POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY

MENAKA M.

(2018-12-026)

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2020

POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY

by

MENAKA M.

(2018-12-026)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY"** 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.

Menaka M

Vellayani **MENAKA M.**

Date: 06/08/2020 (2018 -12-026)

CERTIFICATE

Certified that this thesis entitled **"POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY"** is a record of bonafide research work done independently by Ms. Menaka M. 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.

Vellayani,
Date: 06|08|2020

Dr. P. R. Geetha Lekshmi
(Major advisor, Advisory committee)
Assistant Professor
Department of Post Harvest Technology
College of Agriculture, Vellayani
Thiruvananthapuram

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Menaka M. (2018-12-026), a candidate for the degree of **Master of Science in Horticulture** with major in Post Harvest Technology, agree that this thesis entitled **"POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY"** may be submitted by Ms. Menaka M., in partial fulfilment of the requirement for the degree.

Dr. P. R. Geetha Lekshmi
(Chairperson, Advisory committee)
Assistant Professor
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. Mini C.
(Member, Advisory committee)
Professor and Head
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. Beena R.
(Member, Advisory committee)
Assistant Professor
Department of Plant Physiology
College of Agriculture, Vellayani

Dr. Gladis R.
(Member, Advisory committee)
Assistant Professor
Department of Soil Science & Agrl. Chemistry
College of Agriculture, Vellayani

ACKNOWLEDGEMENT

I bow my head before the Almighty God for the blessings and enlightenment throughout my work and enabled me to complete my thesis work successfully on time.

I feel immense pleasure to express my sincere gratitude and personal thankfulness to ***Dr. P. R. Geetha Lekshmi****, Assistant professor, Dept. of Post Harvest Technology, for her valuable guidance, constant encouragement, support and co-operation that she has given throughout the course of my PG work.*

I am grateful to ***Dr. Mini C****, Professor and Head, Department of Post Harvest Technology, for her timely advice and her support to complete my thesis work on time.*

I convey my heartfelt thanks to ***Dr. Beena R,*** *Assistant Professor, Dept. of Plant Physiology, for her valuable suggestions in the pursuit of the work.*

I humbly express my gratitude to ***Dr. Gladis R****, Assistant Professor, Dept. of Soil Science and Agricultural Chemistry, for her valuable suggestion, encouragement and continued support in the work.*

I also express my thankfulness to ***Athulya mam, Baby chechi, Shreeja chechi and Archana chechi*** *for their sincere co-operation, timely help and assistance during the lab work.*

Words cannot express my heartfelt thanks to ***Chandu, Sinchu, Yashu, Bhoomika, and Aparna Nath****. I would not never complete my work without their support and I am thankful for their unbound love and affection.*

I also express my thanks to ***Maneesha, Elso, Gayathri, Bindu*** *and my other classmates, for their help, encouragement, care and co-operation.*

I express my sincere thanks to, ***Manasa akka, Pooja akka, Aparna chechi, Athira chechi, Lekshmi chechi and Archana chechi*** *and for their valuable suggestion, help and support.*

Words are inadequate to express my thanks to my lovely friend **Dr. Madhushree.**

Words cannot express my deep sense of gratitude and indebtness to my beloved ***father, mother, smiley and family*** *for their moral support and motivation.*

Finally, I thank all those who extended help and support to me in one way or another in the successful completion of this thesis work.

Menaka M.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

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
NAA	: 1-Napthlene Acetic Acid
GA_3	: Gibberellic Acid
SA	: Salicylic Acid
$CaCl_2$	: Calcium chloride
PLEAG	: Papaya Leaf Extract Aloe Gel
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
GRAS	: Generally Recognised As Safe
ACC	: 1-aminocyclopropane carboxylic acid

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Advanced technologies in fruit and vegetable production have greatly become a part of improved production. Although the production is enhanced, people around the globe fail to get their daily requirement having very low Human Development Index (HDI) and considerable gap exists between total production and net availability owing to improper postharvest handling practices (Choudhury, 2006).

Papaya *(Carica papaya* L.*)* is a delicious fruit widely cultivated in tropical and sub-tropical areas. India is leading among major papaya producing countries and fourth most traded crop belonging to the family Caricaceae. The fruit is rich in sugar, carotenoids, potassium, ascorbic acid and highly valued for its nutraceutical properties (Parker *et al*., 2010). Because of its flavour and nutritional qualities is gaining commercial importance as a table fruit as well as for papain production. In India it is estimated to grow in an area of 143 thousand hectares with production of 5.99 million MT (NHB, 2018).

Papaya being a highly perishable fruit has short shelf life. Harvest and postharvest losses during farm operation, storage and transportation in papaya are reported to be 7.36% (Bhanushree *et al*., 2018). Higher water content, rapid flesh softening, mechanical damages and postharvest diseases altogether contribute to the substantial increase in qualitative and quantitative postharvest losses.

Papaya is a climacteric fruit showing climacteric peak at the onset of ripening and undergo biochemical changes associated with respiration and transpiration reaching senescence causing catabolic destruction of substances at a faster rate. Hence adoption of adequate postharvest treatments can combat the deterioration by reducing respiration rate and thus extending the shelf life (Dasu *et al*., 2016). The tropical climate favours the accelerated ripening and reduces the shelf life of papaya fruits. The ripening associated biochemical and physiological changes occur at a faster rate after the harvest leading to postharvest losses.

Postharvest handling practices and postharvest treatments have been reported to enhance the quality and improve firmness by maintaining cell integrity that prolongs the shelf life with minimum losses. They extend the green life of fruits through delayed ripening and senescence by retardation of respiration and ethylene biosynthesis or its action (Asghari and Aghdam, 2010).

Postharvest treatments of fruits extend the shelf life without any quality deterioration. Within the same species, different varieties respond differently to postharvest chemical treatments for delaying the ripening process and extending shelf life. The papaya cv. Red Lady has emerged as a leading commercial variety and there is an urgent need to increase the shelf life with minimum loss in quality.

Hence the present study entitled Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani, during the year 2018-2020 with the objective to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss through postharvest handling practices.

Review of literature

2. REVIEW OF LITERATURE

Papaya (*Carica papaya* L.), belongs to the family Caricaceae, is originated in Tropical America and extensively cultivated as cash crop in tropical and sub-tropical regions of the world. India is one among the major papaya producing countries and the fourth most traded crop of the country. Papaya is cultivated mainly in Karnataka, Andhra Pradesh, West Bengal, Orissa, Gujarat, Madhya Pradesh, Kerala, Assam, and Maharashtra (Reddy and Gowda, 2014) and cultivated in 143 thousand hectares with a production of 5.99 million MT (NHB, 2018).

The fruit is rich in sugar, carotenoids, potassium, ascorbic acid and highly valued for its nutraceutical properties (Parker *et al*., 2010). Because of its notable flavour and nutritional qualities, papaya is gaining commercial importance as a table fruit as well as for papain production and is recognised as a highly remunerative crop (Sharma and Zote, 2010).

Papaya is highly perishable with short shelf life and postharvest losses during farm operation, storage and transportation are reported to be 7.36% (Bhanushree *et al*., 2018). High water content, rapid flesh softening, mechanical damages and postharvest diseases altogether contributed to substantial increase in qualitative and quantitative postharvest losses in papaya. Lack of infrastructure facilities and poor handling practices in papaya accounted for postharvest losses of 75% and 90% respectively (Ramesh *et al*., 2016).

Red Lady also known as "Taiwan 786" is a red fleshed F_1 hybrid variety with excellent fruit quality, flavour, aroma, texture and sweet with 13-14% sugar content and recently it became popular among Indian farmers due to flesh firmness and red flesh colour (Bhardwaj *et al.*, 2010). Papaya is a climacteric fruit and has short shelf life under tropical conditions, the present study was conducted to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss. The present chapter reviews the literature on different postharvest treatments for extending the shelf life of papaya and other relevant fruit crops.

2.1. POSTHARVEST TREATMENTS

Papaya being a highly perishable commodity has a short storage life of one week accounting for a postharvest loss of 25.49 % at ambient conditions (Mandal *et al.,* 2017). Several studies have reported that effective use of postharvest treatments can delay the fruit ripening, retain quality, improve consumer acceptance and extend the shelf life so as to reduce the postharvest losses.

Delayed ripening using different pretreatment is the commonly used method in recent days. Pretreatment with growth regulators and ethylene inhibitors are found associated with preventing moisture loss, inhibit oxidative browning and microbial density in fruit crops such as papaya, grapes, oranges and sweet cherries (Kumar and Bhatnagar, 2014). Postharvest treatments including edible coating improve glossiness and shelf life with better fruit quality by preventing microbial activity, retarding respiration rate, ethylene biosynthesis and ripening (Mandal *et al*., 2017).

2.1.1. Naphthalene acetic acid (NAA)

1-Naphthaleneaceticacid, commonly referred as NAA, is a synthetic plant hormone which has role in cell expansion but it also aids in preventing ripening process by inhibiting abscisic acid and effectively extends the shelf life of fruits (Aristya *et al.*, 2019).

Individually shrink-wrapped custard apple fruits stored at ambient condition after postharvest treatment with NAA (30 ppm) and waxol (6%) recorded the lowest weight loss of 9.63% while it reported 24.29% TSS, 0.25% acidity and 22.53% total sugars after 7 days of storage (Masalkar and Garande, 2005). Dikki *et al*. (2010) reported that postharvest treatment of papaya with 250 ppm NAA combined with 6% wax coating recorded the lowest physiological loss in weight (19.98%) and retained the maximum TSS (11.88%), reducing sugars (6.29%), total sugars (8.23%) and extended the shelf life up to 15 days stored at ambient conditions as compared to control with shelf life of 7 days. Devi *et al*. (2016) suggested the treatment of kinnow mandarin with 75 ppm NAA was effective in reducing fruit decay, delayed fruit ripening, retained maximum fruit firmness and also recorded highest scores for organoleptic attributes with shelf life extension up to one week.

Singh *et al*. (2018) reported that postharvest application of naphthalene acetic acid (1- 2 minutes) to guava fruits kept under cold storage significantly prolonged the shelf life without affecting the physical and chemical attributes which retained good consumer acceptance. Thokchom and Mandal (2018) assessed the effect of NAA on aonla cv. Chakaiya and noticed that NAA at 20 ppm had recorded total mass loss and spoilage percentage of 10.12 % and 5 % respectively. A study conducted by Bakshi *et al*. (2019) showed that naphthalene acetic acid (200 ppm) treated guava cv. Allahabad safed stored at ambient condition had showed increase in total sugars and total soluble solids with lower acidity. The application of NAA @ 200 ppm was desirable in retaining the maximum total sugar and total soluble solids and the minimum acidity was reported for guava treated with NAA of 100 ppm (Singh *et al.,* 2019).

Hazarika *et al*. (2016) investigated the application of NAA @ 200 ppm on Red Lady papaya had maintained the quality parameters *viz*., acidity (0.162%), total soluble solids (14.72%), reducing sugar (6.71%), total sugar (8.56%) and ascorbic acid (81.12%) after 12 days of storage. Dubey *et al.* (2020) reported the treatment of Red Lady papaya with NAA of 150 ppm was effective in retaining quality parameters which showed 13.96 ^{o}Brix TSS, 80.8 mg 100g^{-1} ascorbic acid, 0.15% acidity, 6.88% reducing sugar, 8.67% total sugar after 15 days of storage.

2.1.2. *Aloe vera* based edible coating

Gel extract of *A. vera* is involved in retarding microbial spoilage, respiration rate and thus delaying ripening in fruits and vegetables. It also key role in retaining firmness and enhances certain phenolic compounds (Benitez *et al.,* 2013). *Aloe vera* gel is made up of polysaccharides, which act as a barrier against oxygen and moisture exchange and is gaining importance as a bio preservative owing to its anti-microbial property, film forming properties, bio degradable nature and helps in retaining biochemical properties as well (Misir *et al*., 2014).

Table grapes cv. Crimson seedless coated with *aloe vera* gel enhanced the shelf life during storage at 20°C (Serrano *et al.,* 2006). Postharvest treatment of pomegranate arils with *aloe vera* gel successfully retained firmness, reduced microbial spoilage and recorded the highest organoleptic scores as reported by

Martinez-Romero *et al.* (2013). Vanaei *et al*. (2014) reported that *aloe vera* gel treated pistachio stored at 4°C for one month was significant in retaining marketability and reduced spoilage severity with highest sensory attributes. A study conducted by Kumar *et al*. (2017) observed that postharvest treatment of guava cv. Pant Prabhat with aloe juice (1:1) preserved the highest fruit firmnesss (8.17 kg cm^{-2}), antioxidant activity (684.27 µmol. TE/100 g Fresh weight) and also recorded maximum organoleptuc scores without affecting quality for 12 days. Papaya leaf extract incorporated aloe gel (1:2) effectively maintained the quality parameters and extended the shelf life of tomato up to 60 days at 12-20^0C in CFB boxes (Chandran, 2018).

Marpudi *et al*. (2011) studied the effect of anti-microbial property of *aloe vera* oriented edible coatings and found that papaya fruits treated with papaya leaf extract combined aloe gel (1:1) delayed ripening, retained maximum titratable acidity of 0.12%, fruit firmness of 4 kg cm^{-2}. It also recorded the lowest weight loss of 33% and 8.2˚Brix TSS after storage period of 15 days with good marketability when placed at 30±3˚C temperature. Brishti *et al*. (2013) observed the influence of papaya leaf extract and aloe gel (PLEAG 1:1) on papaya fruits stored at ambient conditions (25-29˚C; 82-84%) and reported that, it sustained maximum titratable acidity (0.142%), TSS (7.4 ˚Brix) and ascorbic acid content (120.20 mg $100g^{-1}$) with prolonged shelf life of 12 days. *Aloe vera* gel coated papaya survived up to 15 days at low temperature with good marketability (Kumar and Bhatnagar, 2014).

Postharvest dipping of papaya in 1.5 % aloe gel solution for 5 minutes retarded colour development, preserved the highest moisture content (89.40%), titratable acidity (0.41%), ascorbic acid (37.658 mg $100g^{-1}$) and recorded the minimum TSS (7.61˚Brix), PLW (7.30%) with extended shelf life up to 12 days at room conditions (Sharmin *et al.*, 2015). A study conducted by Mendy *et al.* (2019) found that papaya (cv. Sekaki) harvested at green with slight yellow colour stage, coated with 50% *aloe vera* gel for 3 minutes, dried and placed in CFB box, stored at ambient temperature (28 ± 2 °C) and relative humidity of 86-70% maintained maximum firmness of 52.29 N, 51.82 mg $100g^{-1}$ ascorbic acid, 0.62% titratable acidity and 48.73% DPPH activity with minimum physiological loss in weight of 2.05% after 15 days of storage. Parven *et al.* (2020) observed that papaya kept under ambient conditions (25 ± 2 °C and 80–85 % RH) treated with aloe gel (100 %) alone showed efficient reduction in weight loss (11 %), moisture content (89.9%), total soluble solids (3˚Brix), disease incidence (29 %) and delayed ripening up to 12 days.

2.1.3. Gibberellic Acid

Gibberellins are growth promoting substances that are known to reduce ripening as well as senescence process of fruits. Even though, various ripening aspects are affected by gibberellic acid, it is found to focus mainly on the colour change. Gibberellic Acid (GA_3) prevents fruit softening, chlorophyll disintegration and reduces sugar acid ratio, TSS and sugar accumulation in fruits like mango and banana (Osman and Abu-Goukh, 2020).

Khader *et al.* (2002) observed that postharvest application of mango cv. Mallika at 100 or 200 mg L^{-1} of GA and stored at minimum temperature of 29 ± 1°C and a maximum of 35 ± 2°C temperature had efficiently reduced total weight loss, reduced amylase and peroxidase activity and ascorbic acid content during ripening. The GA_3 treated guava fruits packed in polyethylene bags containing $KMnO_4$ glazed silica gel had effectively retained physico-chemical properties of fruit, reduced acidity, prolonged shelf life up to 6 days by retarding activity of several enzymes that aid in oxidation and reduction process. The treated fruits also showed less postharvest loss and enhanced marketability (Hiwale and Singh, 2003). Gautam and Chundawat (2005) observed that GA_3 (300 ppm) treated sapota cv. Kalipatti was significant in retarding ripening process by declining respiration and transpiration rate and extended the shelf life.

Sapota cv. Kalipatti treated with gibberellic acid (200 mg L^{-1}) stored up to eight days had recorded gradual increment in reducing and total sugars, total soluble solids, reduced content of titrable acidity and ascorbic acid with least postharvest losses and better acceptability (Kadu and Gajipara, 2009). Bhalerao *et al.* (2010) observed that Grand Naine banana subjected to postharvest application of Gibberellic acid (GA 100 mg L^{-1}) reduced loss in weight, delayed the ripening process and prolonged the shelf life. It also aids in the retention of firmness and maintained other quality attributes. A study conducted by Gol and Rao (2011) concluded that banana fruit coated with gibberellic acid in combination with chitosan and stored at 34 ± 1°C and 70–75% relative humidity had potential to decrease percent weight loss, retardation of decay and extended the shelf life with intact quality attributes after 10 days of storage.

Duguma *et al.* (2014) revealed that gibberellic acid treated banana fruits for 15 minutes stored at 13±2˚C was effective in delaying spoilage, weight loss, total sugars, peel colour development, carbon di oxide and ethylene production rates and ripening process. However, this has enhanced the total soluble solids, pulp to peel ratio and shelf life. A study conducted by Sembok *et al.* (2016) suggested that gibberellic acid treatment of banana resisted the changes in peel colour, retained fruit firmness and adjoining quality attributes with extended storage life of 16 days as against fruits without any treatment. Thokchom and Mandal (2018) revealed that the treatment of aonla cv. Chakaiya with GA_3 at 100 ppm recorded the cumulative physiological loss in weight of 9.28%, 413.13 mg 100 g^{-1} ascorbic acid, 1 2.46 ^{o}Brix TSS, 8.62% total sugars and 1.89% acidity after 12 days of storage by retaining its quality.

The investigation carried out by Ramakrishna *et al*. (2002) on 'Co-2' papaya indicated that GA_3 at 150 ppm was desirable in retarding acceleration of percent weight loss, total soluble solids and total sugars with retention of fruit firmness. Furthermore, there was slow down of ripening attributes such as total carotenoid content and colour, therefore enhancing the shelf-life of additional 4 days over the control fruits. Papaya cv. Red Lady fruits treated with GA_3 (100 ppm) and wrapped in craft paper stored at 15°C inhibited the ripening process and prolonged the shelf life with good quality attributes (Rao, 2004). The papaya cv. Co2 subjected to post-harvest treatment of GA3 @ 100 ppm significantly reduced the PLW (13.52%) during storage period, with the maximum retention of firmness (2.50 kg cm^{-2}), titratable acidity (0.08%), total soluble solids (11.23°Brix), ascorbic acid content (46.85 mg $100g^{-1}$) and the highest score for sensory attributes with extended shelf life of nine days (Rajkumar *et al*., 2005).

Desai (2008) observed that papaya cv. Red Lady treated with GA_3 (100 ppm) had recorded the highest total sugar content of 8.43 %, 10.18 ˚Brix TSS, titratable acidity of 0.06 % and ascorbic acid content of 47.97 mg $100g^{-1}$ with highest marketability than control after 6 days of storage. Premalata (2009) carried out a study on postharvest dipping of Red Lady papaya fruits in gibberellic acid (100 ppm) followed by butter paper wrapping and kept at 12˚C and 80% RH, recorded the maximum shelf life, highest marketablility and minimised postharvest losses. Jashvantlal (2012) studied the effect of GA_3 @ 200 ppm on delayed ripening of papaya (cv. Red Lady) stored at ambient condition and observed that it retained maximum acidity of 0.174%, 48.94 mg $100g^{-1}$ ascorbic acid with minimum respiration rate of 14.5 mg CO_2 kg^{-1} h^{-1}, 9.38% PLW and prolonged the shelf life up to 5.53 days as compared with control. A study conducted by Ramesh *et al.* (2014) suggested that postharvest treatment of gibberellic acid (100mg L^{-1}) on papaya cv. Red Lady significantly recorded the lowest reducing sugars (6.78%) and total sugars (11.12%). Moreover, treated fruits sustained the highest fruit firmness (7.92kg cm^{-2}) and titratable acidity (0.19%) as compared with control with extended storage life of 12 days. Papaya cv. Hortus Gold treated with gibberellic acid had significantly reduced weight loss, colour development, respiration rate, inhibited fungal growth and off flavour development and extended the shelf life without affecting its quality as reported by Ghebreslassie (2017).

Dasu *et al.* (2016) revealed that postharvest application of Red Lady papaya fruits with GA_3 (100 ppm) recorded the lowest physiological loss in weight (8.84%), total soluble solids (11.14%), the highest ascorbic acid content (42.67 mg $100g^{-1}$) and maximum organoleptic scores with minimum loss of quality. Ram (2017) reported that papaya treated with GA_3 @ 150 ppm showed positive effect in maintaining the quality attributes like reducing sugar (7.71%), total sugar (9.48%), acidity (0.139%) and ascorbic acid content (81.99 mg $100g^{-1}$) to the maximum while it recorded the minimum loss in weight of treated fruits. The effect of gibberellic acid @ 200 ppm on papaya studied by Sharma (2017) reported the extension of shelf life up to 14.02 days and recorded total sugars of 11%, 8.62 % reducing sugars, 0.05% titratable acidity, 11.08 ˚Brix TSS and 15.83% of weight loss with better sensory parameters in Red Lady papaya.

2.1.4. Calcium chloride

Fruits treated with calcium had higher retention of firmness due to its accumulation in the cell wall which resulted in cross linking of pectic polymers that help in cell cohesion and maintain wall strength in plants (White and Broadley, 2003). Bansal *et al.* (2015) observed fruits and vegetables had been treated with calcium to enhance shelf life reacts with pectin components of cell wall and forms calcium pectate.

Chardonnet *et al*. (2003) described that calcium chloride is commercially handled as a firming agent for both fresh cut and whole products in fruit and vegetable industry. Calcium based treatments retain or enhance firmness and maintains crispness in case of minimally processed fruits. Dhatt and Mahajan (2004) assessed the outcome of use of calcium chloride on pear fruit and found that there was significant reduction in weight loss. Reduction in weight loss was due to the decreased rate of respiration, transpiration and retardation of senescence. Anino *et al.* (2006) conducted a study and found that sensory analysis of apples treated with calcium had improved textural attributes. Manganaris *et al.* (2007) concluded that various types of calcium have been applied in food industry *viz*., calcium chloride, calcium propionate, calcium phosphate, calcium gluconate and calcium lactate. All these played a role in prolonged shelf life and improved firmness of commodities.

Postharvest treatment of loquat with calcium chloride had retained more ascorbic acid content and improved firmness due to higher levels of calcium that masked the faster oxidative process of ascorbic acid (Attiq *et al*., 2010). Shafiee *et al*. (2010) noted that strawberry cv. Camarosa treated with 1 % calcium chloride solution had recorded minimum weight loss, fruit decay and higher firmness as compared to control. Custard apple treated with $CaCl_2$ at 2 % for 5 minutes and stored under ambient conditions had showed least spoilage, highest organoleptic scores and maximum shelf life (9.80 days) due to delayed ripening and senescence of fruits (Nagaraja *et al.*, 2011). An experiment conducted by Amith (2012) showed that calcium chloride treated fresh cut pineapple and pomegranate was significant in retaining quality, freshness and extended shelf life.

A study conducted by Dhillon and Kaur (2013) revealed that Dashehari mango fruits treated with 6 % calcium chloride for 10 minutes at room temperature had proven effect in reducing weight loss, increasing TSS, acidity and maintained better organoleptic scores. Rai (2014) studied the efficacy of calcium chloride on Dashehari mango and found that treatment with 1.5 % $CaCl_2$ exhibited low physiological loss in weight, high TSS, total sugar, low acidity and ascorbic acid as compared to control. Shahia *et al.* (2015) reported that treatment of *Zizyphus mauritiana* with calcium chloride and stored under refrigerated conditions retained the fruit quality. Postharvest dipping of loquat in 2 and 3 % calcium chloride had significantly reduced mass loss, retained ascorbic acid content, firmness and extended the shelf life than untreated fruits (Babu *et al.,* 2015).

