. B., Moreira, E. G. S., dos Santos, E. X., and Tripoloni, F. M. 2017. Extension of the shelf life of pitangas submitted to treatment with calcium chloride. *Acta Iguazu* 6(1): 45-58.

Saraiva, L.D.A., Castelan, F.P., Shitakubo, R., Hassimotto, N.M.A., Purgatto, E., Chillet, M., and Cordenunsi, B.R. 2013. Black leaf streak disease affects starch metabolism in banana fruit. *J. Agric. Food Chem.* 61(23): 5582-5589.

Sayyari, M., Babalar, M., Kalantari, S., Serrano, M., and Valero, D. 2009.Effect of salicylic acid treatment on reducing chilling injury in stored pomegranates.*Postharvest Biol. Technol*. 53: 152–154.

Scriven, F. M., Gek, C. O., and Wills, R. H. 1989. Sensory differences between bananas ripened without and with ethylene. *Hortic. Sci.* 24(6): 983-984.

Seleshi, G., Woldetsadik, K., and Azene, M. 2019. Effect of Calcium Chloride Dipping and Beeswax Coating on the Shelf Life and Quality of Nectarine (*Prunus persica* (L.)Batsch var. nucipersica) Fruits. *Agric. Food Sci. Res.* 6(1): 71-78.

Sembok, W. Z. W., Hamzah, Y., and Loqman, N. A. 2016.Effect of plant growth regulators on postharvest quality of banana (*Musa* sp. AAA Berangan). *J. Trop. Plant Physiol*. 8: 52-60.

Seymour, G.B. and Tucker, G.A. 1993.*Biochem.fruit ripening* . Springer Publishers, London, 53-81pp.

Shafiee, M., Taghavi, T. S., and Babalar, M. 2010. Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid, and calcium dipping) improved postharvest fruit quality of strawberry. *Sci. Hortic*.124(1): 40-45.

Sharma, O. P. and Bhat, T. K. 2009.DPPH antioxidant activity assay revisited. *Food Chem*. 113: 1202-1205.

Sheela, K. B. and Reni, M. 2005. Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes. Ph.D. thesis, Kerala Agricultural University, Thrissur, 138p.

Shear, C. B. 1975. Calcium-related disorders of fruits and vegetables. *Hort. Sci.* 10: 361-365.

Shiga, T.M., Soares, C.A., Nascimento, J.R., Purgatto, E., Lajolo, F.M., and Cordenunsi, B.R., 2011. Ripening-associated changes in the amounts of starch and non-starch polysaccharides and their contributions to fruit softening in three banana cultivars. *J. Sci. Food Agric.* 91(8): 1511-1516.

Shirzadeh, E., Rabiei, V., and Sharafi, Y. 2011.Effect of calcium chloride ($CaCl_2$) on postharvest quality of apple fruits. *Afr. J. Agric. Res.* 6(22): 5139-5143.

Siddiqui, S., Sharma, R.K., and Gupta, O.P. 1991. Physiological and quality response of guava fruits to posture during storage. *Hort. Sci.* 26(10): 1295-1297.

Singh, S. P. and Singh, T. P. 1992.Effect of certain postharvest treatments on the storage life and quality of mango.*Indian Food Pack*. 46: 57-59.

Soltani, M., Alimardani, R., and Omid, M. 2011. Changes in physico-mechanical properties of anana fruit during ripening treatment. *J. Am. Sci*. 7(5): 16.

Sothornvit, R. and Rodsamran, P. 2008. Effect of a mango film on quality of whole and minimally processed mangoes. *Postharvest Biol. Technol.* 47(3): 407-415.

Srivastava, M. K. and Dwivedi, U. N. 2000.Delayed ripening of banana fruit by salicylic acid. *Plant Sci*. 158(1-2): 87-96.

Stover, R. H. and Simmonds, N. W. 1987.*Bananas* (3rd Ed.).Longman Scientific & Technical. Harlow, pp. 468.

Supapvanich, S. and Promyou, S. 2013.Efficiency of salicylic acid application on postharvest perishable crops. In: Hayat, S. and Alyemei, A. A. M., *Salicylic Acid: Plant Growth Develop.* Springer, New York, USA.339-355pp.