Strawberry cv. "Winter Dawn" immersed in $CaCl_2$ at 2 % for 5 minutes recorded lower weight loss (18.60 %), spoilage percentage (59.00 %), organoleptic score (4.11), acidity (0.43 %), ascorbic acid content (19.75 mg/ 100g) and total sugar (5.70 %) after 12 days of storage as compared to control (Bola *et al.,* 2016). Pitangas treated with $CaCl_2$ @ 1 or 2 % had retained pulp firmness, solids content, lower mass loss, ascorbic acid and phenolic contents and it was also effective in maintaining quality of fruits up to nine days as against six days in control (Sanches *et al.,* 2017). Dalvadi *et al*. (2018) concluded that jamun fruits treated with $CaCl_2$ at 1.5% had significantly declined physiological weight loss, spoilage loss, shrivelling of fruits, preserved firmness and marketability.

Manivannan and Rajkumar (2005) revealed that CO-2 papaya variety of uniform size dipped in $CaCl_2$ at 2% solution for 5 minutes delayed the fruit ripening, recorded the highest shelf life of 9 days with better retention of firmness (2.30 kg cm^{-2}), TSS (11.8˚Brix), titratable acidity (0.073%) and ascorbic acid content (38.51 mg $100g^{-1}$). A study carried out by Ghadage (2011) observed that postharvest application of 3.5% calcium chloride combined with 8% wax coating on papaya cv. Tai wan Red Lady extended the shelf life up to 10.33 days with low physiological loss in weight, reduced respiration rate and the highest retention of firmness, titratable acidity and ascorbic acid content. The papaya cv. Holland fruits treated with 2.5% calcium chloride for 5 minutes and stored at ambient conditions (27˚C and 80% RH) exhibited minimum weight loss of 15.18% at the end of shelf life of 8 days, maintained fruit firmness (0.20 kg cm^{-2}) and delayed redness as compared to control fruits (Chutichudet and Chutichudet, 2014).

Postharvest application of 2% $CaCl_2$ was found very effective in enhancing shelf life of papaya fruits with better physical, physiological, biochemical and sensory quality attributes under ambient storage condition (Singh *et al.*, 2012). Ramesh *et al.* (2016) studied the effect of $CaCl_2$ on Papaya cv. Red Lady and found that $CaCl_2$ at 4 % resulted the lowest weight loss (13.55%), maximum organoleptic scores, ascorbic acid content (43.03 mg $100g^{-1}$), fruit firmness (1.07 kg cm^{-2}) and acidity (0.22%) with the highest shelf life of 10. 67 days. Yadav *et al.* (2016) studied the influence of postharvest dipping of 1% $CaCl_2$ for 5 minutes on papaya (cv. Madhubindhu). It recorded the maximum content of vitamin A (1135.47 IU 100 g^{-1}), reducing sugar (1.73%), total sugar (15.11%) and ascorbic acid (35.89 mg $100g^{-1}$) after storage up to 8 days. Srinu *et al*. (2017) reported that papaya fruits treated with 3 % $CaCl_2$ exhibited maximum fruit firmness of 2.03 kg cm^{-2}, 11.28 ˚Brix TSS, 0.11% titratable acidity and 44.66 mg $100g^{-1}$ of ascorbic acid content with minimum physiological loss in weight of 15.12% after 15 days of storage.

2.1.5. Salicylic acid

Salicylic acid is an endogenous signal mediator in plant defence mechanism against pathogens. Treatment with salicylic acid reduces moisture loss, inhibit oxygen uptake, reduce respiration rate, and restrict ethylene production, which together prevents discoloration, retard microbial growth and thus, extending the shelf life (Montanaro *et al.,* 2006). Supapvanich and Promyou (2013) reported the salicylic acid as a phytohormone, which is classified under phenyl propanoid compound group. It is activated under both biotic and abiotic stress condition as a plant defence mechanism and recognised as a Generally Recommended As Safe (GRAS) for postharvest application of fruits and vegetables.

A study conducted by Srivastava and Dwivedi (2000) suggested that banana cv. 'Hari chhal' fruit treated with salicylic acid (0.5 or 1 mM) slowed down respiration rate, ethylene production, thus delayed ripening with marketability up to 8 days. Mo *et al*. (2008) concluded that Sugar apple deteriorates at a faster rate with the onset of ripening during storage. Up on treatment with salicylic acid (0.8 mmol L^{-1}) combined with storage at low temperature of 15˚C maintained the membrane integrity, decay rates and slowed down the ripening process by reducing respiration rate and ethylene production rate with improved storability up to 10 days. Bal and Celik (2010) reported that Hayward kiwifruit treated with 0.5-1 mM salicylic acid and stored in MAP at 0°C with 85-95% RH was effective in extending the shelf life for 200 days without affecting its quality and also maintained better physical and chemical parameters. An experiment conducted shows that Hayward kiwifruit immersed in 1 mM of salicylic acid solution (SA) for 5-10 minutes and stored at 0.5^{o}C up to 90 days reduced weight loss, prevented fruit softening and improved skin and flesh appearance, aroma and maintained overall fruit quality (Fattahi *et al.*, 2010).

Shafiee *et al*. (2010) reported that strawberry cv. Camarosa immersed in 2 mM of salicylic acid solution prevented the fruit softening and showed the lowest weight loss, fruit decay and higher retention of firmness, ascorbic acid and quality than control. The experiment carried out by Lu *et al.* (2011) observed that winter pineapple fruits subjected to SA @ 2 mM concentration significantly declined the respiration rate, ethylene production and also delayed ripening. A study conducted by Sayyari *et al.* (2011) suggested that pomegranate treated with acetyl salicylic acid could able to delay the ripening process and increased the antioxidant activity due to high rate of bioactive compounds and ascorbic acid content. Cornelian cherry fruits treated with salicylic acid and stored at 4°C for 21 days had significantly enhanced ascorbic acid content and postharvest antioxidant potential. It was found that enhanced antioxidant potential might be due to activation of PAL enzyme and hence triggering the phenylpropanoid-flavonoids pathway (Dokhanieh *et al.*, 2013). Khademi and Ershadi (2013) reported that 2 mM salicylic acid treatment of peach retained firmness and antioxidant activity without having negative impact on organoleptic properties.

Barman and Asrey (2014) investigated that mango cv. Chausa immersed in 2mM solution of salicylic acid as a pre storage treatment for 5 minutes was found as the best in recording minimum weight loss, reduced fruit softening and disease incidence and also effective in maintaining higher bioactive compounds like carotenoids and antioxidant activity. Hong *et al*. (2014) concluded that mango fruits stored at 25˚C for 11 days treated with salicylic acid suppressed the gene expression associated with ethylene biosynthesis and signalling there by inhibiting ethylene production and ripening process and maintained fruit quality. The investigation carried out by Shipra *et al.* (2016) reported that salicylic acid treatment of mango cv. Amrapali extended the shelf life up to 17 days.

Alrashdi *et al*. (2017) reported that postharvest dipping of 'El-Bayadi' variety of table grapes in salicylic acid (4 mM) declined enzyme activity and enhanced antioxidant components than untreated fruits. A study conducted by Ezzat *et al.* (2017) showed that apricot cv. 'Bergarouge' dipped in 2 mmol L^{-1} of salicylic acid for 15 minutes and kept under cold storage condition at 1˚C with 95% relative humidity followed by storage at ambient condition (25˚C) recorded a shelf life of 21 days which significantly reduced the fruit softening, weight loss and retained the soluble solid content and acidity throughout the storage period. The postharvest dipping of grape cv. Superior Seedless with salicylic acid of 4 mM concentration was found to reduce increment in weight loss, enhanced fruit firmness and shelf life up to 4 days (Loay, 2017). An improved shelf life in banana cv. Nendran was observed with salicylic acid treatment at 2mM (Nair, 2018). Mandarin orange (cv. Kinnow) fruits treated with Salicylic acid (5 mM) exhibited lowest titrable acidity (0.94 %), total sugar contents (4.79 %), TSS (10.37̊ B) and ascorbic acid (30.00 mg $100g^{-1}$) as compared to control (Haider *et al.*, 2020). Postharvest dipping of pistachionut in 2 mmol L^{-1} SA significantly reduced the accelerated activity of polyphenol oxidase than control. Moreover, it also reported the best colour score of fruits (Molamohammadi *et al*., 2020).

A postharvest immersion of 'Kaek Dam' papaya fruit in 2 mM SA had significantly declined fruit ripening and retained firmness during refrigerated storage by hindering the levels of EL and, EDTA and Na_2CO_3 soluble pectin components and enhanced scavenging activity of treated fruits (Promyou and Supapvanich, 2014). The postharvest treatment of papaya cv. Red Lady with SA at 1 mM concentration significantly enhanced the fruit firmness with 8.46 kg cm^{-2}, titratable acidity (0.23%), antioxidant activity (87.54%) and ascorbic acid content (27.80 mg $100g^{-1}$) with low physiological loss in weight of 11.07% than control (Lata, 2017). Mandal *et al.* (2017) reported that papaya cv. Red Lady immersed in salicylic acid at 2.5 mM L^{-1} for five minutes and stored at 20-25˚C and 75-80 % relative humidity recorded the lowest weight loss (11.46%) at 7 days after storage. Furthermore, fruits subjected to this treatment also had low TSS (7.75˚B), carotenoid content (1.06 mg 100^{-1}) and colour score (2.08), indicated delayed ripening and the highest shelf life (14 days) with minimum decay percentage (6.25%) of fruits. An investigation conducted by Supapvanich and Promyou (2017) showed that **'**Holland' papaya fruits exposed to 2.0 mM of SA coupled with hot water dip at 42˚C maintained postharvest fruit quality with enhanced bioactive components like carotenoids, ascorbic acid content, antioxidant activity in fruit kept under ambient condition of storage for a period of 6 days**.** Devarakonda *et al*. (2020) revealed that SA application of papaya cv. Red Lady at 150 ppm recorded the lowest physiological loss in weight of 11.89% while biochemical attributes like total sugars (8.26%), TSS, reducing sugars (4.86%) increased during a storage period of 12 days.

2.1.6. Hot water treatment

Fungal diseases and insect damages in several fruits were eradicated using heat treatments during postharvest handling practices. An important advantage of heat treatment is that there is no chemical residue on the surface of fruits and commercially used heat treatments are vapour heat, hot water and hot air. Vapour heat treatment is particularly used for insect disinfection, while hot water is basically used for the control of fungal diseases and extended up to insect control and hot air has been used for controlling both insect and fungal damage (Lurie, 1998). Kader (2013) reported that heat treatments controlled postharvest diseases like anthracnose in mango and crown rot in banana and also insect infestation were regulated to meet the quarantine requirements in some produce, like papaya and mango.

Papaya cv. Tainung subjected to 48-50˚C for 20 minutes and stored at 5˚C was effective reducing rate of respiration and ethylene production and maintained the organoleptic properties (Allong *et al.,* 2000). The hot water treatment (47±1˚C for 10 minutes) of papaya cv. Eksotika II was able to maintain the quality of fruit when it was allowed to ripen at room temperature and played a role as disinfectant (Martins *et al.,* 2004). Arina *et al.* (2010) studied that papaya cv. Eksotika exposed to hot water as a postharvest quarantine treatment for fruit fly disinfection for the export of papaya fruit to different countries and reported improved postharvest fruit quality during ripening process. Martins *et al.* (2010) reported that papaya fruits exposed to hot water treatment of different temperatures did not influence the quality parameters like firmness, titratable acidity and total soluble solids. However, hot water treatment of 48-50°C for 20 minutes was effective in controlling fungal species like *Phoma caricae* and *Colletrotrichum gleosporoides.*

Kechinski *et al.* (2012) provided heat treatments to papaya fruits using hot water brushing system at temperatures of 45, 55 and 65°C and no mould growth was observed under wax film coating of fruits treated under hot water. NHB (2012**)** suggested hot water treatment of papaya as a method to combat anthracnose for export industries. The effect of hot water treatment (55˚C for 0, 3, 6 and 9 minutes) on papaya was studied by Carrillo-Lopez *et al*. (2013) and observed that these treatments did not have negative effect on its biochemical parameters such as TSS, titratable acidity, PLW and fruit firmness at any duration. Chavez-Sanchez *et al*. (2013) opined that hot water treatment at 55°C for 3 minutes contributed to anti-fungal property and did not badly affect the quality parameters of both pulp and skin of papaya fruits at their colour break stage of ripeness. Hence, this treatment is considered promising to reduce the decay of fruits when marketed at non-refrigerated condition (25°C).

A study conducted by Li *et al*. (2013) reported that hot water treatment at 54˚C for 4 minutes reduced fruit softening and decay, preserved fruit quality and extended shelf life of papaya fruits. Zhao *et al.* (2013) revealed that papaya fruits treated with hot water at 54°C for 4 minutes slowed down the ripening process and declined postharvest decay by 43.7 percent after storage of 9 days when stored at 25°C. Fruits treated with hot water maintained fruit firmness due to decline in ripening with improved colour development as compared to control, which enhanced its economic value. The appropriate treatment of fruits with hot water affected the respiration rate, ethylene production rate, and suppressed the activity of enzymes associated with cell wall degradation such as polygalacturonase and pectin methylesterase and enhanced the expression of protein gene associated with inhibition of polygalacturonase.

Papaya cv. Coorg Honey Dew harvested at maturity stage of 1/4th yellowing and immersed in hot water at 50^{0}C for 20 minutes had significantly reduced weight loss, microbial growth, controlled postharvest diseases and extended the shelf life at room temperature as reported by (Jayasheela *et al.*2015). Shadmani *et al.* (2015) observed that papaya cv. Frangi exposed to double dip hot water treatment (42 °C for 30 minutes and 49 °C for 20 minutes) followed by storage at low temperature prolonged the storage life. Papaya cv. solo subjected to heat treatment (49^{o}C for 90 minutes) and then stored at 15°C exhibited lowest physiological loss in weight, acidity, retained firmness, improved the organoleptic qualities and extended the shelf life up to 20 days (Benjamin *et al.*, 2018).

2.1.7. Ozonation

Ozonation is a novel, non-thermal approach effective in inactivation of microbes which causes damage to cellular constituents by attributing changes in cell permeability, oxidation of proteins and lipids in the microbial cell (Priyanka *et al.*, 2014).

Ozonation helps in degradation of toxic contaminants through oxidative process (Ong *et al*., 1996) and also aids in minimising postharvest loss ensuring food quality and safety (Karaca and Velioglu, 2007). It is an eco-friendly sanitizer due to rapid auto- decomposition in to molecular oxygen and is free of chemical residues and is considered as an emerging “green technology” (Pandiselvam *et al.,* 2019).

Amaranthus sanitized with 2 ppm ozonised water revealed the lowest physiological loss in weight, highest relative water content with high acceptability after 4 hours of storage at room temperature (George, 2015). Ambareesha (2016) reported that amaranthus surface sanitized with 2 ppm ozonised water had maximum content of ascorbic acid, anthocyanin and mean score for visual parameters. Ozone treatment extended green life of fresh fruits and vegaetables by retarding microbial activity and through ethylene oxidation (Beuchat, 2016). Shetty (2017) observed that rambutan fruits subjected to ozonation of 2 ppm recorded the lowest physiological loss in weight, improved colour retention and extended shelf life for 5 days with highest retention of nutrients and better consumer acceptability.

Papaya cv. "Sekaki" fruits were dipped with ozonised water 2.5 ppm exhibited higher levels of TSS, ascorbic acid, antioxidant activity after 10 days after storage (Skog and Chu, 2001). Bataller *et al.* (2012) reported that papaya cv. Maradol-red immersed in ozone-containing water (1 m*g* L^{-1}) was desirable in reducing fungal pathogens and delayed the fruit decay. The papaya fruits subjected to ozone fumigation of 1.6 ppm for 96 hours declined the disease incidence to an extent of 40%, thereby reducing postharvest losses caused due to anthracnose as proved by Ong *et al.* (2013). Papaya treated with 3.5 ppm of ozone exhibited the highest antioxidant activity (30.9%) and vitamin C content (12.4%) after 10^{th} day of storage (Ali *et al.*, 2014). A study conducted by Silva Neto *et al*. (2019) reported that papaya cv. Sunrise solo exposed to 3.3 ppm ozone and kept at room temperature of 27 ± 2 ºC and RH 65 ± 2% potentially reduced the severity of anthracnose incidence. Terao *et al.* (2019) studied the combined effect of ozonation (3 mg L^{-1}) with heat treatment (70 °C for 15 Seconds) on papaya and found that it as an effective method of sanitization.

2.2. STORAGE STUDIES

Rao (2004) reported that papaya fruits packed in polyethylene film wrap recorded less physiological weight loss and maintained good quality attributes during the storage period. Chonhenchob and Singh (2005) noticed that papaya fruits cushioned with paper based material in CFB boxes, significantly preserved the quality as compared to plastic based cushioning material (foam nets, crates). Papaya hybrid Formosa 'Tainung 01' covered individually using bubble wrap and then packing in wavy cardboard boxes maintained the quality of fruits with minimum damage during transit (Santos *et al.*, 2008).

Papaya cv. Taiwan Red Lady immersed in postharvest treatment (GA_3 and $CaCl_2$) and packed with butter paper exhibited lowest physiological loss in weight of 21.87%, preserved firmness (5.88 kg cm^{-2}) with highest marketability than control (Premalata, 2009). Lanka *et al.* (2011) reported that papaya subjected to hot water dip (49°C; 20 minutes) followed by pre treatment and spraying with 5 % ethanol and sealed in low density polyethylene bag maintained the shelf life up to 12 days under ambient conditions. The papaya fruits harvested at colour break stage, treated with 1-MCP and packed in polyethylene lined CFB boxes slowed down the ripening and fruit softening with increased consumer acceptability (Paull and Chen, 2011). Papaya fruits wrapped in polyethylene bag coupled with evaporative storage retained the freshness, firmness, fruit quality for 25 days and increased shelf life by two folds by (Azene *et al.*, 2014). Barot *et al.* (2016) investigated that papaya cv. Madhu Bindhu subjected to 2% calcium chloride and stored in CFB boxes at room temperature recorded the highest TSS of 12.50%, 21.00% total sugars, 2.40% reducing sugars and also maximum ascorbic acid content of 38 mg $100g^{-1}$ with superior fruit quality.

Bhuvaneswari *et al.* (2017) observed that papaya cv. Red Lady packed in cushion intact telescopic customised corrugated fibre board (450×300×300mm, 18 kg/ cm^2 bursting strength) exhibited the lowest weight loss of 3.75% with highest acidity (0.16%), total soluble solids (12 ˚Brix) and carotenoid content (1.13 mg $100g^{-1}$) during ripening period of 12 days. The postharvest dipping of Red Lady papaya at colour break stage in chitosan solution for 5 minutes, air dried and wrapped with paper and stored in CFB boxes at ambient temperature **(**28±1ºC) recorded the minimum cumulative weight loss of 5.1%, higher retention of firmness (633g) with slow ripening and extended prolonged shelf life up to 8 to 9 days (Bhanushree *et al*., 2018). Patel *et al.* (2019) reported that papaya cv. Red Lady dipped in botanical extracts were air dried, wrapped using paper and stored under ambient temperature decreased the incidence of postharvest diseases with good consumer acceptance. Papaya cv. Red Lady-786 harvested at colour break stage when stored for ripening studies reported that fruits at 25°C took 72-96 hours for ripening, which was superior in quality over fruits kept at 20°C and 30°C. It was also noted that fruit firmness decreased with rise in temperature and ripening period (Singh *et al*., 2019).

Materials and Methods

3. MATERIALS AND METHODS

The materials and methodologies adopted during the present experiment entitled "Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady" conducted with the objective to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss through postharvest handling practices are described in this chapter.

3.1. EXPERIMENTAL MATERIAL

3.1.1. Experimental site

The present investigation was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2018-2020.

3.1.2. Selection of fruits

Good quality papaya fruits (cv. Red Lady) of uniform maturity (colour break stage), size and shape were procured from the field of progressive farmers of, Sanghamaitri, Farmer Producer Organisation at Pallichal. The fruits were harvested at early morning and brought to the Post Graduate research lab of Department of Post Harvest Technology without delay. The fruits were subjected to different postharvest treatments in order to assess the effectiveness of postharvest treatments for delayed ripening and to extend the shelf life.

3.1.3. Postharvest treatments

The selected fruits after sanitization (ozonisaton 2 ppm) followed by hot water treatment (50^0C for 20 minutes) were subjected to different postharvest treatments by dipping for 5 minutes. The postharvest treatments used were Naphthalene acetic acid (250 ppm), Edible coating (Papaya Leaf Extract Aloe Gel 1:1), Gibberellic acid (100 ppm), Calcium chloride (2%) and Salicylic acid (2 mM).

3.1.3.1. Preparation of Naphthalene acetic acid (NAA 250 ppm) solution

Naphthalene acetic acid of 250 ppm was prepared by adding 250 mg in small quantity of 1 N NaOH before being mixed with 1 L distilled water and Tween 80 (sticker) of 0.1% was added to it as a wetting agent.

3.1.3.2. Preparation of Edible coating (Papaya Leaf Extract Aloe Gel) (PLEAG)

Gel matrix (colourless hydroparenchyma) underneath the leaf rind extracted from fresh *aloe vera* leaves were ground using blender and was filtered to remove fibres. The pure aloe gel (AG; 100%) obtained was pasteurized at 70˚C for 45 minutes. To facilitate uniform coating 1% sodium alginate was added as a stabiliser.

To prepare PLEAG 1:1, 500 g of fresh papaya leaves washed in running water were sterilised using 0.1% sodium hypochlorite for l0 minutes and then washed with distilled water to remove the residues of chemicals. Papaya leaves were then crushed with aloe gel in 1:1. Final filtration was done to remove fibre (Brishti *et al*., 2013). Tween 80 @ 0.1% was added to the solution as a wetting agent.

3.1.3.3. Preparation of Gibberellic acid (GA_3 100 ppm) solution

The GA_3 @ 100 ppm concentration was prepared by taking 100 mg in small quantity of 95% ethanol which was dissolved in distilled water (1 L) containing 0.1% Tween 80 (wetting agent).

3.1.3.4. Preparation of Calcium chloride ($CaCl_2$ 2%) solution

The 2% concentration of calcium chloride solution was made up by dissolving 2 g in 100 ml of distilled water and 0.1 % of Tween 80 was added to it.

3.1.3.5. Preparation of Salicylic Acid (SA 2 mM) solution

Salicylic Acid solution of 2 mM was made up by adding 276 mg in 1 L of distilled water after being dissolved in small quantity of 95% ethyl alcohol and Tween 80 @ 0.1% was added to it as a wetting agent.

Plate 1. Red Lady papaya orchard

Plate 2. Red Lady papaya harvesting

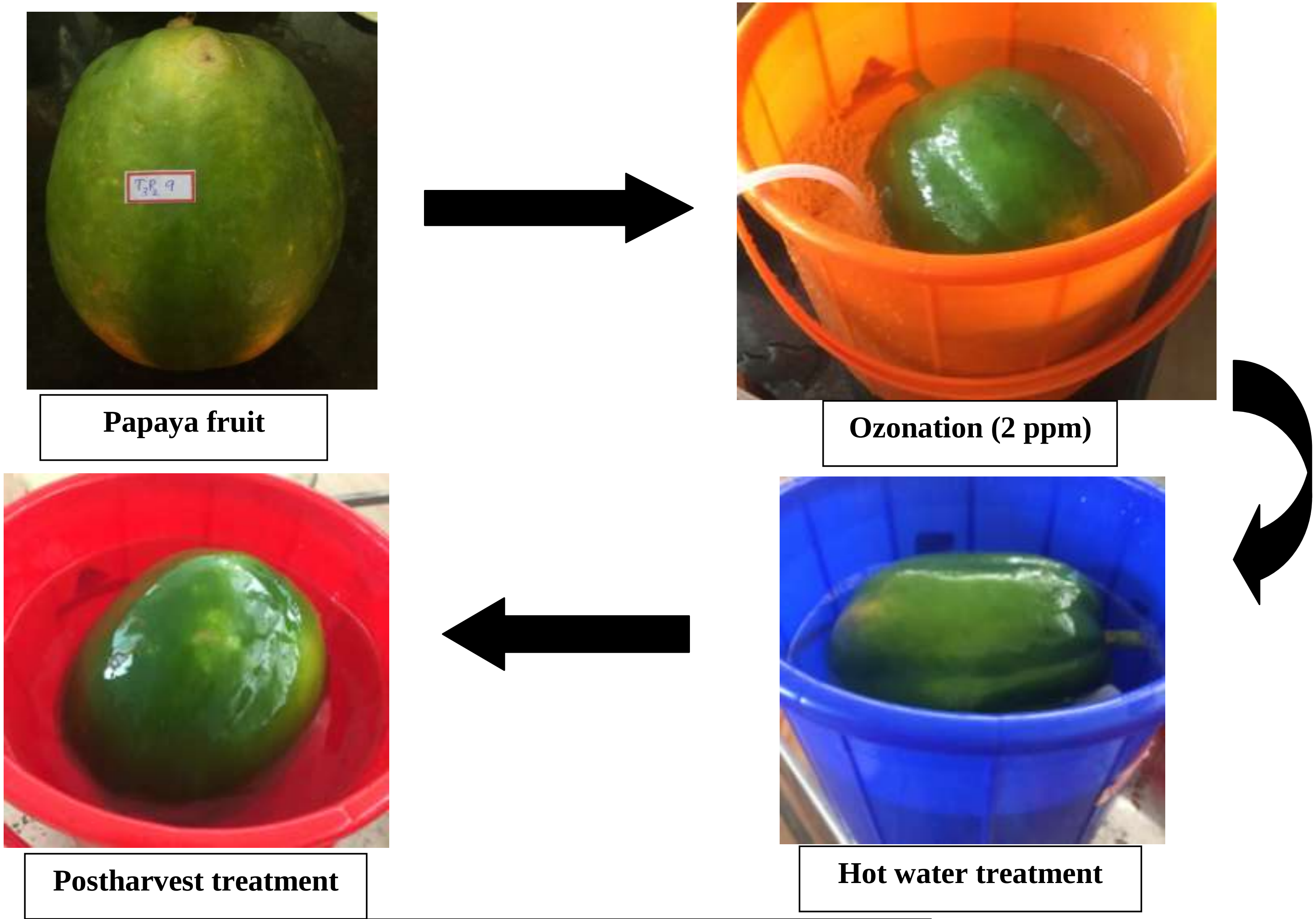

Plate 3. Postharvest treatment of Red Lady papaya

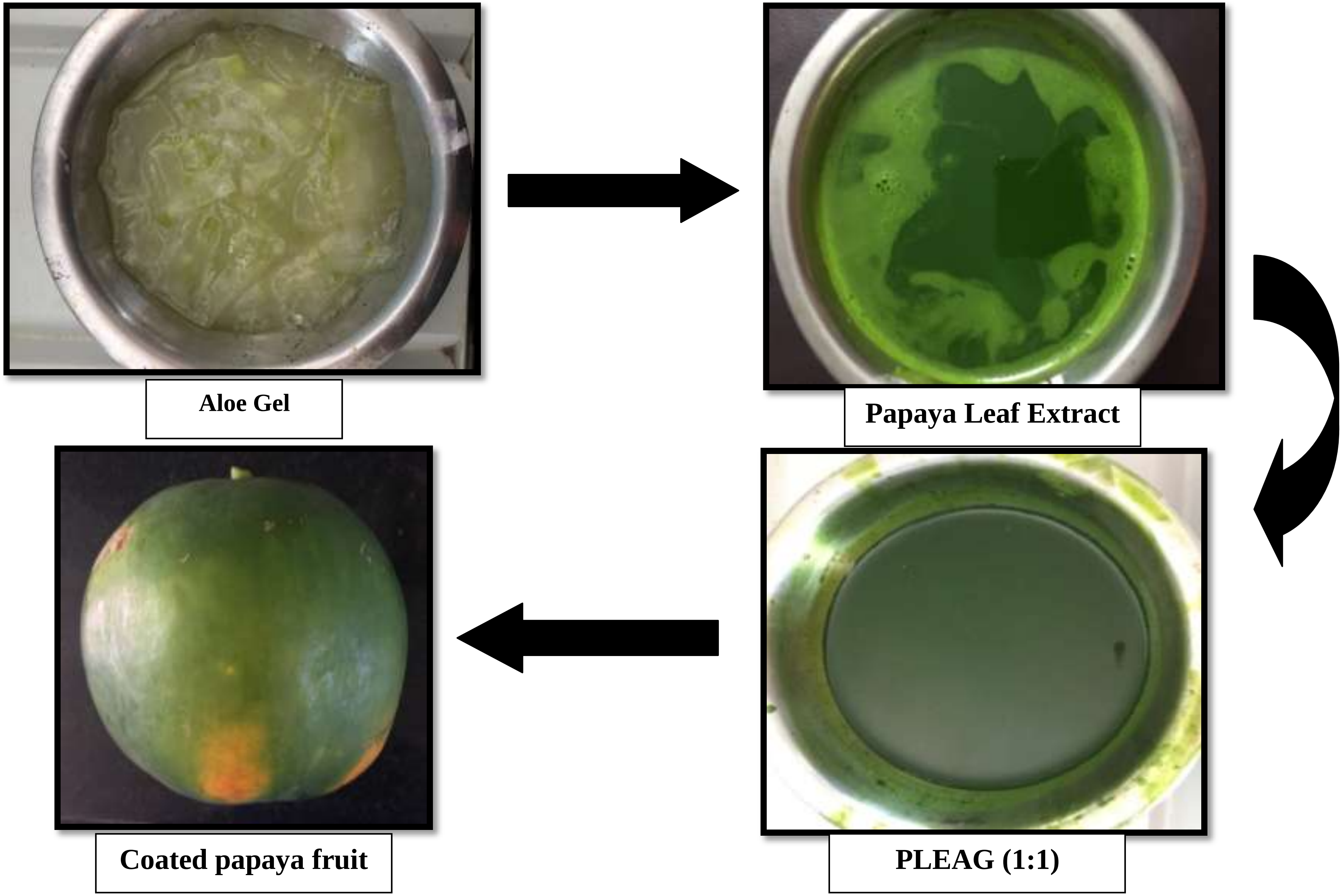

Plate 4. Papaya Leaf Extract Aloe Gel coating of papaya fruit

3.2. TREATMENT DETAILS

T_1- NAA (250 ppm)

T_2- Edible coating (Papaya Leaf Extract Aloe Gel) (PLEAG)

T_3- GA_3 (100ppm)

T_4- $CaCl_2$ (2%)

T_5- Salicylic Acid (2mM)

T_6- Hot water treatment alone

T_7- Control (without any postharvest treatment)

Number of treatments : 7

Number of replications : 3 (10 fruits per replication)

Experimental Design : Completely Randomised Design (CRD)

3.2. OBSERVATIONS

The pre treated papaya fruits were air dried for removing the surface moisture and stored in Corrugated Fibre Board boxes with 5% ventilation under ambient conditions (30±2˚C; 80-85% RH). Physiological, biochemical, physical, and sensory parameters of fruits during storage were recorded at an interval of three days till the end of shelf life.

3.2.1. Physiological parameters

Physiological parameters *viz*., physiological loss in weight and respiration rate of pre treated papaya fruits during storage was determined.

3.2.1.1. Physiological Loss in Weight (PLW)

Physiological loss in fruit weight was determined by noting the weight of sample at 3 days interval and deducted from the initial weight recorded at the time of storage. PLW was calculated using the formula mentioned below and expressed as percentage (Koraddi and Devendrappa, 2011).

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

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

The pre treated papaya fruits after weighing precisely were placed in a closed plastic container (5 L capacity by volume) for estimation of respiration rate. Immediately after one hour CO_2 concentration was recorded using Checkpoint Portable Gas Analyser by penetrating needle through a silicon rubber septum fixed to lid and expressed in mL CO_2 kg^{-1} h^{-1} (Bhande *et al*., 2008).

3.2.2. Biochemical parameters

Biochemical attributes such as moisture content, Total Soluble Solids, reducing sugar, total sugar, titratable acidity, carotenoids, ascorbic acid and antioxidant activity of pre-treated papaya fruits were analysed at three days interval till the end of shelf life.

3.2.2.1. Moisture content (%)

One gram of fruit pulp was kept in moisture analyser (Essae, AND MAX 50) to record the moisture content based on principle of thermo gravimetric analysis, expressed in terms of percentage.

3.2.2.2. Total Soluble Solids (^{o}B)

Total Soluble Solids (TSS) of papaya was determined at an interval of three days using Atago - 0 to 53% digital refractometer and was expressed in ^{o}Brix**.**

3.2.2.3. Reducing Sugar (%)

Reducing sugar was analysed as per the titrimetric method of Lane and Eynon as described by Ranganna (1986). Reducing sugar was calculated using the following formula and expressed as percentage.

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total vol. made up (ml) x 100}}{\text{Titre value x Weight of sample taken (g)}}$$

3.2.2.4. Total Sugar (%)

Total sugar content was determined as per the procedure described by (Ranganna, 1986) and calculated using the following formula and the results were

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

3.2.2.5. Titratable acidity (%)

Titratable acidity was measured according to the procedure provided by Ranganna (1986) and was expressed in per cent citric acid equivalent using following formula.

$$\text{Acidity} = \frac{\text{Titre value X 0.1 X Volume made up (ml) X 0.064}}{\text{Volume of sample taken (ml) X Wt. of the sample (g) X 10}}$$

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

Carotenoids of a treated fruit were determined as per the procedure of Saini *et al.* (2001) and expressed in mg 100g^{-1} of sample.

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

The titrimetric method using 2, 6 dichlorophenol Indophenol outlined by Ranganna (1986) was used for the estimation of ascorbic acid and was calculated using the following formula. It was expressed as mg 100g^{-1} of fruit on fresh weight basis.

$$\text{Ascorbic acid} = \frac{\text{Titre value X Dye factor X Volume made up (ml) X 100}}{\text{Aliquot of extract taken (ml) X Wt. of sample (g)}}$$

3.2.2.8. Antioxidant activity (%) (DPPH assay)

Total antioxidant activity of postharvest treated papaya was estimated using 2, 2- diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured as per the procedure given by Sharma and Bhat

(2009). Scavenging effect was expressed in per cent inhibition of DPPH as mentioned in the following equation:

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

Where,

A_{blank} – Absorbance of DPPH solution without sample

A_{sample} – Absorbance of the test sample after 30 min

3.2.3. Physical parameters

Physical parameters *viz.*, texture (fruit firmness) and skin colour of postharvest treated papaya were analysed.

3.2.3.1. Texture (N)

Textural properties of treated papaya fruits were evaluated using a texture analyzer TA–HD® (Stable Micro systems, Surrey, England) equipped with a 50kg load cell. The analyzer was linked up to a computer that recorded data via a software program called Texture Expert (version 1.22, Stable Micro Systems, UK). Texture evaluation was carried out by placing the whole fruit with skin on the platform of the texture analyzer and penetrating it with a 2 mm diameter cylindrical stainless steel (P/2 dia cylinder stainless steel) at a speed of 0.5mm/s with automatic return to plot a corresponding deformation curve. The penetration was taken at three different positions on same vertical axis. The downward distance (penetration distance into the fruit) was set at 15mm and pre-test speed, test speed and post-test speed were 5 mm/s, 2 mm/s and 10 mm/s; respectively. The trigger force and data acquisition rate were set as 0.049 N and 200 pps respectively. The maximum distance covered by probe was considered as a measure of fruit texture and expressed in newton (N).

3.2.3.2. Skin colour

Papaya fruits after postharvest treatment were visually observed during storage and scored relying on the standard colour index scaling from 0 to 6 as developed by Mandal *et al*. (2017).

Score 0 : Green skin without yellow stripe

Score 1 : Green skin with light yellow stripe

Score 2 : Green skin with well-defined yellow stripe

Score 3 : One or more orange-coloured stripes in skin

Score 4 : Clearly orange-coloured skin with some light green areas

Score 5 : Characteristic orange-coloured skin of papaya, and

Score 6 : Fruit colour similar to stage 5, but more intense

3.2.4. Sensory analysis

Pre treated papaya fruits were evaluated for sensory attributes *viz.*, texture, colour, odour, taste, flavour, appearance and overall acceptability by semi trained panel of 30 members during storage. Sensory characteristics were evaluated using nine point hedonic scale set out by Ranganna (1986) where each character was scored from 1 to 9.

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

Plate 5. Moisture Analyzer

Plate 6. Gas Analyzer

3.2.5. Shelf Life (days)

Shelf life of treated papaya fruits was examined by recording the number of days for 10% spoilage during storage, which was expressed as days (Ramesh *et al.*, 2016).

3.3. Statistical analysis

The data obtained from an experiment were statistically analyzed using Completely Randomized Design (CRD). Sensory attributes were statistically analysed by using Kruskall Wallis test.

The sensory scores were statistically analysed using Kruskall-Wallis test (chi-square value) and ranked as per the procedure described by Shamrez *et al*. (2013).

Results

4. RESULTS

The experimental data collected from the investigation on "Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady" were analyzed and the results are interpreted in this chapter.

Papaya fruits were subjected to different postharvest treatments *viz.*, Naphthalene Acetic Acid (NAA), Edible coating (papaya leaf extract aloe gel), Gibberellic Acid (GA_3), Calcium chloride ($CaCl_2$), Salicylic Acid (SA), hot water treatment alone and control (without any postharvest treatment). Treated papaya fruits, after removal of surface moisture, were stored in corrugated fibre board boxes at room temperature (30±2ºC, RH 80-85%). The fruits were analyzed for physiological, biochemical, physical and sensory parameters during storage.

4.1. PHYSIOLOGICAL PARAMETERS

4.1.1. Physiological Loss in Weight (PLW %)

Effect of postharvest treatments on physiological loss in weight of Red Lady papaya during storage is depicted in Table 1. Physiological loss in weight of papaya fruits showed significant difference among the treatments and increased during storage from 4.10% after 3rd day of storage to 8.08% and 10.81% after 6th and 9th days respectively. The postharvest treatment with Salicylic acid (SA 2 mM) (T_5) recorded the lowest loss in weight (4.53%) followed by T_1 (NAA 250 ppm) (5.42%) and the highest weight loss of 11.45% was recorded in fruits without postharvest treatment (T_7) after 9 days of storage.

With respect to the observations recorded on interaction effects, T_5 (SA 2 mM) with 2.60% recorded the lowest loss in weight followed by T_1 (NAA 250 ppm) (2.94%) and T_3 (GA_3 100 ppm) (3.29%) after 3 days of storage. However the highest weight loss (5.93%) was observed in fruits without any postharvest treatment (T_7). After 6th day of storage, T_5 (SA 2 mM) (4.45%) showed the lowest value for loss in weight followed by T_1 (NAA 250 ppm) with 5.84% weight loss while the highest value for physiological loss in weight of 11.78% was found in T_7 (control without any postharvest treatment). The lowest weight loss (6.55%) was recorded in T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 7.49% but, the highest cumulative loss in weight of 16.65% had been recorded in fruits stored without any postharvest treatment (T_7) after 9 days of storage.

The papaya fruits without any postharvest treatment (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. The papaya fruits with SA treatment (T_5) recorded the lowest weight loss of 9.34% after 12 days of storage followed by the NAA treatment (T_1) with 10.84% of cumulative weight loss. The highest loss in weight of 16.82% was recorded by the treatment T_4 ($CaCl_2$) followed by T_2 (PLEAG edible coating) with 14.56% of weight loss.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. The lowest weight loss of 13.10% was observed in T_5 (SA 2 mM) treated papaya after 14 days of storage and the highest cumulative loss in weight of 16.49% was reported in T_2 (PLEAG edible coating).

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

Effect of postharvest treatments on respiration rate of papaya cv. Red Lady during storage is represented in Table 2. After 9 days of storage, minimum respiration rate of 50.02 mL CO_2 kg^{-1} h^{-1} was recorded in T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 51.47 mL CO_2 kg^{-1} h^{-1} and the maximum values (65.49 mL CO_2 kg^{-1} h^{-1}) for respiration rate was noticed in T_7 (without any postharvest treatments) followed by T_6 (hot water treatment) with 62.19 mL CO_2 kg^{-1} h^{-1}. Respiration rate of stored papaya fruits showed an increased rate of respiration from 30.79 to 86.54 mL CO_2 kg^{-1} h^{-1} during the storage period of 9 days. Respiration rate of Red Lady papaya at the time of storage was 30.79 mL CO_2 kg^{-1} h^{-1} which increased to 44.88, 67.02 and 86.54 mL CO_2 kg^{-1} h^{-1} after 3rd, 6th and 9th day of storage respectively.

At the time of storage, respiration rate of Red Lady papaya ranged between 29.30 mL CO_2 kg^{-1} h^{-1} and 32.30 mL CO_2 kg^{-1} h^{-1}. The minimum rate of respiration was observed in T_5 (SA 2 mM) with 40.21 mL CO_2 kg^{-1} h^{-1} which was on par with T_1 (NAA 250 ppm) (41.01, mL CO_2 kg^{-1} h^{-1}) after 3 days of storage and the maximum

Table 1. Effect of postharvest treatments on Physiological Loss in Weight (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)			Treatment Mean (T)	12	14
	3	6	9			
T_1 (NAA 250 ppm)	2.94 (1.98)	5.84 (2.62)	7.49 (2.91)	5.42 (2.50)	10.84 (3.44)	13.95 (3.87)
T_2 (PLEAG edible coating)	3.47 (2.11)	7.88 (2.98)	9.31 (3.21)	6.89 (2.77)	14.56 (3.94)	16.49 (4.18)
T_3 (GA_3 100 ppm)	3.29 (2.07)	6.83 (2.80)	8.55 (3.09)	6.22 (2.65)	12.46 (3.67)	14.27 (3.91)
T_4 ($CaCl_2$ 2%)	4.63 (2.37)	8.92 (3.15)	11.63 (3.55)	8.39 (3.03)	16.82 (4.22)*	-
T_5 (Salicylic Acid 2 mM)	2.60 (1.90)	4.45 (2.34)	6.55 (2.75)	4.53 (2.33)	9.34 (3.22)	13.10 (3.76)
T_6 (Hot water treatment)	5.83 (2.61)	10.84 (3.44)	15.47 (4.06)*	10.71 (3.37)	-	-
T_7 (Control)	5.93 (2.63)	11.78 (3.57)	16.65 (4.20)*	11.45 (3.47)	-	-
Days (D) Mean	4.10 (2.24)	8.08 (2.99)	10.81 (3.40)			
	SE± (m)	CD (0.05)				
Treatments (T)	0.007	0.020			SE± (m) 0.015	SE± (m) 0.013
Days (D)	0.005	0.013			CD (0.05) 0.046	CD (0.05) 0.041
Treatments (T) × Days (D)	0.012	0.034				

(Square root transformed values are provided in parenthesis)

*Papaya fruits were discarded due to spoilage

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

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	29.82	41.01	57.88	77.45	51.54	89.62	95.65
T_2 (PLEAG edible coating)	30.81	43.60	68.99	86.85	57.56	93.58	98.56
T_3 (GA_3 100 ppm)	30.40	42.45	61.68	81.34	53.97	91.45	97.63
T_4 ($CaCl_2$ 2%)	31.34	45.98	71.85	92.32	60.37	94.65*	-
T_5 (Salicylic Acid 2 mM)	29.30	40.21	54.57	75.99	50.02	88.55	94.83
T_6 (Hot water treatment)	31.54	48.91	75.41	92.90*	62.19	-	-
T_7 (Control)	32.30	51.97	78.78	98.92*	65.49	-	-
Days (D) Mean	30.79	44.88	67.02	86.54			
	SE± (m)	CD (0.05)					
Treatments (T)	0.263	0.747				SE± (m) 0.126	SE± (m) 0.249
Days (D)	0.199	0.564				CD (0.05) 0.402	CD (0.05) 0.08
Treatments (T) × Days (D)	0.526	1.493					

*Papaya fruits were discarded due to spoilage

respiration rate of 51.97 mL CO_2 kg^{-1} h^{-1} was reported in T_7 (control) followed by T_6 (hot water treatment) with a respiration rate of 48.91 mL CO_2 kg^{-1} h^{-1}.

During storage, the lowest respiration rate was recorded in T_5 (SA 2 mM) with 54.57 and 75.99 mL CO_2 kg^{-1} h^{-1} after 6 and 9 days of storage respectively which was followed by T_1 (NAA 250 ppm) with 57.88 and 77.45 mL CO_2 kg^{-1} h^{-1} after 6 and 9 days of storage. The highest values for respiration rate was noticed in T_7 (control) and the values were 78.78 and 98.92 mL CO_2 kg^{-1} h^{-1} after 6 and 9 days of storage respectively.

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. After 12th day of storage, Salicylic Acid treated papaya fruits (T_5) showed the lowest (88.55 mL CO_2 kg^{-1} h^{-1}) respiration rate followed by T_1 (NAA 250 ppm) (89.62 mL CO_2 kg^{-1} h^{-1}) while the highest value of respiration rate (94.65 mL CO_2 kg^{-1} h^{-1}) had been recorded in T_4 ($CaCl_2$ 2%) followed by T_2 (PLEAG edible coating) (93.58 mL CO_2 kg^{-1} h^{-1}).

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. After 14th day of storage, SA treatment of papaya recorded the lowest respiration rate of 94.83 mL CO_2 kg^{-1} h^{-1} followed by T_1 (NAA 250 ppm) with 95.65 mL CO_2 kg^{-1} h^{-1} and the highest respiration rate of 98.56 mL CO_2 kg^{-1} h^{-1} was reported by T_2 (PLEAG edible coating).

4.2. BIOCHEMICAL PARAMETERS

4.2.1. Moisture content (%)

Moisture content of postharvest treated papaya cv. Red Lady during storage is outlined in Table 3. Papaya fruits with different postharvest treatments recorded moisture content ranged between 82.74% and 83.24% at the time storage without any significant difference between the treatments. After 9 days of storage, the lowest moisture content value of 87.31% was recorded for T_5 (SA 2 mM) followed by NAA treated fruits (T_1) (88.06%). However the highest value of 91.72% had been recorded in T_7 (control) followed by T_6 (hot water treatment) with a moisture content of 90.64%. It was found that there was reasonable increase in the moisture content from

82.94% to 88.45%, 91.90% and 94.23% after 3rd, 6th and 9th days respectively and recorded significant difference during the storage period. The lowest moisture content of 85.86% was observed in T_5 (SA 2 mM) which was on par with T_1 (NAA 250 ppm) (86.25%) and the highest moisture content of 91.78% was reported in T_7 (control) followed by T_6 (hot water treatment) after 3 days of storage.

During storage, papaya treated with T_5 (SA 2 mM) recorded the lowest value of 88.65% moisture content followed by NAA 250 ppm with 89.90% (T_1) while the highest value of 95.01% of moisture content was found in T_7 (control) followed by T_6 (hot water treatment) with 94.12% after 6 days of storage. Moisture content of SA treated (T_5) papaya fruits was the lowest with 91.69% followed by T_1 (NAA 250 ppm) with 92.84% after 9th day of storage while the highest moisture content of 97.31% was reported in papa T_7 (control) followed by T_6 (hot water treatment with 95.53%.

The papaya fruits without any postharvest treatment (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. After 12 days of storage, the lowest moisture content (93.77%) was recorded by T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) (94.93%). However, the highest percentage of moisture content was observed in T_4 ($CaCl_2$ 2%) with 97.42 % followed by T_2 (PLEAG edible coating) with 96.77% moisture content.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. SA treated fruits (T_5) recorded the lowest moisture content of 95.27% after 14 days of storage.