Singh , S. D. and Rao, G. P. 2005. Stevia: the herbal sugar of 21st century. *Sugar Tech*. 7(1): 17-24.

Supapvanich, S. and Promyou, S. 2017. Hot water incorporated with salicylic acid dips maintaining physicochemical quality of 'Holland' papaya fruit stored at room temperature. *Emirates J. Food Agric.* 18-24.

Tapas, S. 2016. Effect of post harvest treatments on shelf life and quality of banana cv. Grand Naine. *Int. J. Agric.Sci.* 6(2):0975-3710.

Tapre, A.R. and Jain, R. K. 2012. Study of advanced maturity stages of banana. *Int. J. Adv. Eng. Res. Stud*. 1(3): 272-274.

Tareen, M. J., Abbasi, N. A., and Hafiz, I. A. 2012. Effect of salicylic acid treatments on storage life of peach fruits cv. Flordaking. *Pakist. J. Bot.* 44(1): 119-124.

Terra, N. N., Garcia, E., and Lajolo, F. M. 1983. Starch sugar transformation during banana ripening: The behavior of UDP glucose Pyrophosphorylase, Sucrose Synthetase and Invertase. *J. Food Sci.* 48: 1097-1112.

Thokchom, R. and Mandal, G. 2018.Effect of Various Post Harvest Treatments on Storage Behaviour of Aonla cv. Chakaiya. *Int. J. Bio-res. Stress Manag.* 9(2): 269-273.

Tian, S., Qin, G., Li, B., Wang, Q., and Meng, X. 2007. Effects of salicylic acid on disease resistance and postharvest decay control of fruits. *Stewart Postharvest Rev*. *6*(2): 1-7.

Tripathi, V.K., Ram, H. B., Jain, S. P., and Singh, S. 1981. Changes in developing banana fruit. *Progr.Hortic*. 22(2): 123-134

USDA [United States Departmenr of Agriculture].2001. USDA Banana ripening Guide.[Online]. Available:http://www.ams.usda.gov/banana-visualaids/database-2018.pdf.

Valérie Passo Tsamo, C., Andre, C. M., Ritter, C., Tomekpe, K., Ngoh Newilah, G., Rogez, H., and Larondelle, Y. 2014. Characterization of Musa sp. fruits and plantain banana ripening stages according to their physicochemical attributes. *J. Agric. Food Chem. 62*(34): 8705-8715.

Valero, D., Diaz-Mula, H. M., Zapata, P. J., Castillo, S., Guillen, F., Martinez-Romero, D., and Serrano, M. 2011. Postharvest treatmenst with salicylic acid, acetylsalicylic acid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. *J. Agric. Food Chem*. 59(10): 5483-5489

Vargas, A. and Lopez, J.A. 2011.Effect of dose rate, application method and commercial formulations of GA3 on banana (*Musa* AAA) fruit green life. *Fresh Produce 5*(1): 51-55.

Vendrell, M. 1970. Acceleration and delay of ripening in banana fruit tissue by gibberellic acid.*Aust. J. Biol. Sci*. 23: 553-559.

Wang, L., Chen, S., Kong, W., Li, S., and Archbold, D.D. 2006. Salicylic acid pretreatmentalleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. *Postharvest Biol. Technol.* 41: 244-251.

Wang, Q., Lai, T., Qin, G., and Tian, S., 2009. Response of jujube fruits to exogenous oxalic acid treatment based on proteomic analysis. *Plant Cell Physiol.* 50(2): 230-242.

Whangchai, K., Saengnil, K., and Uthaibutra, J. 2005. Effect of ozone in combination with some organic acids on the control of postharvest decay and pericarp browning of longan fruit. *Crop Prot.* 25(8): 821-825.

White, P. J. and Broadley, M. R. 2003.Calcium in plants. *Ann. Bot.* 92(4): 487-511.

Wills, R.B.H. and Tirmazi, S.I.H. 1982.Inhibition of ripening of avocados with calcium. *Sci. Hortic.* 16(4): 323-330.

Wisniewska, H. and Chelcowski, J. 1999. Influence of exogenic salicylic acid on fusarium seedling blight reduction in barley. *Acta Physiol. Plant*. 21 (1): 63–66

Wolucka, B. A., Goossens, A., and Inzee, D. 2005. Methyl jasmonate stimulates the de novo biosynthesis of vitamin c in plant cell suspensions. *J. Exp. Bot*. 56: 2527- 2538.