4.2.2. Total Soluble Solids (TSS) (^{o}Brix)

Effect of postharvest treatments on total soluble solids (^{o}Brix) of papaya cv. Red Lady during storage is outlined in Table 4. Papaya fruits dipped in postharvest treatments recorded the minimum TSS of 5.91 ^{o}Brix by T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 6.26 ^{o}Brix while the maximum TSS of 9.66 ^{o}Brix was reported in T_7 (control) followed by T_6 (hot water treatment) with 8.44 ^{o}Brix after the storage of 9 days.

Red Lady papaya fruits subjected to postharvest treatments showed significant difference for TSS during the storage and it increased from 4.55 ^{o}Brix to 10.04 ^{o}Brix during storage. At the time of storage, TSS of treated papaya was 4.55 ^{o}Brix and increased to 6.69 ^{o}Brix, 8.60 ^{o}Brix and 10.04 ^{o}Brix after 3rd, 6th and 9th day of storage respectively.

When the interaction effects are considered TSS ranged between 4.49 ^{o}Brix and 4.66 ^{o}Brix which didn't show any significant difference between the treatments on the initial day of storage. TSS recorded the lowest value of 5.17 ^{o}Brix for T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) (5.47 ^{o}Brix) after 3 days of storage. Treated papaya fruits with maximum TSS was recorded for T_7 (control) (8.47 ^{o}Brix) followed by T_6 (hot water treatment) (7.16 ^{o}Brix) after 3 days of storage.

After 6 days of storage, papaya fruits treated with T_5 (SA 2 mM) recorded the minimum TSS (6.32 ^{o}Brix) followed by T_1 (NAA 250 ppm) (6.85 ^{o}Brix) while the maximum TSS of 12.30 ^{o}Brix was observed in T_7 (control) followed by T_6 (hot water treatment) (10.02 ^{o}Brix). TSS of treated papaya fruit recorded the minimum value of 7.66 ^{o}Brix for T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) (8.21 ^{o}Brix) and the maximum value of 13.24 ^{o}Brix was observed in T_7 (control) followed by T_6 (hot water treatment) (12.03 ^{o}Brix) after 9 days of storage.

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. Papaya fruits treated with SA 2 mM (T_5) recorded the minimum TSS of 9.74 ^{o}Brix followed by T_1 (NAA 250 ppm) (10.34 ^{o}Brix) while the maximum TSS of 13.20 ^{o}Brix was observed in T_4 ($CaCl_2$ 2%) followed by T_2 (PLEAG edible coating) with 12.02 ^{o}Brix after 12th day of storage.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. The papaya fruits treated with SA (T_5) recorded the lowest TSS of 11.52 ^{o}Brix after 14 days of storage followed by T_1 (NAA 250 ppm) with 11.93 ^{o}Brix.

Table 3. Effect of postharvest treatments on moisture content (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)		
	0	3	6	9		12	14
T_1 (NAA 250 ppm)	83.24	86.25	89.90	92.84	88.06	94.93	96.29
T_2 (PLEAG edible coating)	82.84	88.76	91.92	94.71	89.56	96.77	97.85
T_3 (GA_3 100 ppm)	83.11	87.97	90.78	93.81	88.92	95.62	96.96
T_4 ($CaCl_2$ 2%)	82.74	88.47	92.93	93.71	89.46	97.42*	-
T_5 (Salicylic Acid 2 mM)	83.02	85.86	88.65	91.69	87.31	93.77	95.27
T_6 (Hot water treatment)	82.87	90.04	94.12	95.53*	90.64	-	-
T_7 (Control)	82.76	91.78	95.01	97.31*	91.72	-	-
Days (D) Mean	82.94	88.45	91.90	94.23			
	SE± (m)	CD (0.05)				SE± (m) 0.138 CD (0.05) 0.439	SE± (m) 0.271 CD (0.05) 0.844
Treatments (T)	0.121	0.345					
Days (D)	0.092	0.261					
Treatments (T) × Days (D)	0.243	0.69					

*Papaya fruits were discarded due to spoilage

Table 4. Effect of postharvest treatments on total soluble solids (˚Brix) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)		
	0	3	6	9		12	14
T_1 (NAA 250 ppm)	4.50	5.47	6.85	8.21	6.26	10.34	11.93
T_2 (PLEAG edible coating)	4.66	6.93	8.24	9.58	7.35	12.02	13.48
T_3 (GA_3 100 ppm)	4.53	6.27	7.19	8.97	6.74	11.58	12.64
T_4 ($CaCl_2$ 2%)	4.53	7.33	9.30	10.61	7.94	13.20*	-
T_5 (Salicylic Acid 2 mM)	4.49	5.17	6.32	7.66	5.91	9.74	11.52
T_6 (Hot water treatment)	4.53	7.16	10.02	12.03*	8.44	-	-
T_7 (Control)	4.61	8.47	12.30	13.24*	9.66	-	-
Days (D) Mean	4.55	6.69	8.60	10.04			
	SE± (m)	CD (0.05)					
Treatments (T)	0.039	0.112				SE± (m) 0.119	SE± (m) 0.066
Days (D)	0.030	0.084				CD (0.05) 0.38	CD (0.05) 0.207
Treatments (T) × Days (D)	0.079	0.223					

*Papaya fruits were discarded due to spoilage

4.2.3. Reducing sugar (%)

Reducing sugar (%) of postharvest treated papaya cv. Red Lady during storage is illustrated in Table 5. After 9 days of storage, T_5 (SA 2 mM) treated fruits recorded the lowest (4.98%) reducing sugar content followed by T_1 (NAA 250 ppm) with 5.20%. The maximum reducing sugar of 7.14% was recorded for T_7 (control) followed by T_6 (hot water treatment) with 6.76%.

Papaya fruits showed significant difference for reducing sugar during storage period which was found to increase from 3.50% at initial day of storage to 4.93%, 7.08% and 7.99% after 3rd, 6th and 9th day respectively.

At the beginning of storage, reducing sugar of fruits ranged between 3.41% and 3.66% and there existed no significant difference between the treatments. After 3 days of storage, reducing sugar of SA 2 mM (T_5) treated fruits showed minimum value of 4.15% which was statistically on par with T_1 (NAA 250 ppm) and T_3 (GA_3 100 ppm). The highest value of reducing sugar (6.30%) was recorded for T_7 (control) and found statistically on par with T_6 (hot water treatment) after 3 days of storage.

After 6 days of storage, papaya fruits treated with SA 2 mM (T_5) recorded minimum reducing sugar of 5.64% which showed no significant difference with T_1 (NAA 250 ppm) and the maximum value for reducing sugar was reported by T_7 (control) (9.46%) that followed by T_6 (hot water treatment)**.** Similar to this SA treated fruits (T_5) recorded the lowest reducing sugar content of 6.69% with no significant difference with T_1 (NAA 250 ppm) after 9 days of storage and the highest reducing sugar content (9.37%) was reported in T_7 (control) followed by T_6 (hot water treatment) with 8.65% of reducing sugar.

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. Papaya fruits treated with SA 2 mM (T_5) recorded the minimum reducing sugar of 8.01% followed by T_1 (NAA 250 ppm) with 8.61% while the maximum reducing sugar content of 9.15% was observed in T_4 ($CaCl_2$ 2%) followed by T_2 (PLEAG edible coating) with 8.61% after 12th day of storage.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. The salicylic acid treated fruits (T_5) recorded the lowest reducing sugar of 8.26% and fruits with edible coating (T_2) recorded the highest reducing sugar content of 9.28% after 14 days of storage.

4.2.4. Total Sugar (%)

Total sugar (%) of postharvest treated papaya cv. Red Lady during storage is depicted in Table 6. After 9 days of storage, SA 2 mM (T_5) treated papaya recorded the lowest total sugar content of 6.57% followed by T_1 (NAA 250 ppm) with 7.50%. The highest total sugar content after 9 days of storage was reported in T_7 (control) with 9.62% which showed on par to T_6 (hot water treatment) with 9.15%.

Total sugar content of postharvest treated papaya recorded significant difference among the treatments during storage and increased from 4.50% at the time of storage to 11.54% after 9 days of storage. At the time of storage, total sugar content was 4.50% which had been increased to 6.96%, 9.82% and 11.54% after 3, 6 and 9 days of storage respectively.

At the initial day of storage, total sugar content of postharvest treated papaya did not differ significantly among the treatments and ranged between 4.35% and 4.59%.

After 3 days of storage, the lowest total sugar content of 5.98% was reported in papaya treated with T_5 (SA 2 mM) which was statistically on par to T_1 (NAA 250 ppm) with 6.56%. Meanwhile, the highest content of total sugar (7.68%) was found in T_7 (control) which was found statistically on par to T_4 ($CaCl_2$ 2%) and T_6 (hot water treatment) with 7.30% and 7.47% respectively.

Red Lady papaya treated with SA 2 mM (T_5) showed the lowest total sugar content of 7.23% and 8.72% after 6 and 9 days of storage respectively. However, the highest total sugar values of 11.70% and 14.53% were reported in T_7 (control) after 6 and 9 days of storage respectively.

Table 5. Effect of postharvest treatments on reducing sugar (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	3.66	4.28	5.90	6.95	5.20	8.61	8.84
T_2 (PLEAG edible coating)	3.42	4.49	6.62	7.68	5.55	8.95	9.28
T_3 (GA_3 100 ppm)	3.53	4.40	6.20	7.33	5.37	8.51	9.05
T_4 ($CaCl_2$ 2%)	3.57	4.81	6.93	9.23	6.14	9.15*	-
T_5 (Salicylic Acid 2 mM)	3.42	4.15	5.64	6.69	4.98	8.01	8.26
T_6 (Hot water treatment)	3.50	6.10	8.78	8.65*	6.76	-	-
T_7 (Control)	3.41	6.30	9.46	9.37*	7.14	-	-
Days (D) Mean	3.50	4.93	7.08	7.99			
	SE± (m)	CD (0.05)					
Treatments (T)	0.046	0.132				SE± (m) 0.056	SE± (m) 0.025
Days (D)	0.035	0.100				CD (0.05) 0.180	CD (0.05) 0.079
Treatments (T) × Days (D)	0.093	0.263					

*Papaya fruits were discarded due to spoilage

Table 6. Effect of postharvest treatments on total sugar (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	4.42	6.56	8.62	10.40	7.50	12.49	13.37
T_2 (PLEAG edible coating)	4.54	6.98	9.87	11.30	8.17	14.16	14.22
T_3 (GA_3 100 ppm)	4.52	6.73	9.35	10.90	7.88	13.43	13.59
T_4 ($CaCl_2$ 2%)	4.51	7.30	10.61	11.79	8.55	14.39	-
T_5 (Salicylic Acid 2 mM)	4.35	5.98	7.23	8.72	6.57	11.61	12.73
T_6 (Hot water treatment)	4.59	7.47	11.39	13.15*	9.15	-	-
T_7 (Control)	4.58	7.68	11.70	14.53*	9.62	-	-
Days (D) Mean	4.50	6.96	9.82	11.54			
	SE± (m)	CD (0.05)				SE± (m) 0.103	SE± (m) 0.049
Treatments (T)	0.113	0.332				CD (0.05) 0.329	CD (0.05) 0.152
Days (D)	0.086	0.244					
Treatments (T) × Days (D)	0.227	0.644					

*Papaya fruits were discarded due to spoilage

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. After 12 days of storage, papaya fruits treated with SA 2 mM (T_5) recorded the lowest total sugar content of 11.61% followed by T_1 (NAA 250 ppm) (12.49%) while the highest total sugar content of 14.39% was observed in T_4 ($CaCl_2$ 2%) which was statistically on par to T_2 (PLEAG edible coating).

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. After 14 days of storage, SA treated fruits (T_5) recorded the lowest sugar content of 12.73% and the highest total sugar (14.22%) was observed for the treatment T_2 (PLEAG edible coating).

4.2.5. Titratable acidity (%)

Titratable acidity of treated papaya fruits showed significant difference among the treatments ranged between 0.14% and 0.28% during the storage (Table 7). Postharvest treated Red Lady papaya recorded the highest titratable acidity of 0.25% T_5 (SA 2 mM) which was on par to the T_1 (NAA 250 ppm) after 9 days of storage. The lowest value (0.16%) for titratable acidity was reported for T_7 (control) followed by T_6 (hot water treatment) with 0.18%. Titratable acidity of Red Lady papaya decreased from 0.28% at the time of storage to 0.22%, 0.18% and 0.14% after 3, 6 and 9 days after storage respectively.

At the beginning of storage, titratable acidity content of Red Lady papaya fruits ranged from 0.27% to 0.29% and did not show significant difference among the postharvest treatments. The treatment of Red Lady papaya with SA 2 mM (T_5) recorded the highest value of 0.27% for titratable acidity which showed on par to the T_1 (NAA 250 ppm) after 3 days of storage where as the lowest value of 0.15% titratable acidity was recorded in T_7 (control) followed by the treatment T_6 (hot water treatment).

After storage for 6 days, the highest (0.24%) titratable acidity was reported for the fruits treated with SA 2 mM (T_5) which was on par to T_1 (NAA 250 ppm) and the lowest titratable acidity content (0.12%) was found for the fruits without any postharvest treatments (T_7) which did not differ significantly with T_6 (hot water treatment). After storage for 9 days, Red Lady papaya exposed to T_5 (SA 2 mM) showed the highest titratable acidity content of 0.21% which found statistically on par to T_1 (NAA 250 ppm) and the lowest titratable acidity of 0.09% was reported in T_7 (control) which showed no significant difference to T_6 (hot water treatment).

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. After 12 days of storage, T_5 (SA 2 mM) recorded the highest titratable acidity content (0.17%) which was on par to T_1 (NAA 250 ppm) and the lowest content of 0.08% was noticed in T_4 ($CaCl_2$ 2%) that did not differ significantly with T_2 (PLEAG edible coating).

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. The papaya fruits treated with SA (T_5) recorded the highest titratable acidity of 0.14% after 14 days of storage and the lowest value of 0.09% was recorded for the treatment with PLEAG edible coating (T_2).

4.2.6. Carotenoid content (mg $100g^{-1}$)

Effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) of papaya cv. Red Lady during storage is delineated in Table 8. After 9 days of storage, T_5 (SA 2 mM) reported the minimum carotenoid content of 1.26 mg $100g^{-1}$ and which was on par with T_1 (NAA 250 ppm) (1.34 mg $100g^{-1}$) and the maximum carotenoid content (1.89 mg $100g^{-1}$) was recorded in T_7 (control) followed by T_6 (hot water treatment) with 1.77 mg $100g^{-1}$. Red Lady papaya treated with GA_3 100 ppm (T_3) recorded 1.43 mg $100g^{-1}$ of carotenoid content which showed no significant difference with T_2 (PLEAG edible coating) (1.44 mg $100g^{-1}$).

Papaya fruits subjected to various postharvest treatments showed that there exist a significant difference for carotenoid content during storage and it ranged from 0.66 mg $100g^{-1}$ to 2.41 mg $100g^{-1}$. At the time of storage, carotenoid content recorded was 0.66 mg $100g^{-1}$ which gradually increased to 1.27, 1.79 and 2.41 mg $100g^{-1}$ after 3, 6 and 9 days of storage respectively.

Table 7. Effect of postharvest treatments on titratable acidity (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)		
	0	3	6	9		12	14
T_1 (NAA 250 ppm)	0.28	0.26	0.21	0.19	0.24	0.16	0.13
T_2 (PLEAG edible coating)	0.27	0.23	0.17	0.13	0.20	0.10	0.09
T_3 (GA_3 100 ppm)	0.28	0.23	0.19	0.16	0.22	0.13	0.11
T_4 ($CaCl_2$ 2%)	0.27	0.20	0.16	0.12	0.19	0.08*	-
T_5 (Salicylic Acid 2 mM)	0.29	0.27	0.24	0.21	0.25	0.17	0.14
T_6 (Hot water treatment)	0.28	0.19	0.14	0.11*	0.18	-	-
T_7 (Control)	0.28	0.15	0.12	0.09*	0.16	-	-
Days (D) Mean	0.28	0.22	0.18	0.14			
	SE± (m)	CD (0.05)					
Treatments (T)	0.005	0.015				SE± (m) 0.007	SE± (m) 0.004
Days (D)	0.004	0.011				CD (0.05) 0.023	CD (0.05) 0.012
Treatments (T) × Days (D)	0.011	0.030					

*Papaya fruits were discarded due to spoilage

Table 8. Effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	0.65	1.09	1.47	2.15	1.34	2.45	2.63
T_2 (PLEAG edible coating)	0.65	1.27	1.58	2.27	1.44	2.50	2.89
T_3 (GA_3 100 ppm)	0.67	1.13	1.68	2.23	1.43	2.53	2.77
T_4 ($CaCl_2$ 2%)	0.68	1.41	1.77	2.56	1.61	2.71*	-
T_5 (Salicylic Acid 2 mM)	0.65	1.04	1.25	2.09	1.26	2.41	2.55
T_6 (Hot water treatment)	0.66	1.42	2.33	2.66*	1.77	-	-
T_7 (Control)	0.67	1.51	2.44	2.92*	1.89	-	-
Days (D) Mean	0.66	1.27	1.79	2.41			
	SE± (m)	CD (0.05)					
Treatments (T)	0.015	0.043				SE± (m) 0.029	SE± (m) 0.005
Days (D)	0.011	0.033				CD (0.05) 0.092	CD (0.05) 0.015
Treatments (T) × Days (D)	0.030	0.086					

*Papaya fruits were discarded due to spoilage

The carotenoid content of treated papaya fruits at the time of storage ranged between 0.65 mg $100g^{-1}$ and 0.68 mg $100g^{-1}$ and showed no significant difference among the treatments at the time of storage. With regard to interaction effects, after 3 days of storage, papaya fruits subjected to SA 2 mM (T_5) recorded the minimum carotenoid content (1.04 mg $100g^{-1}$) which was statistically on par to T_1 (NAA 250 ppm) and T_3 (GA_3 100 ppm). The maximum content of carotenoid (1.51 mg $100g^{-1}$) was observed for the fruits in the treatment T_7 (control) and did not differ significantly with T_6 (hot water treatment).

After 6 days of storage, the minimum value for carotenoid content (1.25 mg $100g^{-1}$) was reported by fruits exposed to T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) (1.47 mg $100g^{-1}$) and the maximum value of 2.44 mg $100g^{-1}$ for carotenoid was recorded in T_7 (control) followed by T_6 (hot water treatment). Treatment of Red Lady papaya with T_5 (SA 2 mM) recorded the minimum carotenoid content (2.09 mg $100g^{-1}$) after 9 days of storage which was found on par with T_1 (NAA 250 ppm) (2.15 mg $100g^{-1}$) and the maximum carotenoid content (2.92 mg $100g^{-1}$) was observed for fruits subjected to T_7 (control) followed by T_6 (hot water treatment). The fruits subjected to T_2 (PLEAG edible coating) and T_3 (GA_3 100 ppm) was on par to each other with a carotenoid content of 2.27 and 2.23 mg $100g^{-1}$ respectively.

The papaya fruits without any postharvest treatment (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. Treatment of papaya with T_5 (SA 2 mM) reported the lowest carotenoid content of 2.41 mg $100g^{-1}$ which was statistically on par to fruits treated with T_1 (NAA 250 ppm) (2.45 mg $100g^{-1}$) after 12 days of storage and the highest content (2.71 mg $100g^{-1}$) was observed in T_4 ($CaCl_2$ 2%) followed by T_3 (GA_3 100 ppm) with 2.53 mg $100g^{-1}$ of fruit.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. After 14 days of storage, the minimum carotenoid content of 2.55 mg $100g^{-1}$ was recorded in T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 2.63 mg $100g^{-1}$ and the maximum carotenoid content (2.89 mg $100g^{-1}$) was found with T_2 (PLEAG edible coating).

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

The changes in ascorbic acid content (mg 100g^{-1}) of papaya cv. Red Lady during storage after the postharvest treatments are represented in Table 9. Ascorbic acid content of treated papaya fruits at the time of storage ranged from 42.62 to 43.36 mg 100g^{-1} that did not significant difference between the treatments. The highest ascorbic acid content of 39.80 mg 100g^{-1} was reported in papaya fruits exposed to T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 38.34 mg 100g^{-1} where as the lowest value of ascorbic acid (32.69 mg 100g^{-1}) was observed for T_7 (control) followed by T_6 (hot water treatment) **(**33.83 mg 100g^{-1}) after 9 days of storage.

The postharvest treated papaya fruits showed significant difference for ascorbic acid content during storage and ranged between 28.29 mg 100g^{-1} and 43.02 mg 100g^{-1}**.** Ascorbic acid content of papaya was 43.02 mg 100g^{-1} at the time of storage which reduced to 39.12, 34.35 and 28.29 mg 100g^{-1} after 3, 6 and 9 days respectively.

After 3 days of storage, papaya fruits subjected to SA treatment (T_5) recorded the highest ascorbic acid content of 41.99 mg 100g^{-1} which was on par with T_1 (NAA 250 ppm). The treatment T_7 (control) reported the lowest ascorbic acid content of 35.83 mg 100g^{-1} followed by T_6 (hot water treatment) with 37.29 mg 100g^{-1}.

Papaya fruits subjected to T_5 (SA 2 mM) reported the highest value (38.60 mg 100g^{-1}) of ascorbic acid content after 6 days of storage followed by T_1 (NAA 250 ppm) containing 36.61 mg 100g^{-1} and the lowest value (31.32 mg 100g^{-1}) was observed for T_7 (control) which reported statistically on par with T_6 (hot water treatment) (31.59 mg 100g^{-1}). Treatments T_2 (PLEAG edible coating) and T_4 ($CaCl_2$ 2%) was on par to each other with an ascorbic acid content of 32.97 and 34.02 mg 100g^{-1} respectively.

After 9 days of storage, T_5 (SA 2 mM) recorded the highest content of ascorbic acid of 35.26 mg 100g^{-1} followed by T_1 (NAA 250 ppm) (32.82 mg 100g^{-1}) and the treatment T_7 (control) reported the lowest ascorbic acid content of 20.28 mg 100g^{-1} followed by T_6 (hot water treatment) with 23.52 mg 100g^{-1}.

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. After 12 days of storage, T_5 (SA 2 mM) recorded the highest ascorbic acid content of 31.69 mg $100g^{-1}$ followed by T_1 (NAA 250 ppm) containing 28.31 mg $100g^{-1}$ and the lowest ascorbic acid content (18.84 mg $100g^{-1}$) was observed in T_4 ($CaCl_2$ 2%) followed by T_2 (PLEAG edible coating) with 21.88 mg $100g^{-1}$ of fruit.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. SA treated (T_5) Red Lady papaya fruits reported the highest ascorbic acid content of 24.96 mg $100g^{-1}$ followed by T_1 (NAA 250 ppm) with 24.25 mg $100g^{-1}$ and the lowest ascorbic acid content of 21.27 mg $100g^{-1}$ was noticed in T_2 (PLEAG edible coating).

4.2.8. Antioxidant activity (%)

Antioxidant activity (%) of postharvest treated papaya cv. Red Lady is represented in Table 10. Antioxidant activity of papaya fruits did not show significant difference between the treatments at the time of storage and ranged between 25.61 to 26.39%. SA treatment (T_5) of papaya fruits recorded the minimum antioxidant activity of 36.31% after 9 days of storage followed by T_1 (NAA 250 ppm) with 37.65% where as the maximum antioxidant activity was reported in T_7 (control). Significant changes were observed for antioxidant activity of papaya during storage. It showed considerable increase in antioxidant activity during storage from 25.97% at the time of storage to 34.73%, 45.49% and 56.55% after 3, 6 and 9 days of storage respectively.

Red Lady papaya fruits subjected to SA treatment (T_5) reported the minimum antioxidant activity of 32.28% and which was on par with T_1 (NAA 250 ppm) at 3 days of storage. It was reported that the maximum antioxidant activity of 36.74% was found in fruits without any postharvest treatment (T_7) which showed no significant difference with T_6 (hot water treatment) and T_4 ($CaCl_2$ 2%).

After 6 days of storage, T_5 (SA 2mM) treated papaya fruits recorded the minimum value (38.52%) of antioxidant activity followed by T_1 (NAA 250 ppm) with

Table 9. Effect of postharvest treatments on ascorbic acid content ($mg\ 100g^{-1}$) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	42.87	41.05	36.61	32.82	38.34	28.31	24.25
T_2 (PLEAG edible coating)	43.01	39.26	32.97	28.91	36.04	21.88	21.27
T_3 (GA_3 100 ppm)	43.04	40.09	35.32	30.38	37.21	25.18	22.96
T_4 ($CaCl_2$ 2%)	42.62	38.33	34.02	26.83	35.45	18.84*	-
T_5 (Salicylic Acid 2 mM)	43.36	41.99	38.60	35.26	39.80	31.69	24.96
T_6 (Hot water treatment)	42.91	37.29	31.59	23.52*	33.83	-	-
T_7 (Control)	43.33	35.83	31.32	20.28*	32.69	-	-
Days (D) Mean	43.02	39.12	34.35	28.29			
	SE± (m)	CD (0.05)					
Treatments (T)	0.224	0.637				SE± (m) 0.312	SE± (m) 0.043
Days (D)	0.169	0 .481				CD (0.05) 0.097	CD (0.05) 0.133
Treatments (T) × Days (D)	0.448	1.274					

*Papaya fruits were discarded due to spoilage

Table 10. Effect of postharvest treatments on antioxidant activity (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)		
	0	3	6	9		12	14
T_1 (NAA 250 ppm)	25.87	32.79	41.16	50.76	37.65	57.99	64.53
T_2 (PLEAG edible coating)	25.61	34.99	44.84	55.62	40.27	56.87	62.29
T_3 (GA_3 100 ppm)	25.83	34.37	42.66	53.51	39.09	57.45	63.92
T_4 ($CaCl_2$ 2%)	26.12	35.64	47.87	57.43	41.77	56.48*	-
T_5 (Salicylic Acid 2 mM)	26.10	32.28	38.52	48.35	36.31	59.61	65.66
T_6 (Hot water treatment)	25.84	36.33	50.58	63.96*	44.18	-	-
T_7 (Control)	26.39	36.74	52.81	66.22*	45.54	-	-
Days (D) Mean	25.97	34.73	45.49	56.55			
	SE± (m)	CD (0.05)				SE± (m) 0.577	SE± (m) 0.344
Treatments (T)	0.245	0.696				CD (0.05) 1.843	CD (0.05) 1.138
Days (D)	0.185	0.526					
Treatments (T) × Days (	0.49	1.392					

*Papaya fruits were discarded due to spoilage

41.16% and the maximum antioxidant activity of 52.81% in papaya without any postharvest treatment (T_7). Treatment, T_5 (SA 2 mM) recorded the lowest antioxidant activity of 48.35% after 9 days of storage which followed by T_1 (NAA 250 ppm) with 50.76%. It was observed that papaya fruit without any postharvest treatment (T_7) had maximum value (66.22%) of antioxidant activity.

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. The highest antioxidant activity was found in SA treated (T_5) papaya fruits with 59.61% after 12 days of storage which recorded on par with T_1 (NAA 250 ppm). The treatment, T_4 ($CaCl_2$ 2%) showed the minimum antioxidant activity of 56.48%.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. At 14th day of storage, the highest antioxidant activity of 65.66% was reported in T_5 (SA 2 mM) which found statistically on par to T_1 (NAA 250 ppm) where as the minimum antioxidant activity of 62.29% was observed in T_2 (PLEAG edible coating).

4.3. PHYSICAL PARAMETERS

4.3.1. Texture (N)

Texture or fruit firmness of postharvest treated papaya cv. Red Lady is outlined in Table 11. The maximum fruit firmness of 74.66 N was reported in T_4 ($CaCl_2$ 2%) which was statistically on par with SA treatment (T_5) and the minimum firmness (47.33 N) was observed in papaya fruits without any treatment (T_7) after a storage period of 9 days. At the initial day of storage, of papaya ranged between 94.15 N to 95.46 N without any significant difference between the treatments and it was noticed that fruit firmness gradually declined during storage with significant difference among the treatments. At the time of storage, firmness was 94.82 N which reduced to 77.54 N, 53.05 N and 35.73 N after 3, 6 and 9 days of storage respectively.

Treatment of papaya with $CaCl_2$ (T_4) showed the maximum firmness retention of 89.73 N and 69.18 N after 3 and 6 days of storage respectively while fruits without any postharvest treatment (T_7) retained the minimum firmness of 59.35 N and 19.94

N after 3 and 6 days of storage respectively. After 9 days of storage, SA treatment (T_5) noticed the maximum firmness retention of 45.12 N which was on par to T_4 ($CaCl_2$ 2%) and T_1 (NAA 250 ppm) while the minimum firmness (15.87 N) was noticed in fruits without any postharvest treatment (T_7).

The papaya fruits without any postharvest treatments (T_7) and with hot water treatment alone (T_6) were discarded after 9 days of storage due to spoilage. The maximum firmness of 27.43 N was observed in T_5 (SA 2 mM) which was on par to T_1 (NAA 250 ppm) with 26.64 N and the minimum firmness (22.73 N) was reported in PLEAG edible coated papaya (T_2) after 12 days of storage.

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. Firmness of papaya was found the highest (19.89 N) with SA treatment (T_5) followed by T_1 (NAA 250 ppm) with 17.65 N after 14 days of storage. It was found that minimum firmness of 15.23 N was noticed in T_2 (PLEAG edible coating).

4.3.2. Skin colour

Skin colour of postharvest treated papaya cv. Red Lady during storage is given in Table 11. Significant difference was recorded for skin colour change in postharvest treated papaya with increaseed storage period. At the beginning of storage, skin colour score of the fruit was green skin without yellow stripe (0) which subsequently turned to green skin with light yellow stripe (1), green skin with well-defined yellow stripe (2), one or more orange-coloured stripes in skin (3), clearly orange-coloured skin with some light green areas (4), characteristic orange-coloured skin of papaya (5) and fruit colour similar to stage 5, but more intense (6). After 3 days of storage, skin colour of Red Lady papaya dipped in T_5 (SA 2 mM) and T_1 (NAA 250 ppm) showed green skin without yellow stripe (0), while the fruits subjected to T_2 (edible coating), T_3 (GA_3 100 ppm) and T_4 ($CaCl_2$ 2%) exhibited colour score of 1.4, 1.2 and 1.6 respectively. Similarly, papaya treated with T_6 (hot water treatment) and T_7 (control) recorded 2.2 and 2.4 mean colour score respectively.

able 11. Effect of postharvest treatments on texture (fruit firmness) (N) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				Treatment Mean (T)	12	14
	0	3	6	9			
T_1 (NAA 250 ppm)	95.46	82.65	66.63	43.82	72.14	26.64	17.65
T_2 (PLEAG edible coating)	94.38	77.81	62.11	41.98	69.07	22.73	15.23
T_3 (GA_3 100 ppm)	94.62	80.87	64.25	42.29	70.51	25.09	15.93
T_4 ($CaCl_2$ 2%)	94.84	89.73	69.18	44.88	74.66	23.72*	-
T_5 (Salicylic Acid 2 mM)	94.91	85.66	68.99	45.12	73.67	27.43	19.89
T_6 (Hot water treatment)	95.39	66.68	20.25	16.15*	49.62	-	-
T_7 (Control)	94.15	59.35	19.94	15.87*	47.33	-	-
Days (D) Mean	94.82	77.54	53.05	35.73			
	SE± (m)	CD (0.05)					
Treatments (T)	0.276	0.783				SE± (m) 0.541	SE± (m) 0.667
Days (D)	0.208	0.592				CD (0.05) 1.725	CD (0.05) 2.208
Treatments (T) × Days (D	0.551	1.565					

*Papaya fruits were discarded due to spoilage

Table 12. Effect of postharvest treatments on skin colour of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				12	14
	0	3	6	9		
T_1 (NAA 250 ppm)	0	0	1.8	3.2	4.4	5.6
T_2 (PLEAG edible coating)	0	1.4	2.8	4.4	5.4	6
T_3 (GA_3 100 ppm)	0	1.2	2.2	4.2	5.2	6
T_4 ($CaCl_2$ 2%)	0	1.6	3.4	4.8	6*	-
T_5 (Salicylic Acid 2 mM)	0	0	1.2	2.2	4	5.4
T_6 (Hot water treatment)	0	2.2	4.6	6*	-	-
T_7 (Control)	0	2.4	5.2	6*	-	-

*Papaya fruits were discarded due to spoilage

Colour score

0: Green skin without yellow stripe
1: Green skin with light yellow stripe
2: Green skin with well-defined yellow stripe
3: One or more orange-coloured stripes in skin
4: Clearly orange-coloured skin with some light green areas
5: Characteristic orange-coloured skin of papaya
6: Fruit colour similar to stage 5, but more intense

After 6th day of storage, skin colour of papaya subjected to T_5 (SA 2 mM) recorded 1.2 colour score where as the fruits treated with T_6 (hot water treatment) and T_7 (without any postharvest treatments) reported 4.6 and 5.2 respectively. Papaya fruits treated with T_5 (SA 2 mM) showed the minimum colour score of 2.2 where as the skin colour of fruits showing similar to stage 5, but more intense (6) was observed in T_6 (hot water treatment) and T_7 (without any postharvest treatments) after 9th day of storage.

The papaya fruits without any postharvest treatments (T_7) and with (hot water treatment) alone (T_6) were discarded after 9 days of storage due to spoilage. After 12 days of storage, clearly orange-coloured skin with some light green areas (4) was reported for Red Lady papaya fruits treated with T_5 (SA 2 mM) and 4.4 colour score was noticed in T_1 (NAA 250 ppm) while fruit colour similar to stage 5, but more intense (6) was observed in T_4 ($CaCl_2$ 2%).

Calcium chloride (T_4) treated papaya fruits were discarded after 12 days of storage due to spoilage. Papaya fruits with SA treatment (T_5) and NAA (T_1) recorded colour score of 5.4 and 5.6 respectively while the fruit colour similar to stage 5, but more intense (6) was reported by remaining treatments after 14 days of storage.

4.4. SENSORY ANALYSIS

Effect of postharvest treatments on sensory parameters of papaya cv. Red Lady after ripening was assessed using Kruskall-Walis chi square test. Sensory parameters such as appearance, flavour, texture, taste, flesh colour and overall acceptability recorded a significant difference between the treatments after 9 days of storage as mentioned in Table 13. Papaya fruits treated with $CaCl_2$ (T_4) recorded the highest mean score for sensory parameters like appearance (8.90), flavour (8.93), texture (8.90), tatse (8.87), flesh colour (8.97) and overall acceptability (8.93) after 9 days of storage. It was observed that the lowest mean score for appearance (7.10), flavour (7.43), flesh colour (7.50) and overall acceptability (7.73) was found in fruits without any postharvest treatment (T_7) where as the lowest mean score for texture (6.60) and taste (6.80) was reported in SA (T_s).

Table 13. Effect of postharvest treatments on sensory parameters of papaya cv. Red Lady after 9 days of storage

Postharvest Treatments (T)	Appearance	Flavour	Texture	Taste	Flesh colour	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 (NAA 250 ppm)	8.77	7.67	6.97	6.73	7.87	7.90
T_2 (PLEAG edible coating)	8.87	8.43	8.53	8.23	8.53	8.67
T_3 (GA_3 100 ppm)	8.80	7.70	7.93	7.57	7.93	8.01
T_4 ($CaCl_2$ 2%)	8.90	8.93	8.90	8.87	8.97	8.93
T_5 (Salicylic Acid 2 mM)	8.70	7.60	6.80	6.60	7.80	7.87
T_6 (Hot water treatment)	7.20	7.63	7.63	7.17	7.77	8.17
T_7 (Control)	7.10	7.43	8.27	7.10	7.50	7.73
KW value	81.27*	54.74*	87.45*	80.04*	46.27*	76.70*
$\chi2$ (0.05)	12.59					

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 14. Effect of postharvest treatments on sensory parameters of papaya cv. Red Lady after 12 days of storage

Postharvest Treatments (T)	Appearance	Flavour	Texture	Taste	Flesh colour	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 (NAA 250 ppm)	8.60	8.57	8.53	8.53	8.59	8.47
T_2 (PLEAG edible coating)	7.83	7.73	7.73	7.70	7.80	7.63
T_3 (GA_3 100 ppm)	8.10	8.07	7.97	7.93	7.97	7.90
T_4 ($CaCl_2$ 2%)	7.33	7.27	7.27	7.23	7.30	7.20
T_5 (Salicylic Acid 2 mM)	8.93	8.87	8.90	8.80	8.90	8.83
T_6 (Hot water treatment)	-	-	-	-	-	-
-T_7 (Control)	-	-	-	-	-	-
KW value	33.07*	33.96*	32.58*	32.64*	32.38*	35.98*
$\chi 2$ (0.05)	9.49					

-Papaya fruits were discarded due to spoilage 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 15. Effect of postharvest treatments on sensory parameters of papaya cv. Red Lady after 14 days of storage

Postharvest Treatments (T)	Appearance	Flavour	Texture	Taste	Flesh colour	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score	Mean score
T_1 (NAA 250 ppm)	8.10	7.97	8.13	8.00	8.03	8.10
T_2 Edible coating (PLEAG)	6.50	6.47	6.57	6.50	6.37	6.63
T_3 (GA_3 100 ppm)	7.10	7.07	7.07	6.90	7.07	6.87
T_4 ($CaCl_2$ 2%)	-	-	-	-	-	-
T_5 (Salicylic Acid 2 mM)	8.60	8.53	8.60	8.30	8.47	8.63
T_6 (Hot water treatment)	-	-	-	-	-	-
T_7 (Control)	-	-	-	-	-	-
KW value	53.73*	38.30*	48.75*	35.93*	47.95*	53.08*
$\chi2$ (0.05)	7.82					

-Papaya fruits were discarded due to spoilage

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

The highest mean score for appearance (8.60), flavour (8.53), texture (8.60), taste (8.30), flesh colour (8.47) and overall acceptability (8.63) was recorded in SA treated after 14 days of storage. Edible coating of papaya fruits with PLEAG (T_2) showed the lowest mean score for appearance (6.50), flavour (6.47), texture (6.57), taste (6.50), flesh colour (6.37) and overall acceptability (6.63) (Table 15).

4.5. SHELF LIFE (Days)

Effect of postharvest treatments on shelf life (days) of papaya cv. Red Lady during storage is depicted in Table 16. The papaya fruits after assessing for physiological, biochemical, physical and sensory parameters, the highest shelf life of 14.56 days was recorded for fruits treated with T_5 (SA 2 mM) followed by T_1 (NAA 250 ppm) with 13.01 days. The treatment of Red Lady papaya fruits with T_7 (without any postharvest treatments) recorded the lowest shelf life of 7.38 days followed by T_6 (hot water treatment) with 8.33 days.

Table 16. Effect of postharvest treatments on shelf life (days) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Shelf life (days)
T_1 (NAA 250 ppm)	13.01
T_2 (PLEAG edible coating)	11.37
T_3 (GA_3 100 ppm)	12.32
T_4 ($CaCl_2$ 2%)	9.75
T_5 (Salicylic Acid 2 mM)	14.56
T_6 (Hot water treatment)	8.33
T_7 (Control)	7.38
SE± (m) 0.139 CD (0.05) 0.427	

Discussion

5. DISCUSSION

The results obtained from the experiment on "Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady" are discussed in the present chapter.

Red Lady papaya fruits subjected to postharvest treatments such as Naphthalene Acetic Acid (NAA), Edible coating (Papaya Leaf Extract Aloe Gel 1:1), Gibberellic acid (GA_3), Calcium chloride ($CaCl_2$), Salicylic Acid (SA), hot water treatment alone and fruits without any postharvest treatment (control) were stored in corrugated fiber board boxes at room temperature (30±2 ºC, RH 80-85%) and were assessed for physiological, biochemical, physical and sensory parameters at 3 days interval.

5.1. PHYSIOLOGICAL PARAMETERS

5.1.1. Physiological Loss in Weight (%)

Physiological loss in weight is a key physiological character determining the shelf life of fruits. In papaya fruits showed increasing trend in all postharvest treatments during the storage period. Thus postharvest applications decreased the rate of weight loss in papaya fruits. It was evident from the current study that Red Lady papaya fruits pretreated with Salicylic Acid recorded the lowest weight loss of 6.55% after 9 days which enhanced to 9.34% and 13.10% after 12 and 14 days of storage respectively (Fig.1). The fruits without any postharvest treatment reported the highest cumulative loss in weight of 16.65% at the 9 days of storage. Increased weight loss of untreated fruits might be due to accelerated rate of metabolism through respiration and transpiration whereas the postharvest treatments delayed the physiological processes. The results are in conformity to the findings of Promyou and Supapvanich (2014) in papaya cv. Kaek Dam.

Srivastava and Dwivedi (2000) observed that salicylic acid application reduced the weight loss through maintaining fruit firmness and by inhibiting action of ACC (1-Aminocyclopropane-1-carboxylic acid) synthase or ACC oxidase or both in ethylene biosynthesis. The postharvest treatment with SA suppressed the activity of hydrolytic enzymes such as polygalactouronase, β-1-3 glucanase, xylanse and pectin methyl esterase associated with cell wall degradation in papaya was reported by Ali *et al.* (2004) and thus decreased the loss in weight and fruit firmness through improved function of cell membrane by suppressing the activity of cell wall degrading enzymes Erkan *et al*. (2005).

SA act as an electron donor and scavenge free radicals, therefore the rate of respiration and weight loss are reduced (Zheng and Zhang, 2004). Shafiee *et al.* (2010) and Jawandha *et al.* (2012) opined that physiological loss in weight increased considerably throughout storage period in all the treatments as a result of enhanced transpiration and respiration rates. The reduction in weight loss of papaya cv. Red Lady during storage and ripening might be due to stomatal closure which led to decrease in transpiration rate (Lata *et al*., 2018 and Mandal *et al*., 2017). Devarakonda *et al.* (2020) reported that the SA application of papaya cv. Red Lady at 150 ppm had lowest PLW of 11.89% followed by SA @ 100 ppm with 12.02% after 12 days of storage. This is in tune with findings of present study in papaya cv. Red Lady.

Red lady papaya fruits treated with NAA at 250 ppm had recorded a weight loss of 10.84% and 13.95% on 12th and 14th day of storage respectively. These results are supported by Masalkar and Garande (2005), Dikki *et al.* (2010) in papaya and Singh *et al*. (2019) in guava cv. Allahabad safeda.

5.1.2. Respiration rate

Papaya shows a peak in respiration rate coincided with ripening, which shows the typical climacteric behavior. Respiration, a catabolic process metabolizes stored complex compounds such as starch, pectin, organic acids and sugars to simple soluble molecules attributing to economic loss and increase senescence (Lu *et al.,* 2011). Thus, it is essential to regulate the rate of respiration through postharvest treatments to delay ripening and enhance storage life of papaya fruits.

The respiration and ethylene production rates enhanced with the advancement of storage period which led to shorter shelf life. Respiration rate of fruits significantly enhanced irrespective of treatments from 30.79 mL CO_2 kg^{-1} h^{-1} at initial day of storage to 44.88, 67.02 and 86.54 mL CO_2 kg^{-1} h^{-1} after 3rd, 6th and 9th day of storage respectively (Fig. 2). All the postharvest treatments were effective in delaying

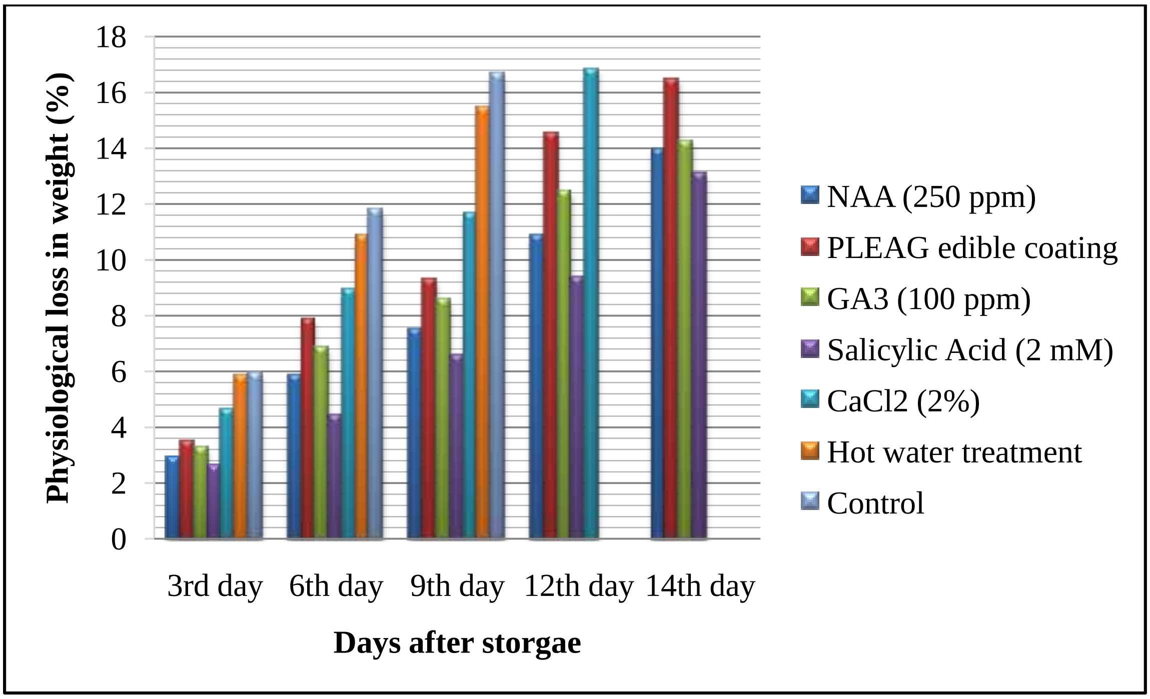

Fig.1. Effect of postharvest treatments on physiological loss in weight (%) of papaya cv. Red Lady after during storage

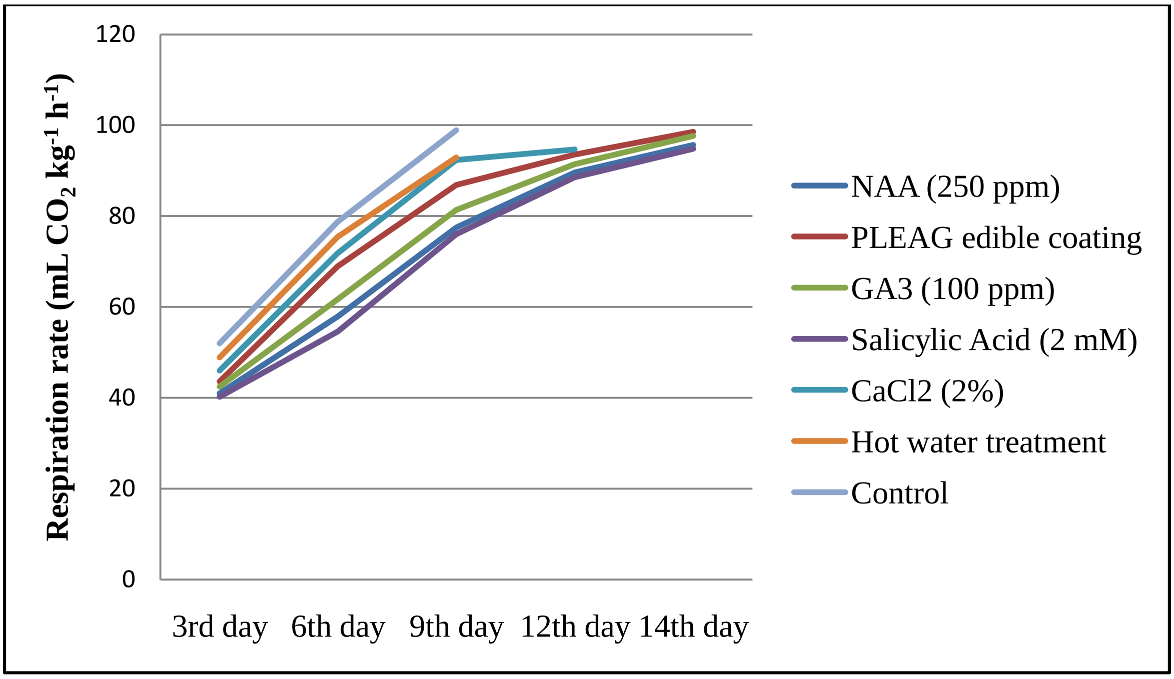

Fig. 2. Effect of postharvest treatments on respiration rate (mL CO_2 kg^{-1} h^{-1}) of papaya cv. Red Lady during storage

respiration rate and prolonged the shelf life of Red Lady papaya. The treatments, SA at 2 mM concentration and NAA @ 250 ppm showed statistically significant reduction of respiratory process, ripening and senescence process when compared to all other treatments. The lowest respiration rate of 75.99 mL CO_2 kg^{-1} h^{-1} was reported in SA 2 mM which was statistically on par to NAA 250 ppm after 9 days of storage and the highest respiration rate of 98.92 mL CO_2 kg^{-1} h^{-1} was found in fruits without any treatment. During storage, the lowest respiration rate of 88.55 mL CO_2 kg^{-1} h^{-1} was found for SA at 2 mM followed by NAA 250 ppm (89.62 mL CO_2 kg^{-1} h^{-1}) after 12 days and increased to 94.83 mL CO_2 kg^{-1} h^{-1} after 14 days in fruits with SA treatment. Similar minimization of respiration rate with SA application was recorded by Srivastava and Dwivedi (2000) in banana cv. Harichal, Zeng and weibo (2008) in mango, Aghdam *et al.* (2009) in kiwifruit and Jaishankar and Kukanoor (2016) in sapota cv. Kalipatti. The exogenous application of Red Lady papaya with NAA also decreased the respiration rate and ethylene biosynthesis similar to SA and the result is supported by the findings of Hodges (2003) in wax apple and Dikki *et al*. (2010) in papaya.