Wu, F., Zhang, D., Zhang, H., Jiang, G., Su, X., Qu, H., Jiang, Y., and Duan, X. 2011.Physiological and biochemical response of harvested plum fruit to oxalic acid during ripening or shelf-life. *Food Res. Int.* 44(5): 1299-1305.

Xiao, Y.Y., Kuang, J.F., Qi, X.N., Ye, Y.J., Wu, Z.X., Chen, J.Y., and Lu, W.J. 2018. A comprehensive investigation of starch degradation process and identification of a transcriptional activator Mab HLH 6 during banana fruit ripening. *Plant Biotechnol. J.* 16(1): 151-164.

Yao, H. and Tian, S. 2005. Effects of pre-and post-harvest application of salicylic acid or methyl jasmonate on inducing disease resistance of sweet cherry fruit in storage. *Postharvest Biol. Technol.* 35(3): 253-262.

Yap, M., Fernando, W. M., Brennan, C.S., Jayasena, V., and Coorey, R. 2017. The effects of banana ripeness on quality indices for puree production. *J. Food Sci.*80: 10-18.

Zaharah, S.S. and Singh, Z. 2011. Postharvest nitric oxide fumigation alleviates chilling injury, delays fruit ripening and maintains quality in cold stored 'Kensington Pride' mango. *Postharvest Biol. Technol*. 60: 202-210

Zainuri., Joyce, D.C., Wearing, A.H., Coates, L., and Terry, L. 2001. Effects of phosphonate and salicylic acid treatments on anthracnose disease development and ripening of 'Kensington Pride' mango fruit. *Aust. J. Exp. Agric*. 41: 805–813.

Zewter, A., Woldetsadik, K., and Workneh, T.S. 2012. Effect of 1-methylcyclopropene, potassium permanganate and packaging on quality of banana. *Afr. J. Agric. Res.* 7(16): 2425-2437.

Zhang, Y., Chen, K., Zhang, S., and Ferguson, I. 2003. The role of salicylic acid in postharvest ripening of kiwifruit. *Postharvest Biol. Technol.* 28(1): 67-74.

Zheng, X., Jing, G., Liu, Y., Jiang, T., Jiang, Y., and Li, J. 2012.Expression of expansin gene, MiExpA1, and activity of galactosidase and polygalacturonase in mango fruit as affected by oxalic acid during storage at room temperature.*Food Chem.* 132(2): 849-854.

Zheng, X. and Tian, S. 2006.Effect of oxalic acid on control of postharvest browning of litchi fruit. *Food Chem.* 96(4): 519-523.

Zheng, X., Tian, S., Gidley, M.J., Yue, H., and Li, B. 2007. Effects of exogenous oxalic acid on ripening and decay incidence in mango fruit during storage at room temperature. *Postharvest biol. Technol.* 45(2): 281-284.

Zheng, Y. and Zhang, Q. 2004. Effects of polyamines and salicylic acid postharvest storage of 'Ponkan' mandarin. *Acta Hortic.* 632: 317-320.

Zhi, H. H., Liu, Q. Q., Dong, Y., Liu, M. P., and Zong, W. 2017 Effect of calcium dissolved in slightly acidic electrolyzed water on antioxidant system, calcium distribution, and cell wall metabolism of peach in relation to fruit browning. *J. Hortic. Sci. Biotechnol.* 92(6): 621–629.

Zomo, S.A., Ismail, S.M., Jahan, M.S., Kabir, K., and Kabir, M.H. 2014.Chemical properties and shelf life of banana (*Musa sapientum* L.) as influenced by different postharvest treatments. *The Agric.* 12(2): 06-17.

Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Score card for banana peel colour

Title: Postharvest quality management in banana (*Musa* spp.) cv. Nendran

Particulars	T_1	T_2	T_3	T_4	T_5
peel colour					

Score:

I- Dark green (Stage I)

II- Light green (Stage 2)

III -More green than yellow (Stage 3)

IV- More yellow than green (Stage 4)

V- Yellow with green tip (Stage 5)

VI- Full yellow (Stage 6)

VII- Yellow with brown spots (Stage 7)

Date: Name:

Signature:

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Score card for sensory evaluation of ripe Nendran banana fruits

Sample: Banana cv. Nendran

Instructions: You are given 5 samples of ripe banana fruits. Evaluate them and give scores for each criterion

Criteria	Samples				
	1	2	3	4	5
Appearance					
Flesh colour					
Flavour					
Taste					
Texture					
Overall acceptability					
Any other remarks					

Score:

Like extremely -9

Like very much -8

Like moderately -7

Like slightly -6

Neither like nor dislike -5

Dislike slightly -4

Dislike moderately -3

Dislike very much -2

Dislike extremely -1

Name:

Date: Signature:

POSTHARVEST QUALITY MANAGEMENT IN BANANA CV. NENDRAN (*Musa* spp.)

by

APARNA NATH S. S.

(2018-12-033)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

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Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

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KERALA, INDIA

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ABSTRACT

The study entitled "Postharvest quality management in banana cv. Nendran (*Musa* spp.)" was conducted in the Department of Post Harvest Technology, College of Agriculture, Vellayani, Thiruvananthapuram during the year 2018-2020. The objective of the experiment was to standardize the postharvest management for delayed ripening and extended shelf life of banana cv. Nendran with minimum nutritional loss through postharvest handling practices.

Good quality banana fruits (cv. Nendran) of uniform size and maturity, procured from progressive farmers of Farmer Producer Organization, Kalliyoor, Thiruvananthapuram were used for the study. The fruits were de-handed and sanitized with ozonation at 2ppm. The sanitized fruits were subjected to different postharvest treatments *viz*., Calcium chloride ($CaCl_2$ 4%), Gibberellic Acid (GA_3 150 ppm), Oxalic Acid (OA 20 mM), Salicylic acid (SA 2 mM) as against fruits without any treatment as control. The treated fruits after the removal of excess moisture were stored in Corrugated Fibre Board boxes under room temperature conditions (30 ± 2 ^{0}C, RH 85-90 %). Effectiveness of the treatments was analysed based on physiological, biochemical, physical and sensory parameters at an interval of 3 days till the end of shelf life.

After 15 days of storage, Nendran banana fruits treated with Salicylic Acid (SA 2 mM) recorded the least Physiological Loss in Weight (PLW) of 13.43 % and respiration rate of 102.70 mL CO_2 $kg^{-1}h^{-1}$ with a pulp percentage of 70.61 %, 29.39 % peel percentage and pulp to peel ratio of 2.40 with a fruit firmness of 10.13 N. The stored fruits also recorded an increase in the moisture content (61.27 %), Total Soluble Solids (24.60 ^{o} Brix), reducing sugar (17.34 %), total sugar (20.21 %), and acidity (0.45 %) with 10.19 % of starch content, 75.52%antioxidant activity and 9.30 mg $100g^{-1}$ ascorbic acid content after 15 days of storage. The fruits had acceptable sensory attributes *viz.,* appearance, colour, flavor, taste, texture and overall acceptability and resulted in a shelf life of 15.67 days.

Nendran banana fruits treated with Gibberellic Acid (GA_3 150 ppm) recorded a shelf life of 14.3 days next to SA (2 mM) with a respiration rate of 112.38 mL CO_2 $kg^{-1}h^{-1}$, Physiological Loss in Weight of 14.3 %, pulp percentage of 73.32 %, 26.68 % peel, pulp to peel ratio as 2.75, 17.80 % reducing sugar, 21.05 % total sugar, 74.31% antioxidant activity, and 8.59 mg $100g^{-1}$ascorbic acid content after 15 days of storage. The untreated Nendran banana fruits recorded a shelf life of 11.13 days with the highest rate of physiological, biochemical, and physical changes and the lowest mean scores for organoleptic qualities.

Application of postharvest treatments significantly reduced the rate of physiological activities which contributed to the delay in ripening and extension of shelf life of Nendran banana. Nendran banana fruits harvested at uniform maturity, sanitized with ozonation (2 ppm) and subjected to postharvest treatment with salicylic acid (2 mM) for 10 minutes as dipping was standardized as the best postharvest treatment based on physiological, biochemical, physical and sensory analysis which recorded a shelf life of 15.67 days under room temperature storage as against 11.13 days in fruits without any postharvest treatments.