Zhang *et al*. (2003) proposed that SA application result in reduced activity of ACC synthase and oxidase declining respiration rate and ethylene production with delayed fruit ripening. Wolucka *et al*. (2005) observed that salicylic acid with an electron donating capacity release free radicals and inhibited the respiration rate. Mo *et al.* (2008) noticed that SA 0.8 mmol L^{-1} concentration delayed the ripening process by decreasing respiration rate. Salicylic Acid decreased the rate of respiration and ethylene production by suppressing the action of ethylene forming enzymes like (1-aminocyclopropane-1-carboxylate) ACC synthase and oxidase (Asghari and Aghdam, 2010). Postharvest treatment of papaya cv. Red Lady with 2.5 mM L^{-1} for five minutes reduced respiration rate, ripening and extended shelf life with good acceptability (Mandal *et al.*, 2017). Supapvanich and Promyou (2017) also reported that postharvest dipping of papaya cv. Holland with 2 mM SA reduced ethylene synthesis, respiration rate, delayed ripening and senescence.

5.2. BIOCHEMICAL PARAMETERS

Biochemical attributes *viz.,* moisture content, TSS, reducing sugars, total sugars, titratable acidity, carotenoid content, ascorbic acid and antioxidant activity are associated with quality of papaya fruits. The postharvest treatments effectively reduced the changes in these parameters which can be correlated with the delayed ripening and senescence thus extending the shelf life.

5.2.1. Moisture content (%)

Moisture content of papaya fruits considerably increases with ripening. Moisture content increased rapidly in control fruits as it approaches ripening. Papaya fruits subjected to postharvest treatments decreased the loss of moisture content by reducing transpiration associated with ripening and senescence. The data from present study confirmed that moisture content increased from 83.02% at the time of storage to 93.77% and 95.27% after 12 and 14 days of storage respectively in Red Lady with salicylic acid treatment. However, fruits without any postharvest treatment (control) showed rapid increase in moisture content and recorded the highest moisture content of 97.31% after 9 days of storage. Similar results were reported by Akaniwor and Arachie (2002) and Zaman *et al*. (2006) in papaya.

Bal and Celik (2010) proved that the SA application of fruits inhibited the activity of two key enzymes involved in ethylene biosynthesis which in turn reduced the ethylene production and moisture loss. Sultana *et al*. (2012) noticed that banana fruits showed rapid increase in moisture content during ripening and senescence. The increase in moisture content of fruits with ripening was perhaps due to complete metabolism of starch to carbon di oxide and water during storage along with osmotic absorption of water from peel to pulp (Hakim *et al.*, 2013).

Postharvest treatment of papaya fruits with SA 2 mM and NAA 250 ppm inhibited water releasing reactions like respiration, thereby minimizing moisture content. After 14 days of storage, NAA treatment of papaya recorded the moisture content of 96.29%. Amoros *et al.* (2014) observed that NAA reduced the respiration rate and ethylene production by suppressing the activity of ethylene forming enzymes like ACC oxidase and synthase which declined loss of moisture in loquat fruits.

5.2.2. Total Soluble Solids (˚Brix)

Total Soluble Solids is associated with palatable quality and confers to the sweetness of fruits. TSS content raise with advancement of storage of papaya fruits considerably increased with irrespective of the treatments. TSS of SA 2 mM treated papaya fruits recorded a slow rate of change during storage form 4.49 ^{0}Brix at the time of harvest to 11.52 ^{0}Brix after 14 days of storage (Fig. 3). While the control fruits recorded a change in TSS from 4.61 ^{0}Brix at the harvest time to a maximum of 13.24 ^{o}Brix after 9 days of storage indicating the accelerated ripening. The slow increment in TSS of SA treated fruits exhibit slower biochemical and enzymatic reactions that lead to delayed ripening than control. Fisk (2006) reported that the hydrolysis of complex starch and pectin into simple soluble sugars led to increase in TSS of fruits during storage. Postharvest treatments could retain maximum TSS probably due to reduced hydrolytic activity associated with ripening (Rajkumar and Manivannan, 2007).

Aghdam *et al*. (2009) noticed that SA treatment of kiwi fruit retained the highest TSS compared with untreated fruits. Salicylic Acid treatment retained maximum TSS by suppressing sucrose-phosphate synthase and reduction in ethylene production rate (Aghdam *et al*., 2011). Khademi and Ershadi (2013) opined that SA could retard the rise in TSS by lowering the respiration rate and inhibiting ethylene biosynthesis thereby reducing total soluble solids content in fruits. Promyou and Supapvanich (2014) addressed that SA treatment of papaya (cv. Kaek Dam) reduced the increase in total soluble solids, total sugars and slowed down the ripening process. Similar results of reduced TSS with SA application was also supported by Maharaj and Sankat (1990) in papaya, Mandal *et al.* (2017) in papaya cv. Red Lady, Supapvanich and Promyou (2017) in papaya cv. Holland and Devarakonda *et al.*, (2020) in papaya cv. Red Lady. The increase in TSS with enhanced ripening during storage was also reported by Hussain *et al*. (2008) in apple, Mo *et al.* (2008) in Sugar apple, Salari *et al.* (2013) in strawberry, Singh and Singh (2015) in Indian gooseberry, Srivastava and Dwivedi (2000) and Nair (2018) in banana

In the present study, exogenous application of NAA to Red Lady papaya also decreased the rate of increase in TSS and recorded 11.93 ^{o}Brix at end of storage life on 14th day. Similar findings with maximum retention of TSS was reported in sapota (Agrawal and Dikshit, 2010), guava (Singh *et al*., 2018) and papaya cv. Red Lady (Hazarika *et al.*, 2016; Dubey *et al.* (2020). NAA significantly reduced the acceleration in TSS which is due to delayed hydrolysis of complex molecules such as starch and pectin to sugars and extended the shelf life was reported by Brothakar and Kumar (2002) and Aristya *et al.* (2019).

5.2.3. Reducing sugar 9%)

Reducing sugar content of papaya increased in all the treatments with the advancement of the storage period. Increase in sugar content could be accomplished by hydrolysis of polysaccharides in the cell wall. Postharvest treated papaya showed slow increase in sugar content which is probably due to slower and lower metabolism of polysaccharides of the cell wall. The results revealed that SA treated fruits recorded the lowest reducing sugar content of 8.26% followed by NAA 250 ppm with 8.84% after 14 days of storage and the highest reducing sugar content of 9.46% was reported in control fruits (without postharvest treatment) after 6 days of storage which was at optimum ripening stage and decreased to 9.37% after 9 days of storage. Due to the conversion of starch to soluble sugars, reducing sugar content reached maximum at the optimum ripening and thereafter declined as sugars were utilized as substrate for respiration (Bhooriya *et al.,* 2018). Reducing sugar of fruits decreased with the advancement of ripening and senescence during storage as reported by Han *et al.* (2002) and Abbasi *et al.* (2010).

Postharvest treatment of salicylic acid retarded the conversion of starch to simple molecules and declined the sugar accumulation Hu *et al.* (2009). During storage, SA @ 2 mM concentration recorded the lowest reducing sugar than control was reported by Moreno *et al*. (2008) in grapes, Tareen *et al*. (2012) in peach, Bhalerao *et al.* (2010) in banana, Desai (2016) in sapota and Lata (2017) in papaya.

NAA was also effective in maintaining the reducing sugar content during storage next to salicylic acid. It also suppressed the metabolic activity of cell wall hydrolyses that aid in the degradation of polysaccharides present in the cell wall to sugars and slowed down the increase in sugar content. Several studies reported that NAA treatment declined reducing sugar content during storage as a result of minimum metabolites accumulation in fruits (Yadav *et al*., 2001; Dikki *et al.,* 2010; Hazarika *et al.*, 2016 and Singh *et al*., 2018).

5.2.4. Total sugar (%)

Papaya consists of sucrose as its major sugar component contributing to 80% of total soluble solids concentration. Generally total sugars shows increasing trend in papaya irrespective of treatments.. During storage, the hydrolysis of complex metabolites into simple molecules or breakdown of starch into simple soluble sugars by amylase resulted in accumulation of glucose and fructose. This might be the reason for increment in total sugars during storage (Jaishankar and Kukanoor, 2006). The present investigation reported the significant difference among the treatments with respect to total sugars during storage. Papaya fruits treated with SA at 2 mM concentration recorded the lowest total sugar content of 12.73% followed by NAA 250 ppm with 13.37% after 14 days of storage (Fig. 4). The highest total sugar content of 14.53% was reported for fruits without any postharvest treatment after 9 days of storage while the remaining treatments rapidly increased total sugar content and decreased further. Initially, total sugars increased as result of breakdown of starch and organic acids into sugars and declined thereafter due to rapid utilization in respiration. This is in tune with reports of Srivastava and Dwivedi (2000) in banana and Lu *et al.* (2011) in pineapple.

Yadav *et al.* (2001) suggested the suppression of amylase activity on conversion of complex starch molecules to soluble sugars by SA application and resulted in slower increase of total sugars. The parallel findings were observed in strawberry (Salari *et al.*, 2013), peach (Khademi and Ershadi, 2013), where they also noticed delayed increment in total sugars with SA treatment. Supapvanich and Promyou (2013) noticed the reduced build up of total sugars in SA treated papaya. This was supported by the reports of Shivendra and Singh (2015) in mango, Lata (2017) and Devarakonda *et al.* (2020) in papaya cv. Red Lady**.**

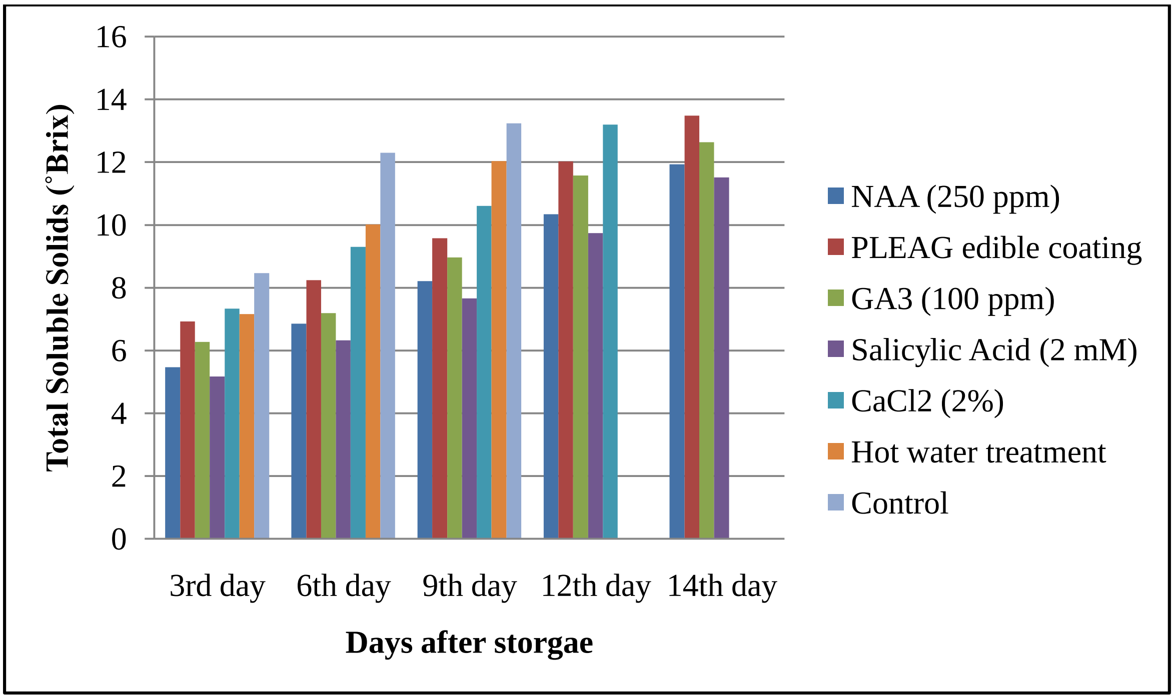

Fig. 3. Effect of postharvest treatments on total soluble solids (˚Brix) of papaya cv. Red Lady during storage

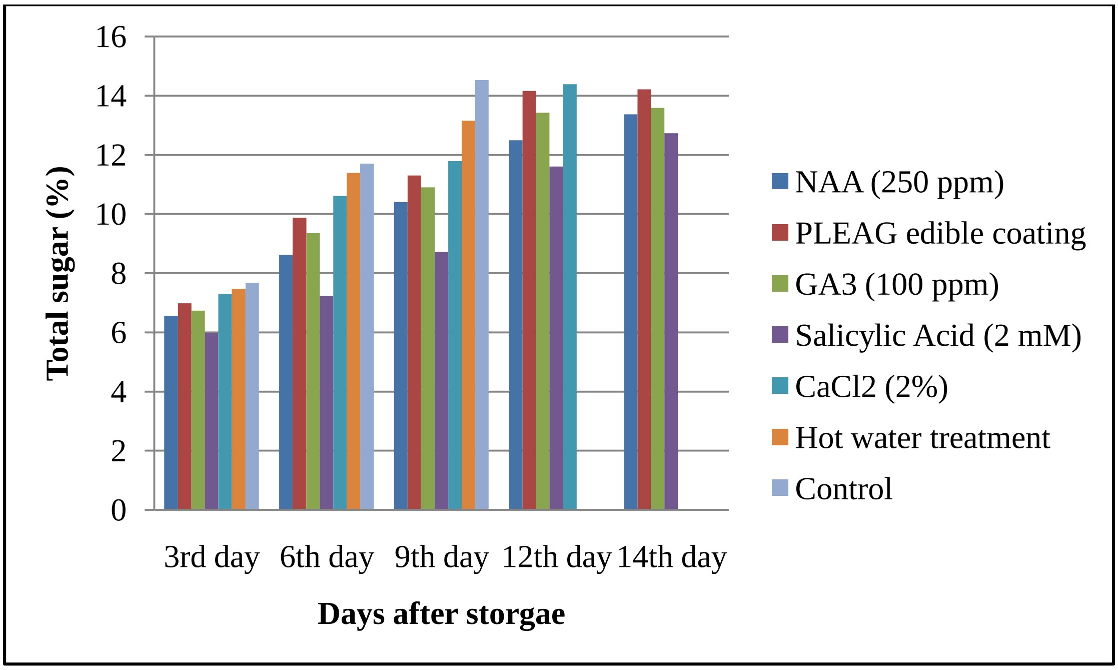

Fig. 4. Effect of postharvest treatments on total sugar (%) of papaya cv. Red Lady during storage

The postharvest treatment of papaya with NAA also reported the decline in increment of total sugars by inhibiting the hydrolytic activity of enzymes that aid the metabolism of polysaccharides of cell wall and organic acids to simple sugars (Dikki *et al*., 2010; Dubey *et al*., 2020).

5.2.5. Titratable acidity

Titratable acidity is associated with organic acids present in fruits and is responsible for flavor and quality. Acidity showed declining trend in both treated and untreated Red Lady papaya fruits during storage. Fruits under control had the highest reduction of titratable acidity while the treated fruits showed the minimum rate of decrease in titratable acidity. The Red Lady papaya treated with 2 mM SA recorded maximum titratable acidity of 0.21% after 9 days of storage which reduced to 0.17% and 0.14% after storage for 12 and 14 days respectively (Fig. 5). However, fruits without any postharvest treatment recorded the lowest titratable acidity of 0.09% after 9 days of storage. The reduction in titratable acidity with the onset of ripening may be due to catabolism of organic acids into simple sugars and its derivatives during respiration as reported by Lokesh and Varu (2013) and Barot *et al*. (2016).

Several studies have been proposed that SA retained maximum titratable acidity during storage in kinnow (Mahajan *et al.*, 2005), peach (Sihag *et al.*, 2005), apple (Kazemi *et al.*, 2011), custard apple (Patel *et al.*, 2011; Swati and Bisen, 2012), strawberry (Salari *et al.*, 2013) and mango (Hong *et al*., 2014). Castro *et al*. (2017) opined that salicylic acid treatment of papaya fruits significantly retained the highest titratable acidity as compared to control and Red Lady papaya fruits treated with SA 2 mM showed maximum titratable acidity of 0.25% after 7 days of storage (Mandal *et al*., 2017).

The postharvest treatment of Red Lady papaya with NAA 250 ppm also retained a titratable acidity of 0.13% after 14 days of storage and the postharvest application of NAA aided the retention of titratable acidity during storage by inhibiting the rapid degradation of organic acids into soluble sugars to utilize as substrate for respiration process as reported by Yadav *et al.* (2001) in guava. This is in agreement with the findings of Tehrani *et al.* (2011) in wax apple, Hazarika *et al.* (2016) in Red Lady papaya and Singh *et al.* (2018) in guava.

5.2.6. Carotenoid content

Carotenoids are prominent plant based secondary metabolites, which contribute to colour, sensory and nutritional quality of fruits. Lycopene and β cryptoxanthins are the major carotenoids present in papaya fruits. The carotenoid content increased in papaya fruits during storage and ripening in all treatments. The postharvest dipping of Red Lady papaya with SA 2mM recorded the maximum carotenoid content of 2.41 mg $100g^{-1}$ after 12 days of storage which increased to 2.55 mg $100g^{-1}$ after 14 days of storage (Fig. 6). The highest carotenoid content of 2.92 mg $100g^{-1}$ was found in fruits without any postharvest treatment (control) after 9 days of storage after which the fruits were discarded due to spoilage. The increase in carotenoid content with the storage period might be due to the chlorophyll degradation and biosynthesis of pigments such as β-carotene, xanthophylls, and anthocyanins and was supported by Ovando-Martinez *et al.* (2018).

The present findings in Red Lady papaya is in conformity with Pila *et al.* (2010) who reported that SA treatment was effective in retaining maximum carotenoid content and SA treatment delayed the rapid increase in carotenoid content by reducing chlorophyll metabolism and delayed ripening during storage with maximum fruit quality (Barman *et al.*, 2014). Similar findings proved in navel oranges (Huang *et al*., 2008), papaya (Singh *et al.*, 2012), apricot (Ezzat *et al.*, 2017), papaya cv. Red Lady (Mandal *et al.*, 2017), and papaya cv. Holland (Supapvanich and Promyou, 2017).

Red Lady papaya subjected to NAA 250 ppm also reduced the rate of ripening and recorded a carotenoid content of 2.63 mg $100g^{-1}$ after 14 days of storage. The NAA treatment also suppressed the activity of enzymes responsible for carotenoid biosynthesis (Khandaker *et al.*, 2012 and Khandaker *et al.*, 2015).

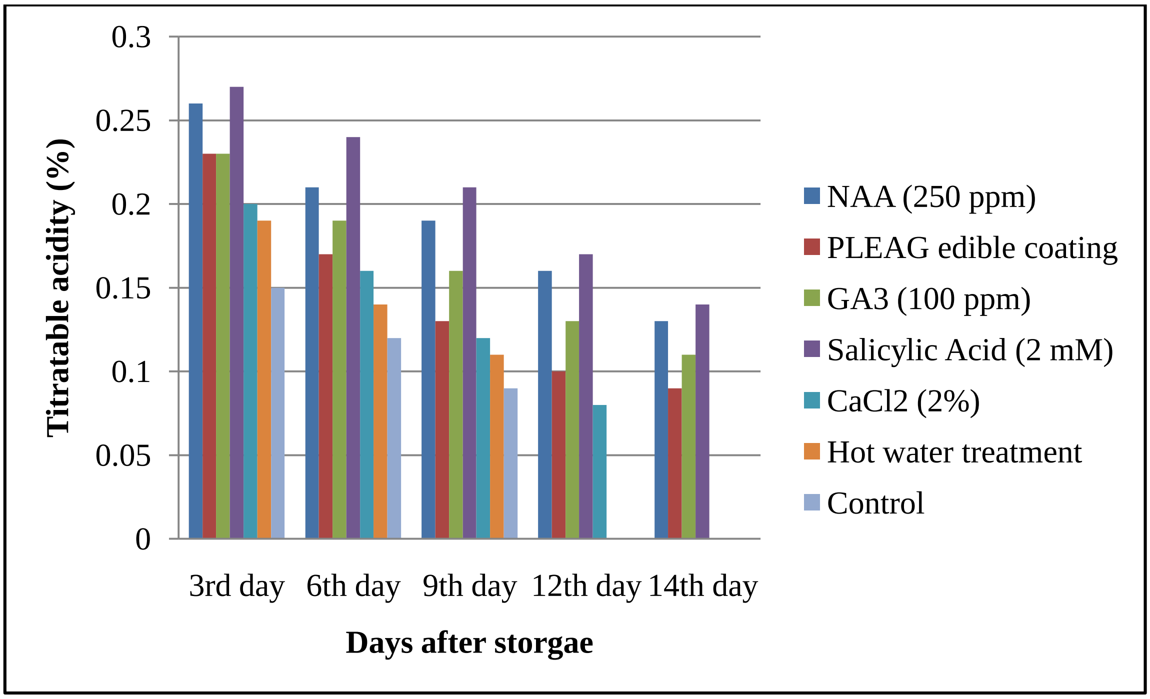

Fig. 5. Effect of postharvest treatments on titratable acidity (%) of papaya cv. Red Lady during storage

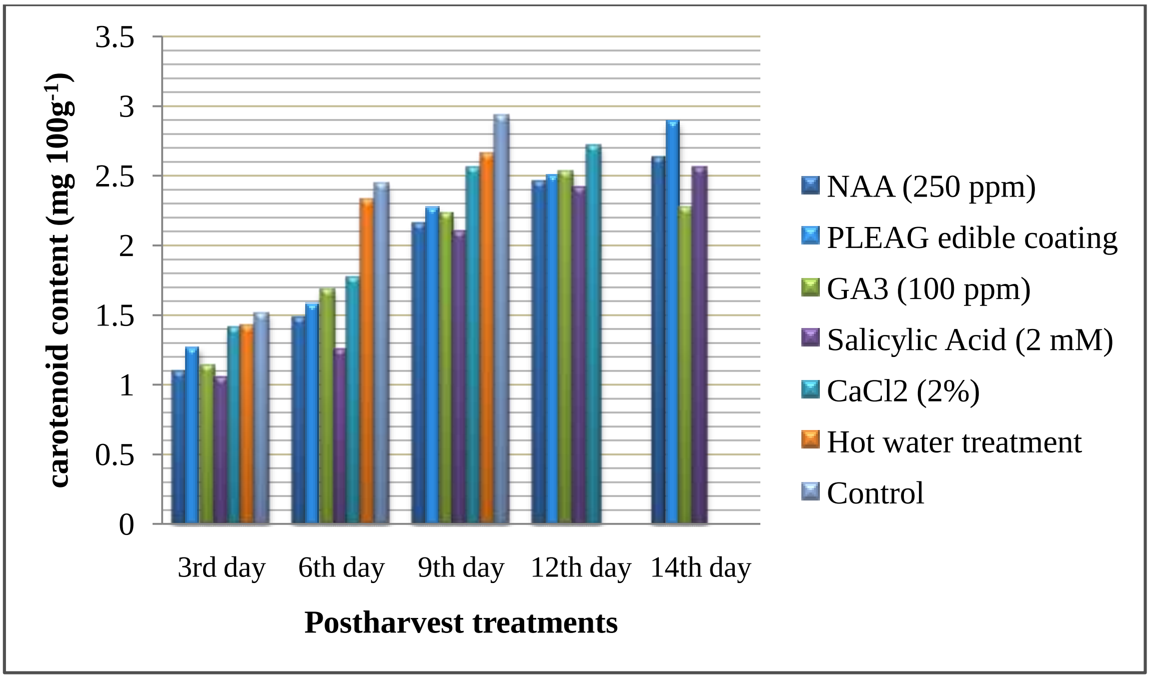

Fig. 6. Effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) of papaya cv. Red Lady during storage

5.2.7. Ascorbic acid content

Ascorbic acid determines the nutritional quality of fruits and it decrease with the ripening of fruits which is probably due to oxidative catabolic activity of oxidative enzymes effect on ascorbic acid (Singh and Rao, 2005). In Red Lady papaya also ascorbic acid decreased with the advancement of storage period irrespective of the treatments. But the postharvest application of SA was found most effective in inhibiting the oxidation of ascorbic acid and retained the maximum ascorbic acid content than control in the present study. The postharvest treatment of Red Lady papaya with salicylic acid of 2 mM concentration showed the highest retention of ascorbic acid content of 24.96 mg $100g^{-1}$after 14 days of storage whereas papaya fruits without any postharvest treatment (control) recorded the lowest ascorbic acid content of 20.28 mg $100g^{-1}$ after 9 days of storage.