സംഗ്രഹം

വെള്ളായണി കാർഷിക കോളേജിലെ വിളവെടുപ്പാനന്തര സാങ്കേതിക വിദ്യാവിഭാഗത്തിൽ 2018-2020 കാലയളവിൽ 'നേന്ത്രൻ വാഴപ്പഴത്തിsâ(*Musa* spp.) ഗുണമേന്മ നിലനിർത്തുന്നതിനായുള്ള വിളവെടുപ്പാനന്തര പരിചരണ മുറകൾ' പഠന വിധേയമാക്കി. നേന്ത്രപ്പഴം പഴുക്കുന്നതിൽ കാലതാമസം വരുത്തുന്നതിലും കുറഞ്ഞ പോഷകനഷ്ടത്തോടെ സൂക്ഷിപ്പുകാലം കൂട്ടുന്നതിനുമായുള്ള വിളവെടുപ്പാനന്തര പരിചരണ മുറകൾ ക്രമീകരിയ്ക്കുക എന്നതായിരുന്നു ഗവേഷണത്തിsâ ലക്ഷ്യം.

കല്ലിയൂർ ഫാർമർ പ്രൊഡ്യൂസർ ഓർഗനൈസേഷനിലുള്ള പുരോഗമന കർഷകരിൽനിന്നും ഒരേ മൂപ്പിലെത്തിയ നേന്ത്രൻ വാഴക്കുലകൾ തെരഞ്ഞെടുത്തു പടലകളാക്കി ഓസോണേഷനിലൂടെ (2 ppm) വ്യത്തിയാക്കിയ ശേഷം വിവിധ പരിചരണ ലായനികളിൽ 10മിനിട്ട്നേരം മുക്കിവെച്ചു. കാൽസ്യം ക്ലോറൈഡ് ($CaCl_2$ 4 %), ജിബ്രലിക് ആസിഡ് (GA_3 150 ppm), ഓക്സാലിക് ആസിഡ് (OA 20 mM), സാലിസിലിക് ആസിഡ് (SA 2 mM) എന്നീ പരിചരണ ലായനികളാണ്പഠന വിധേയമാക്കിയത്. ഇതിനോടൊപ്പം യാതൊരു പരിചരണലായനിയും കൂടാതെയുള്ളനേന്ത്രകായ്കളും (കേവലനിയന്ത്രണം) പഠനത്തിനുൾപ്പെടുത്തി. ഇത്തരത്തിൽ പരിചരിച്ച നേന്ത്രകായ്കൾ സാധാരണ അന്തരീക്ഷ താപനിലയിൽ (30±2 ^{0}C, ആർദ്രത 85-90 %) കോറുഗേറ്റഡ്ഫൈബർ ബോർഡ്ബോക്സിനുള്ളിൽ സൂക്ഷിച്ചു. പരിചരണ മുറകളുടെ ഫലപ്രാപ്തി വിലയിരുത്താൻ ഫിസിയോളജിക്കൽ, ബയോകെമിക്കൽ, ഫിസിയ്ക്കൽ, സെൻസറി ഗുണങ്ങൾ 3 ദിവസം ഇടവേളയിൽ സൂക്ഷിപ്പുകാലം അവസാനിയ്ക്കുന്നതുവരെ വിശകലനം ചെയ്തു.

സാലിസിലിക്ആസിഡ് (SA) 2 mM പരിചരണം നടത്തിയ നേന്ത്രകായ്കൾ 15 ദിവസത്തെ സംഭരണത്തിനുശേഷം ഏറ്റവും കുറവ്ഭാര നഷ്ടവും(13.43 %),ശ്വസന നിരക്കും (102.70 mL CO_2 $Kg^{-1}h^{-1}$) കൂടാതെ 70.61 % പൾപ്പ് ശതമാനവും, 29.39 % പീൽ ശതമാനവും, പൾപ്പ് പീൽ അനുപാതവും (2.40), 10.13 N ഫല ദൃഢതയും രേഖപ്പെടുത്തി. ഈർപ്പം (61.27 %), TSS (24.60 ^{0}Brix), റെഡ്യൂസിം ഷുഗർ (17.34 %),