Salicylic Acid treatment significantly reduced the oxidation of ascorbic acid by suppressing the activity of enzymes like catalase, peroxidise, ascorbic acid oxidase and polyphenol oxidase which led to slow decline in acidity and ascorbic acid during storage was reported by Bal and Celik (2010). The SA treatment of papaya had positive effect in reduction of respiration rate and ethylene production with maximum retention of ascorbic acid content and is supported by the findings of Asghari (2006) and Coltro *et al.* (2014) in strawberry, Renhua *et al.* (2008) and Sayyari *et al.* (2009) in pomegranate, Aghdam *et al*. (2011) in kiwifruit, Jaishankar and Kukanoor (2016) in sapota, Awad *et al.* (2017) and Al-Qurashi *et al*. (2017) in ‘Sukkari’ bananas, Lata (2017) in papaya cv. Red Lady and Supapvanich and Promyou (2017) in papaya (cv. Holland),

The papaya fruits treated with NAA at 250 ppm had also preserved the maximum ascorbic acid content of 24.25 mg $100g^{-1}$ over the control after 14 days of storage which might be due to reduced oxidation of ascorbic acid and is in conformity with the findings of Singh *et al*. (2008), who reported that the oxidative enzymes such as catalase, oxidase, polyphenol oxidase and peroxidase reduced their activity with the postharvest treatment of ber during storage. It was found that NAA was desirable in inhibiting the activity of ascorbic acid oxidase on degradation of dehydroascorbic acid and also prevented its biosynthesis from the precursor, glucose-6-phosphate in papaya fruits (Hazarika *et al*., 2016) and in guava (Singh *et al.*, 2018).

5.2.8. Antioxidant activity

Antioxidant activity in papaya is expressed as DPPH free radical scavenging capacity which increased as storage and ripening progressed in both treated and untreated fruits. But it is noticeable in the present study that postharvest treatments help in gradual increase of antioxidant activity with the advancement of fruit ripening. The antioxidant activity of Red Lady papaya treated with 2 mM SA was 65.66% at the end of shelf life of 14 days while the untreated fruits reported an antioxidant activity of 66.22% after 9 days of storage which might be due to increased concentration of carotenoids during ripening process (Fig. 7). Salicylic Acid treatment of Red Lady papaya fruits helped in maintaining the antioxidant activity even after 14 days of storage which may due to delayed ripening and enzymatic regulatory action. Zeng *et al*. (2006) observed that SA application stimulates the action of enzymes such as peroxides, β -1, 3- glucanase and phenylalanine which in turn enhanced the antioxidant activity of fruits. Huang *et al*. (2008) stated that SA being one of the important phenolic compounds stimulates the production of bioactive compounds including enzyme mediated antioxidants and Gerailoo and Ghasemnezhad (2011) identified that salicylic acid treatment activated the bioactive compounds including antioxidants and its enzymes.

The present findings are in conformity with the previous studies of Qin *et al.* (2003) and Yao and Tian (2005) in sweet cherries, Asghari (2006) in strawberry, Wang *et al*. (2006) and Mo *et al*. (2008) in sugar apples, Cao *et al*. (2010) in peach, Sarikhani *et al.* (2010) in grape, Wei *et al.* (2011) in asparagus, Barman and Asrey (2014) and Saxsena *et al*. (2014) in mango and Supapvanich (2015) in rambutan. Antioxidant activity along with total phenol content of papaya (cv. Kaek Dam) treated with SA 2 mM recorded the maximum retention during storage was reported by Supapvanich and Promyou (2017) in papaya cv. Holland and Lata *et al.* (2018) in papaya.

The postharvest treatment with NAA recorded an antioxidant activity of 64.53% after storage of 14 days at room temperature and is in conformity with the findings of Mohamed *et al*. (2014) and Ramos *et al.* (2019).

5.3. PHYSICAL PARAMETERS

5.3.1. Fruit firmness

Fruit firmness is the key factor indicating the ripening as well as consumer acceptability of papaya fruits. Firmness decreased with the advance of storage and ripening. Postharvest treatments effectively retained the highest firmness at the end of storage period which indicate the delayed ripening and longer shelf life. In the present study, Red Lady papaya treated SA 2 mM, recorded the highest firmness of 45.12 N during the 9 days of storage. The fruits without any postharvest treatment recorded the lowest retention of firmness of 15.87 N and the hot water treatment alone recorded a firmness of 16.15 N after the storage for 9 days indicating that fruits are very soft and reached the senescence stage The loss of fruit firmness is because of increased activity of β-galactosidase and polygalacturonase (PG) leading to cell wall metabolism including hydrolysis of pectin and hemicelluloses (Brummell, 2006; Goulao and Oliveira, 2008 and Maqbool *et al.*, 2011). Salicylic Acid application of papaya fruits retained the maximum firmness of 27.43 N and 19.89 N on 12^{th} and 14^{th} day of storage respectively (Fig. 8) which might be due to reduced breakdown of cell wall polysaccharides and improved cell membrane integrity which in turn delayed the ripening and fruit softening. The present findings are supported by Srivastava and Dwivedi (2000) in banana, Zhang *et al*. (2003) in kiwifruit and Mo *et al*. (2008) in sugar apple, Othman (2008) in pineapple Shafiee *et al*. (2010) and Supapvanich and Promyou (2013) in banana, Hong *et al*. (2014) in mango, Mandal *et al*. (2017) papaya cv. Red Lady with increased storage.

Papaya treated with NAA also significantly retained the fruit firmness of 26.64 N and 17.65 N after 12^{th} and 14 days of room temperature storage. NAA was found useful in preserving the fruit firmness by inhibiting the polygalactouronase activity in strawberry (Figueroa *et al*., 2012) and wax apple (Supapvanich *et al*., 2011; Khandaker *et al*., 2015).

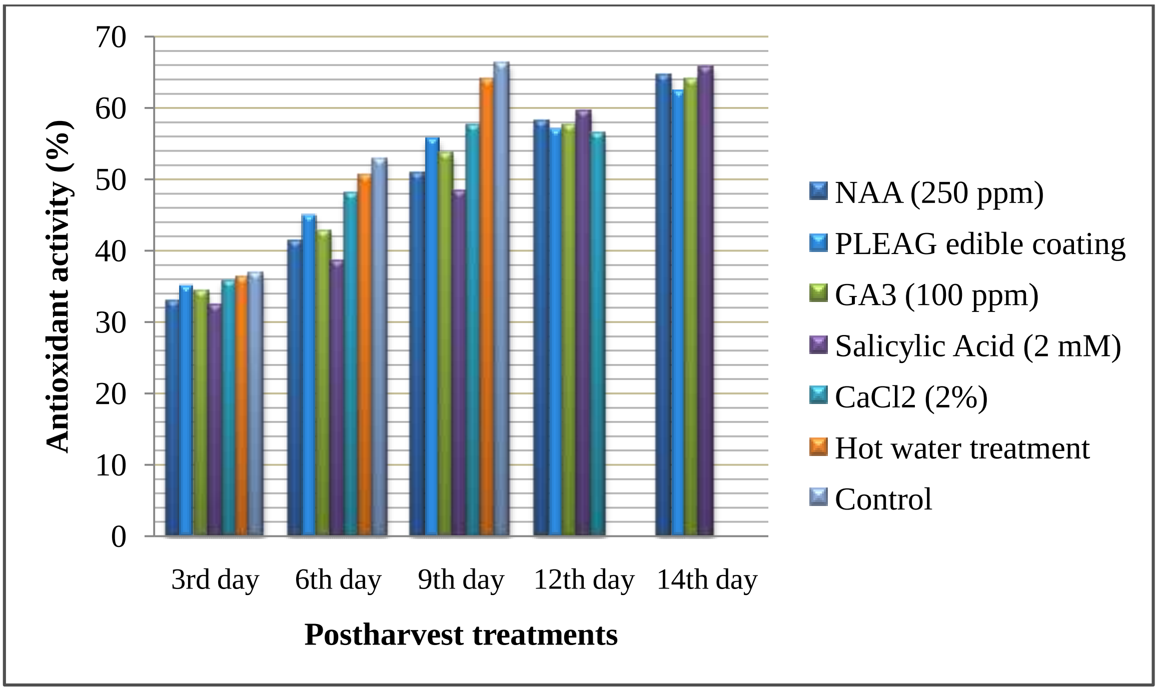

Fig. 7. Effect of postharvest treatments on antioxidant activity (%) of papaya cv. Red Lady during storage

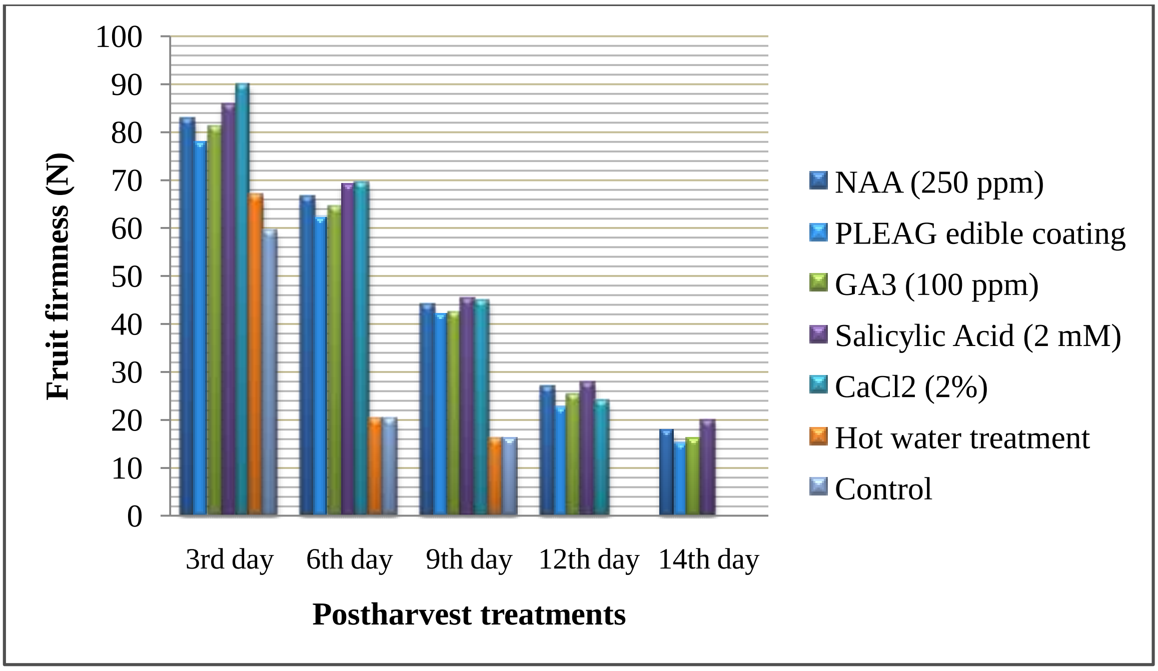

Fig. 8. Effect of postharvest treatments on fruit firmness (N) of papaya cv. Red Lady during storage

5.3.2. Skin colour

Colour development in papaya is an indication of ripening and an important visual sensory attribute contributing to better marketability and consumer acceptability. The increased rate of respiration and ethylene production in papaya fruits through ripening process change its colour from green to yellow owing to chlorophyll degradation and carotenoid biosynthesis that is not desirable for long term storage (Salvador, 2007). The major carotenoids found in papaya are α-carotene, β-carotene, β-cryptoxanthin and lycopene and skin of papaya fruits contains lutein and zeaxanthin as important carotenoids (Barreto *et al.,* 2011). All the postharvest treatments were found effective in reducing of the colour development which is a sign of ripening and senescence.

The present investigation indicated the significant inhibition of colour development in SA treated papaya fruits with a colour score of 2.2 after 9 days of storage and 4.0 and 5.4 after storage for 12th and 14 days of storage respectively. During storage, skin colour of papaya fruits intensified considerably high in control (without any postharvest treatment) and hot water treatment alone with a mean colour score of 6.0 each after 9 days of storage indicating the full ripeness. The results are in conformity to the findings of Singh *et al.* (2012) in papaya cv. Pusa Delicious, Hakim *et al.* (2013) in banana and Lata *et al.* (2018) in papaya cv. Red Lady.

Postharvest application of SA delayed ripening and also resisted the chlorophyll degradation and colour development (Shafiee *et al.*, 2010 and Tareen *et al.*, 2012). Brishti *et al. (*2013) observed that postharvest treated papaya fruits inhibited ethylene production which in turn helped in delayed ripening, chlorophyll break down, carotenoid biosynthesis and ultimately the colour development than control. This is in tune with reports of Srivastava and Dwivedi (2000) and Mandal *et al.* (2016) in banana. Mandal *et al.* (2017) identified the anti-senescent nature of SA which delayed the ripening and carotenoid production in postharvest treated papaya cv. Red Lady.

The exogenous application of NAA also inhibited the chlorophyll degradation and pigment synthesis thereby resisting the colour development in papaya fruits which recorded a mean colour score of 4.4 and 5.6 after 12th and 14th days of room temperature storage. Similar findings are also reported by Dikki *et al.* (2010), Hazarika *et al.* (2016) in papaya cv. Red Lady and Singh *et al*. (2019) in guava.

5.4. SENSORY PARAMETERS

Sensory parameters include appearance, flavor, texture, taste, flesh colour and over all acceptability and these attributes enhanced with the storage and ripening in both treated and untreated papaya fruits that recorded maximum mean score on optimum ripening and then reduced with onset of senescence. The highest sensory scores were observed for Red Lady papaya fruits treated with SA at 2 mM followed by NAA 250 ppm after 9 days of storage and retained maximum organoleptic attributes till 14 days of storage while the fruits without any postharvest treatment and subjected to hot water treatment alone recorded the highest scores on optimum ripening and decreased thereafter to the lowest scores on 9 days of storage indicating the over ripening.

All the postharvest treatments were effective in maintaining sensory qualities, of which SA reported the highest scores as a consequence of delayed ripening and senescence by inhibiting the synthesis of ACC oxidase or synthase and its action after 14 days of storage also. These results are agreement with the findings of Lata (2017) in Red Lady papaya. The postharvest application of SA inhibited the activity of cell wall hydrolyses and its degradation which in turn reduced the fruit softening maintaining fruit firmness, TSS and overall acceptability was reported by Valero *et al*. (2011), Supapvanich and Promyou (2013) and Mandal *et al*. (2017).

The postharvest application of papaya with NAA also delayed the fruit ripening and retained fruit firmness, slowed down the colour development and increased taste and overall acceptability of papaya fruits. It was found that all the organoleptic attributes were maximum on the optimum day of ripening and declined thereafter due to increased ripening and senescence (Masalkar and Garande, 2005). The present findings are in line with the reports of Dikki *et al*. (2010) in papaya and Tehrani *et al.* (2011) in wax apple.

5.5. SHELF LIFE

The postharvest treatments of papaya cv. Red Lady fruits reduced the rate of physiological activities as well as biochemical changes contributing to better retention of firmness and colour with acceptable sensory attributes which ultimately increased the shelf life. The postharvest application of SA at 2 mM concentration significantly recorded the highest shelf life of 14.56 days in Red Lady papaya which act as anti-senescent phytohormone by minimizing changes in physiological, biochemical, physical and sensory attributes. However, the fruits without any postharvest treatment (control) and hot water treatment alone reported a shelf life of 7.38 and 8.33 days respectively as they recorded the lowest green life as a consequence of rapid ripening, senescence and fruit decay.

The increase in shelf life of papaya fruits with salicylic acid application attributed to increased fruit firmness by potentially suppressing the activity of cell wall degrading enzymes like pectinmethyl esterase, cellulase, polygalactronase, xylanse, and β-1-3 glucanase (Ali *et al.,* 2004). The salicylic acid treatment of papaya delayed ripening and adjoining biochemical changes as a result of reduced respiration rate and ethylene production which significantly recorded the highest shelf life while untreated fruits maintained the lowest shelf life Mandal *et al*. (2017). Similarly, salicylic acid treatment was found effective in enhancing shelf life of banana (Srivastava and Dwivedi, 2000), strawberry (Babalar *et al*., 2007) and papaya (Bhanushree *et al.,* 2018 and Devarakonda *et al.,* 2020).

The postharvest treatment of Red Lady papaya with NAA 250 ppm also delayed the ripening associated changes and recorded a shelf life of 13.01 days and the results are in conformity with the findings of Masalkar and Garande (2005) and Dikki *et al.* (2010).

6. SUMMARY

The investigation entitled "Postharvest quality management of papaya cv. Red Lady (*Carica papaya* L.)" was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2018-2020, with the objective to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss through postharvest handling practices. The prominent findings from the study are summarized as below.

Good quality papaya fruits (cv. Red Lady) of uniform maturity (at colour break stage), size and shape were procured from the field of progressive farmers of Farmer Producer Organisation at Pallichal, Thiruvananthapuram. The selected fruits after sanitization (ozonisaton 2 ppm) followed by hot water treatment (50^0C for 20 minutes) were subjected to different postharvest treatments. The postharvest treatments were Naphthalene acetic acid (250 ppm), Edible coating (Papaya Leaf Extract Aloe Gel 1:1), Gibberellic Acid (100 ppm), Calcium chloride (2%) and Salicylic Acid (2 mM) as dipping for five minutes along with the fruits with hot water treatment alone and without any postharvest treatment as control. The treated papaya fruits after removal of surface moisture were stored in corrugated fiber board boxes at room temperature (30±2ºC, RH 80-85%). Physiological, biochemical, physical and sensory attributes of the fruits were analyzed at an interval of three days till the end of shelf life.

Postharvest treatments significantly influenced the physiological loss in weight and respiration rate of Red Lady papaya fruits during storage. The postharvest dipping of papaya fruits with Salicylic acid (SA 2 mM) recorded the lowest physiological loss in weight of 13.10% followed by NAA 250 ppm (13.95%) after 14 days of storage and the fruits subjected to GA_3 at 100 ppm and PLEAG edible coating recorded a weight loss of 14.27% and 16.49% after 14 days of storage respectively. The highest cumulative loss in weight of 10.81% was reported in papaya fruits without any postharvest treatment (control) after 9 days of storage. Postharvest treatments reduced the cumulative weight loss and extended the shelf life of papaya fruits.

Respiration rate, which is an indication of rate of ripening, is also retarded by the postharvest treatments of papaya. The lowest rate of respiration (94.83 mL CO_2 kg^{-1} h^{-1}) was observed in SA 2 mM treated fruits followed by NAA 250 ppm with 95.65 mL CO_2 kg^{-1} h^{-1} after 14 days of storage. Papaya fruits dipped in GA_3 100 ppm and PLEAG edible coating recorded a respiration rate of 97.63 mL CO_2 kg^{-1} h^{-1} and 98.56 mL CO_2 kg^{-1} h^{-1} respectively after 14 days of storage. However, the maximum respiration rate of 98.92 mL CO_2 kg^{-1} h^{-1} was reported in control (without any postharvest treatment) followed by fruits with hot water treatment alone (92.90 mL CO_2 kg^{-1} h^{-1}) after 9^{th} day of storage indicating the climacteric peak and senescence of fruits.

Biochemical parameters of postharvest treated Red Lady papaya fruits were assessed during storage. A slow rate of change was observed in all postharvest treatments and the changes were faster in untreated fruits. Among the postharvest treatments, papaya fruits treated with SA (2 mM) recorded the lowest value of 95.27% moisture content followed by NAA 250 ppm with 96.29% after 14 days while the highest value of 97.31% was observed in fruits without any postharvest treatment after 9 days of storage. Total Soluble Solids recorded a gradual increase for the SA (2 mM) treated fruits and recorded 11.52 ^{o}Brix after 14 days of storage followed by NAA 250 ppm with 11.93 ^{o}Brix. Among the treatments, GA_3 at 100 ppm and PLEAG edible coating recorded a TSS of 12.64 ^{o}Brix and 13.48 ^{o}Brix respectively after 14 days of storage. There was a rapid increase in the TSS content of Red Lady papaya fruits without any treatments during storage and recorded the highest TSS of 13.24 ^{o}Brix after the 9^{th} day of storage indicating faster ripening as compared to the treated fruits.

Similar trend was observed for the changes in reducing and total sugar of papaya fruits subjected to postharvest treatments. Among the treatments, fruits treated with SA 2 mM recorded a reducing sugar content of 8.26% followed by NAA 250 ppm with 8.84% after 14 days of storage. The reducing sugar content was 9.05%

and 9.28% for GA_3 100 ppm and PLEAG edible coated treated fruits after 14 days of storage at room temperature. The highest value of reducing sugar (9.37%) was reported for the fruits without any postharvest treatment (control) at the end of 9 days of storage period. The total sugar content of 12.73% was recorded after 14 days of storage for SA 2 mM treated papaya fruits followed by those treated with NAA 250 ppm with 13.37%. Postharvest treated papaya with GA_3 100 ppm and PLEAG edible coating recorded the total sugar content of 13.59% and 14.22% respectively after 14 days of storage. The highest total sugar content of 14.53% was noticed in fruits without any postharvest treatment followed by 13.15% for fruits with hot water treatment alone after 9^{th} day of storage.