ടോട്ടൽ ഷുഗർ (20.21 %), അമ്ലത്വം (0.45 %) എന്നിവസംഭരണ കാലത്തു കൂടുകയും അന്നജം (10.19 %), നിരോക്സികരണ ശേഷി (75.52%), അസ്കോർബിക് ആസിഡ് (9.30 mg 100 g^{-1}) എന്നിവ കൂടുതൽ നിലനിർത്തുന്നതായും സംഭരണത്തിsâ അവസാനകാലത്തു നിരീക്ഷിച്ചു. അതുപോലെ ഇവ സെൻസറി ഗുണങ്ങളായ കാഴ്ചയിലും, നിറത്തിലും, ഫ്ലേവറിലും, രുചിയിലും, ടെക്സ്ചറിലും, മൊത്തത്തിൽ സ്വീകാര്യമായും15.67 ദിവസങ്ങൾ സൂക്ഷിപ്പ്കാലവുമായി SA 2 mM പരിചരണം മികച്ചതായി രേഖs,ടുത്തി.

ജിബ്രലിക് ആസിഡ് (GA_3 150 ppm) പരീക്ഷിച്ച നേന്ത്രൻകായ്കൾ 14.3 ദിവസങ്ങൾ വരെ സൂക്ഷിപ്പുകാലവും അതോടൊപ്പം 112.38 mL CO_2 $Kg^{-1}h^{-1}$ ശ്വസന നിരക്കും, 14.3 %, ഫിസിയോളജിയ്ക്കൽ ഭാരനഷ്ടം, 73.32 % പൾപ്പ് ശതമാനം, 26.68 % പീൽ ശതമാനം, 2.75 പൾപ്പ് പീൽ അനുപാതം, 17.80 % റെഡ്യൂസിംഗ് ഷുഗർ, 21.05 % ടോട്ടൽ ഷുഗർ, 74.31 % നിരോക്സികരണ ശേഷി, 8.59 mg 100 g^{-1} അസ്കോർബിക് ആസിഡും 15 ദിവസത്തെ സംഭരണത്തിനു ശേഷം രേഖപ്പെടുത്തി. യാതൊരു പരിചരണമുറകളും കൂടാതെയുള്ള നേന്ത്രകായ്കൾ (കേവല നിയന്ത്രണം) 11.13 ദിവസങ്ങൾ സൂക്ഷിപ്പുകാലവും അതോടൊപ്പം കൂടുതൽ നിരക്കിലുള്ള ഫിസിയോളജിക്കൽ, ബയോകെമിക്കൽ, ഫിസിയ്ക്കൽ ഗുണങ്ങളും ഏറ്റവും കുറവ്സെൻസറി ഗുണങ്ങളും പ്രദർശിപ്പിച്ചു. ഒരേമൂപ്പിലെത്തിയ നേന്ത്രകായ്കൾ പടലകളാക്കി 2 ppm ഓസോണേഷനിലൂടെ ശുചിത്വവൽക്കരിച്ചശേഷം സാലിസിലിക് ആസിഡ് 2 mM ൽ 10 മിനിട്ട്മുക്കി വെച്ച്പരിചരിക്കുന്നതുവഴി കായ്കൾ പഴുക്കുന്നതിനുള്ള കാലദൈർഘ്യം കൂട്ടുന്നതിനും ഗുണങ്ങൾനിലനിർത്തി കൊണ്ട്സൂക്ഷിപ്പുകാലം സാധാരണ താപനിലയിൽ 15.67 ദിവസങ്ങൾ വരെ വർദ്ധിപ്പിക്കാമെന്നുള്ള വിളവെടുപ്പാനന്തര പരിചരണം ഈപഠനത്തിലൂടെ ക്രമീകരിക്കുവാൻ സാധിച്ചു. എന്നാൽ യാതൊരു പരിചരണ മുറകളും അവലംബിക്കാത്ത (കേവലനിയന്ത്രണം) നേന്ത്രകായ്കൾ സാധാരണ അന്തരീക്ഷ താപനിലയിൽ 11.13 ദിവസങ്ങൾ മാത്രം സൂക്ഷിപ്പുകാലാവധി ഉള്ളതായി പഠനത്തിൽ വ്യക്തമായി.