Salicylic Acid (2 mM) and NAA 250 ppm treated Red Lady papaya effectively retained the titratable acidity of 0.14% and 0.13% respectively after 14 days of storage whereas titratable acidity of 0.11% and 0.09% was found in GA_3 100 ppm and PLEAG edible coating dipped fruits at the end of 14 days of storage. The titratable acidity diminished rapidly in control fruits from 0.28% at the time of storage to 0.09% after 9 days of storage indicating the accelerated ripening process. Salicylic Acid treatment of papaya reduced the chlorophyll degradation and recorded a carotenoid content of 2.55 mg $100g^{-1}$ followed by NAA 250 ppm with 2.63 mg $100g^{-1}$ after 14 days of storage. Papaya treated with GA_3 100 ppm and PLEAG edible coating had a carotenoid content of 2.77 mg $100g^{-1}$ and 2.89 mg $100g^{-1}$ after 14 days of storage. Untreated papaya fruits (control) recorded the maximum carotenoid content of 2.92 mg $100g^{-1}$ after the storage of 9 days at room temperature.

Ascorbic acid content retention was higher in fruits with postharvest treatments and recorded the highest value of 24.96 mg $100g^{-1}$ for SA (2 mM) treated papaya followed by NAA 250 ppm with 24.25 mg $100g^{-1}$ after 14 days of storage. The postharvest applications of GA_3 100 ppm and PLEAG edible coating recorded an ascorbic acid content of 22.96 mg $100g^{-1}$ and 21.27 mg $100g^{-1}$ respectively after 14 days of storage. However, fruits without any postharvest treatment reported the lowest ascorbic acid content of 20.28 mg $100g^{-1}$ after 9th day of storage. Among the treatments, SA and NAA treated papaya fruits recorded an antioxidant activity of 65.66% and 64.53% respectively after 14 days of storage. It was 63.92% and 62.29%

for papaya fruits treated with GA_3 100 ppm and PLEAG edible coating respectively after 14 days of storage. Calcium chloride (2%) treatment of Red Lady papaya showed an antioxidant activity of 56.48% after 12^{th} day of storage. The untreated fruits recorded an antioxidant activity of 66.22% at the end of 9 days of storage at room temperature.

Fruit firmness (texture) and skin colour, which are the physical parameters of fruit ripening, were analysed during storage of treated Red Lady papaya fruits. Postharvest treatment of papaya with SA (2 mM) retained the maximum fruit firmness of 19.89 N followed by NAA (250 ppm) with 17.65 N after 14 days of storage. The fruit firmness of 15.93 N and 15.23 N was reported for GA_3 100 ppm and PLEAG edible coated fruits respectively after 14 days of storage. $CaCl_2$ (2%) treatment noticed a firmness retention of 23.72 N in papaya fruits after 12^{th} day of storage. The minimum fruit firmness of 15.87 N was observed in fruits without any postharvest treatment after 9 days of storage indicating more flesh softening. The rind colour development was also delayed by the postharvest treatments showing the delayed ripening. Salicylic Acid treated papaya fruits recorded the skin colour score of 5.4 followed by NAA 250 ppm (5.6) while the colour score of 6 (fruit colour similar to stage 5, but more intense) was observed by remaining postharvest treatments after 14 days of storage. But the papaya fruits without any postharvest treatment recorded a maximum colour score of 6 (fruit colour similar to stage 5, but more intense) after 9 days of storage showing the full ripeness.

Sensory parameters such as appearance, flavour, texture, taste, flesh colour and overall acceptability of treated papaya fruits were studied and found that SA 2 mM and NAA 250 ppm recorded the. The fruits without postharvest treatment recorded the highest sensory mean scores after 9 days of storage attributing to enhanced ripening. The postharvest treatments did not affect sensory qualities at optimum ripening and SA dipping recorded the highest scores on 12^{th} day of storage asserting optimum ripening and was acceptable at 14 days of storage.

Postharvest treatments influenced the shelf life of treated Red Lady papaya fruits and the treatment with SA 2 mM effectively maintained the highest shelf life of

14.56 days with minimum quality loss followed by NAA 250 ppm with 13.01 days of shelf life. Fruits without any postharvest treatment (control) noticed the shortest shelf life of 7.38 days.

The postharvest treatments of Red lady papaya fruits had influenced the physiological, biochemical, physical and sensory parameters during storage and delayed the ripening process, of which Salicylic Acid 2mM treatment was promising. Red lady papaya fruits, harvested at colour break stage, after sanitization with ozonation (2 ppm) followed by hot water treatment (50 ˚C for 20 minutes) and subjected to postharvest dipping in SA 2 mM for 5 minutes effectively reduced the physiological activities and associated physico-chemical changes which delayed the ripening and extended the shelf life up to 14.56 days at room temperature. The papaya fruits without any postharvest treatment ripened faster and recorded a shelf life of 7.38 days only.

Future line of work

The current investigation revealed that Red Lady papaya subjected to postharvest treatments could effectively prolong the shelf life without affecting its quality. The standardized methodology can be commercialized after assessing the performance in the present market system as future line of work and can assure better income to farmers.

Summary

6. SUMMARY

The investigation entitled "Postharvest quality management of papaya cv. Red Lady (*Carica papaya* L.)" was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2018-2020, with the objective to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss through postharvest handling practices. The prominent findings from the study are summarized as below.

Good quality papaya fruits (cv. Red Lady) of uniform maturity (at colour break stage), size and shape were procured from the field of progressive farmers of Farmer Producer Organisation at Pallichal, Thiruvananthapuram. The selected fruits after sanitization (ozonisaton 2 ppm) followed by hot water treatment (50^0C for 20 minutes) were subjected to different postharvest treatments. The postharvest treatments were Naphthalene acetic acid (250 ppm), Edible coating (Papaya Leaf Extract Aloe Gel 1:1), Gibberellic Acid (100 ppm), Calcium chloride (2%) and Salicylic Acid (2 mM) as dipping for five minutes along with the fruits with hot water treatment alone and without any postharvest treatment as control. The treated papaya fruits after removal of surface moisture were stored in corrugated fiber board boxes at room temperature (30±2ºC, RH 80-85%). Physiological, biochemical, physical and sensory attributes of the fruits were analyzed at an interval of three days till the end of shelf life.

Postharvest treatments significantly influenced the physiological loss in weight and respiration rate of Red Lady papaya fruits during storage. The postharvest dipping of papaya fruits with Salicylic acid (SA 2 mM) recorded the lowest physiological loss in weight of 13.10% followed by NAA 250 ppm (13.95%) after 14 days of storage and the fruits subjected to GA_3 at 100 ppm and PLEAG edible coating recorded a weight loss of 14.27% and 16.49% after 14 days of storage respectively. The highest cumulative loss in weight of 10.81% was reported in papaya fruits without any postharvest treatment (control) after 9 days of storage. Postharvest

treatments reduced the cumulative weight loss and extended the shelf life of papaya fruits.

Respiration rate, which is an indication of rate of ripening, is also retarded by the postharvest treatments of papaya. The lowest rate of respiration (94.83 mL CO_2 kg^{-1} h^{-1}) was observed in SA 2 mM treated fruits followed by NAA 250 ppm with 95.65 mL CO_2 kg^{-1} h^{-1} after 14 days of storage. Papaya fruits dipped in GA_3 100 ppm and PLEAG edible coating recorded a respiration rate of 97.63 mL CO_2 kg^{-1} h^{-1} and 98.56 mL CO_2 kg^{-1} h^{-1} respectively after 14 days of storage. However, the maximum respiration rate of 98.92 mL CO_2 kg^{-1} h^{-1} was reported in control (without any postharvest treatment) followed by fruits with hot water treatment alone (92.90 mL CO_2 kg^{-1} h^{-1}) after 9^{th} day of storage indicating the climacteric peak and senescence of fruits.

Biochemical parameters of postharvest treated Red Lady papaya fruits were assessed during storage. A slow rate of change was observed in all postharvest treatments and the changes were faster in untreated fruits. Among the postharvest treatments, papaya fruits treated with SA (2 mM) recorded the lowest value of 95.27% moisture content followed by NAA 250 ppm with 96.29% after 14 days while the highest value of 97.31% was observed in fruits without any postharvest treatment after 9 days of storage. Total Soluble Solids recorded a gradual increase for the SA (2 mM) treated fruits and recorded 11.52 ^{o}Brix after 14 days of storage followed by NAA 250 ppm with 11.93 ^{o}Brix. Among the treatments, GA_3 at 100 ppm and PLEAG edible coating recorded a TSS of 12.64 ^{o}Brix and 13.48 ^{o}Brix respectively after 14 days of storage. There was a rapid increase in the TSS content of Red Lady papaya fruits without any treatments during storage and recorded the highest TSS of 13.24 ^{o}Brix after the 9^{th} day of storage indicating faster ripening as compared to the treated fruits.

Similar trend was observed for the changes in reducing and total sugar of papaya fruits subjected to postharvest treatments. Among the treatments, fruits treated with SA 2 mM recorded a reducing sugar content of 8.26% followed by NAA 250 ppm with 8.84% after 14 days of storage. The reducing sugar content was 9.05%

and 9.28% for GA_3 100 ppm and PLEAG edible coated treated fruits after 14 days of storage at room temperature. The highest value of reducing sugar (9.37%) was reported for the fruits without any postharvest treatment (control) at the end of 9 days of storage period. The total sugar content of 12.73% was recorded after 14 days of storage for SA 2 mM treated papaya fruits followed by those treated with NAA 250 ppm with 13.37%. Postharvest treated papaya with GA_3 100 ppm and PLEAG edible coating recorded the total sugar content of 13.59% and 14.22% respectively after 14 days of storage. The highest total sugar content of 14.53% was noticed in fruits without any postharvest treatment followed by 13.15% for fruits with hot water treatment alone after 9th day of storage.

Salicylic Acid (2 mM) and NAA 250 ppm treated Red Lady papaya effectively retained the titratable acidity of 0.14% and 0.13% respectively after 14 days of storage whereas titratable acidity of 0.11% and 0.09% was found in GA_3 100 ppm and PLEAG edible coating dipped fruits at the end of 14 days of storage. The titratable acidity diminished rapidly in control fruits from 0.28% at the time of storage to 0.09% after 9 days of storage indicating the accelerated ripening process. Salicylic Acid treatment of papaya reduced the chlorophyll degradation and recorded a carotenoid content of 2.55 mg $100g^{-1}$ followed by NAA 250 ppm with 2.63 mg $100g^{-1}$ after 14 days of storage. Papaya treated with GA_3 100 ppm and PLEAG edible coating had a carotenoid content of 2.77 mg $100g^{-1}$ and 2.89 mg $100g^{-1}$ after 14 days of storage. Untreated papaya fruits (control) recorded the maximum carotenoid content of 2.92 mg $100g^{-1}$ after the storage of 9 days at room temperature.

Ascorbic acid content retention was higher in fruits with postharvest treatments and recorded the highest value of 24.96 mg $100g^{-1}$ for SA (2 mM) treated papaya followed by NAA 250 ppm with 24.25 mg $100g^{-1}$ after 14 days of storage. The postharvest applications of GA_3 100 ppm and PLEAG edible coating recorded an ascorbic acid content of 22.96 mg $100g^{-1}$ and 21.27 mg $100g^{-1}$ respectively after 14 days of storage. However, fruits without any postharvest treatment reported the lowest ascorbic acid content of 20.28 mg $100g^{-1}$ after 9th day of storage. Among the treatments, SA and NAA treated papaya fruits recorded an antioxidant activity of 65.66% and 64.53% respectively after 14 days of storage. It was 63.92% and 62.29%

for papaya fruits treated with GA_3 100 ppm and PLEAG edible coating respectively after 14 days of storage. Calcium chloride (2%) treatment of Red Lady papaya showed an antioxidant activity of 56.48% after 12^{th} day of storage. The untreated fruits recorded an antioxidant activity of 66.22% at the end of 9 days of storage at room temperature.

Fruit firmness (texture) and skin colour, which are the physical parameters of fruit ripening, were analysed during storage of treated Red Lady papaya fruits. Postharvest treatment of papaya with SA (2 mM) retained the maximum fruit firmness of 19.89 N followed by NAA (250 ppm) with 17.65 N after 14 days of storage. The fruit firmness of 15.93 N and 15.23 N was reported for GA_3 100 ppm and PLEAG edible coated fruits respectively after 14 days of storage. $CaCl_2$ (2%) treatment noticed a firmness retention of 23.72 N in papaya fruits after 12^{th} day of storage. The minimum fruit firmness of 15.87 N was observed in fruits without any postharvest treatment after 9 days of storage indicating more flesh softening. The rind colour development was also delayed by the postharvest treatments showing the delayed ripening. Salicylic Acid treated papaya fruits recorded the skin colour score of 5.4 followed by NAA 250 ppm (5.6) while the colour score of 6 (fruit colour similar to stage 5, but more intense) was observed by remaining postharvest treatments after 14 days of storage. But the papaya fruits without any postharvest treatment recorded a maximum colour score of 6 (fruit colour similar to stage 5, but more intense) after 9 days of storage showing the full ripeness.

Sensory parameters such as appearance, flavour, texture, taste, flesh colour and overall acceptability of treated papaya fruits were studied and found that SA 2 mM and NAA 250 ppm recorded the. The fruits without postharvest treatment recorded the highest sensory mean scores after 9 days of storage attributing to enhanced ripening. The postharvest treatments did not affect sensory qualities at optimum ripening and SA dipping recorded the highest scores on 12^{th} day of storage asserting optimum ripening and was acceptable at 14 days of storage.

Postharvest treatments influenced the shelf life of treated Red Lady papaya fruits and the treatment with SA 2 mM effectively maintained the highest shelf life of

14.56 days with minimum quality loss followed by NAA 250 ppm with 13.01 days of shelf life. Fruits without any postharvest treatment (control) noticed the shortest shelf life of 7.38 days.

The postharvest treatments of Red lady papaya fruits had influenced the physiological, biochemical, physical and sensory parameters during storage and delayed the ripening process, of which Salicylic Acid 2mM treatment was promising. Red lady papaya fruits, harvested at colour break stage, after sanitization with ozonation (2 ppm) followed by hot water treatment (50 ˚C for 20 minutes) and subjected to postharvest dipping in SA 2 mM for 5 minutes effectively reduced the physiological activities and associated physico-chemical changes which delayed the ripening and extended the shelf life up to 14.56 days at room temperature. The papaya fruits without any postharvest treatment ripened faster and recorded a shelf life of 7.38 days only.

Future line of work

The current investigation revealed that Red Lady papaya subjected to postharvest treatments could effectively prolong the shelf life without affecting its quality. The standardized methodology can be commercialized after assessing the performance in the present market system as future line of work and can assure better income to farmers.

References

7. REFERENCE

Abbasi, N. A., Hafeez, S., and Tareen, M.J. 2010. Salicylic acid prolongs shelf life and improves quality of' Maria Delicia'peach fruit. *Acta Hortic.* 880: 191-197.

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. In proceedings of the *VI Int. Postharvest Symp.* 8-12 April. 2009, Antalya, Turkey: 43-748.

Aghdam, M. S., Motallebiazar, A., Mostofi, Y., Moghaddam, J. F., and Ghasemnezhad, M. 2011. Methyl salicylate affects the quality of Hayward kiwifruit during storage at low temperature. *J. Agric. Sci.* 3 (2): 149–156.

Agrawal, S. and Dixit, S. N. 2010. Studies on the effect of plant growth regulators on growth and yield of sapota (*Achras sapota* L.) cv. Cricket ball. *Indian J. Agric. Res*. 42(3): 207-211.

Akaniwor, J. O. and Arachie, S. N. 2002. Nutritive values of fruits and seeds usually eaten raw in papaya. *Nigeria J. Appl. Sci. Environ. Manag*. 6(2): 77-78.

Ali, A., Ong, M. K., and Forney, C. F. 2014. Effect of ozone pre-conditioning on quality and antioxidant capacity of papaya fruit during ambient storage. *Food Chem.* 142: 19-26.

Ali, Z., Chin, L. H., and Lazan, H. 2004. A comparative study on wall degrading enzymes, pectin modifications and softening during ripening of selected tropical fruits. *Plant Sci.* 167: 317–327.

Allong, R., Wickham, L. D., and Majeed, M. 2000. Effect of cultivar, hot water treatment and storage conditions on quality of fresh-cut papaya (*Carica papaya* L.). *J. Appl. Hortic.* 2(1): 15-18.

Al-Qurashi, A. D., Awad, M. A., Mohamed, S. A., and Elsayed, M. I. 2017. Postharvest chitosan, trans-resveratrol and glycine betaine dipping affect quality, antioxidant compounds, free radical scavenging capacity and enzymes activities of 'Sukkari'bananas during shelf life. *Scientia Hortic.* 219: 173-181.

Alrashdi, A. M., Al-Qurashi, A. D., Awad, M. A., Mohamed, S. A., and Al-rashdi, A. A. 2017. Quality, antioxidant compounds, antioxidant capacity and enzymes activity of 'El-Bayadi' table grapes at harvest as affected by preharvest salicylic acid and gibberellic acid spray. *Sci. Hortic.* 220: 243-249.

Ambareesha. K. N. 2016. Standardisation of minimal processing of amaranthus (*Amaranthus tricolor* L.) M. Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 160p.

Amith, P. K. 2012. Protocol development for fresh cut fruits and fruit mix. M. Sc. (Hort.) thesis, Kerala Agricultural University. Thrissur, 125 p.

Amoros, A., Zapata, P., Pretel, M. T., Botella, M. A., Almansa, M. S., and Serrano, M. 2014. Role of naphthalene acetic acid and phenothiol treatments on increasing fruit size and advancing fruit maturity in loquat. *Sci. Hortic.* 101(4): 387-398.

Anino, S. V., Salvatori, D. M., and Alzamora, S. M. 2006. Changes in calcium level and mechanical properties of apple tissue due to impregnation with calcium salts. *Food Res. Int*. 39(2): 154-164.

Arina, M. A., Boyce, A. N., and Chandran, S. 2010. Effects of postharvest hot water treatment on physiological and biochemical properties of 'Eksotika' papaya during ripening. *Acta Hortic.* 875: 177-184.

Aristya, G. R., Maulina, N. T. A., Arif, M. F., Kasiamdari, R.S., and Widiastuti, A. 2019. Detection and analysis of delayed-ripening genes in the growth of strawberries (Fragaria× Ananassa) Treated 1-Naphtaleneacetic acid. *Int. J. Physics: Conference Series* 11-12 July. 2019, Malang, Indonesia 1374 (1): 218p.

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 post-harvest physiology of horticultural crops. *Trends Food Sci. Technol*. 21: 502-509.

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.

Awad, M. A., Al-Qurashi, A. D., Mohamed, S. A., El-Shishtawy, R. M., and Ali, M. A. 2017. Postharvest chitosan, gallic acid and chitosan gallate treatments effects on shelf life quality, antioxidant compounds, free radical scavenging capacity and enzymes activities of 'Sukkari' bananas. *J. Food Sci. Technol*. 54: 447–457.

Azene, M., Workneh, T. S., and Woldetsadik, K. 2014. Effect of packaging materials and storage environment on postharvest quality of papaya fruit. *J. Food Sci. Technol.* 51(6): 1041-1055.

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.

Babu, I., Ali, M. A., Shamim, F., Yasmin, Z., Asghar, M., and Khan, A. R. 2015. Effect of calcium chloride application on quality characteristics and post harvest performance of loquat fruit during storage. *Int. J. Adv. Res.* 3(1): 602-610.

Bakshi, M., Singh, G., and Kaur, M. 2019. Post-harvest treatment for improvement of shelf life in guava (*Pisidium guajava.* L.) cultivar 'Allahabad Safeda'under ambient storage condition. *Plant Arch.* 19(2): 3005-3010.

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.

Bansal, V., Siddiqui, M. W., and Rahman, M. S. 2015. Minimally processed foods: overview. In *Minimally processed foods*, Springer publishers, Italy, pp. 1-15.

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.

Barman, K., Siddiqui, Md. W., Patel, V. B., and Prasad M. 2014. Nitric oxide reduces pericarp browning and preserves bioactive antioxidants in litchi. *Sci. Hortic*. 171: 71-77.

Barot, H. R., Sitapara, H. H., Nurbhanej, K. H., Gadhavi, A. V., and Raval, V. H. 2016. Effect of post harvest treatments on bio-chemical parameters of papaya (*Carica papaya* L.) cv. Madhu bindu. *Advan. Life Sci*. 5 (2): 486-489.

Barreto, G. P., Fabi, J. P., De Rosso, V. V., Cordenunsi, B. R., and Lajolo, F. M. 2011. Influence of ethylene on carotenoid biosynthesis during papaya postharvesting ripening. *J. Food Comp. Anal*. 24: 620-624.

Bataller, M., Gonzalez, J. E., Veliz, E., and Fernandez, L. A. 2012. Ozone applications in the post-harvest of papaya (*Carica papaya* L.): an alternative to Amistar fungicide. *Ozone: Sci. Eng.* 34(3): 151-155.

Benitez, M. S., Hersh, M. H., Vilgalys, R., and Clark, J. S. 2013. Pathogen regulation of plant diversity via effective specialization. *Trends Ecol. Evol.* 28(12): 705-711.

Benjamin, Y. N. Z., Clement, Y. B. Y., Edith, K. K. N., and Kablan, T. 2018. The effect of the thermal treatment (49^{o}C-90 min) coupled with storage at 15^{o}C on the infection rate, physicochemical and nutritional characteristics of the papaya (*Carica papaya* L. var Solo). *Int. J. Adv. Res. Biol. Sci*. 5(5): 1-11.

Beuchat, L. R. 2016. Surface disinfection of raw produce. *Dairy Food Environ. Sanitation* 12(1): 6-9.

Bhalerao, P. P., Bhalerao, R. R., Patil, S. J., Gaikwad, S. S., and Patel, C. M. 2010. Effect of growth regulators on shelf life of banana fruits (*Musa paradisica* L.) cv. Grand Naine. *Green Farming* 1(1): 55-58.

Bhande, S. D., Ravindra, M. R., and Goswami, T. K. 2008. Respiration rate of banana fruit under aerobic conditions at different storage temperatures. *J. Food Eng.* 87(1): 116-123.

Bhanushree, L. S., Vasudeva, K. R., Suresha, G. J., Sadananda, G. K., Mohamad, T. H., and Halesh, G. K. 2018. *J. Pharmacognosy Phytochemistry* 7(2): 2010-2014.

Bhardwaj, R. L., Dhashora, L. K., and Mukherjee, S. 2010. Effect of ozone treatment and benzyladenine on post-harvest shelf life of orange (*Citrus reticulata* Blanco). *J. Adv. Dev. Res*. 1(1): 32-37.

Bhooriya, M. S., Bisen, B. P., and Pandey, S. K. 2018. Effect of post-harvest treatments on shelf life and quality of Guava (*Psidiun gujava* L.) fruits. *Int. J. Chemical Stud.* 6(4): 2559-2564.

Bhuvaneswari, S., Rao, D. V. S., and Kumaran, S. G. 2017. Shelf life extension of papaya (*Carica papaya* L.) packaged in customized corrugated fibre board (CFB) box after subjecting to vibration and drop tests. *Plant Arch.* 17(1): 341-347.

Bola, P. K., Jain, S. K., and Choudhary, A. 2016. Improvement in shelf-life of strawberry (*Fragaria ananassa* Duch.) cv. Winter Dawn with edible coatings enriched with Chitosan. *Hortic. Flora Res. Spect.* 5(1): 28-33.

Brishti, F. H., Misir, J., and Sarker, A. 2013. Effect of biopreservatives on storage life of papaya (*Carica papaya* L.). *Int. J. Food Stud.* 2(1): 126-136.

Brothakar, P. K. and Kumar, R. 2002. Effect of plant extracts on size and rind thickness of Baromasi lemon fruits (Citrus lemon) during storage. *J. Agric. Sci. Soc. N.-E. India* 15: 98–103.

Brummell, D. A. 2006. Cell wall disassembly in ripening fruit. *Funct. Plant Biol.* 33(2): 103-119.

Cao, S., Hu, Z., Zheng, Y., and Lu, B. 2010. Synergistic effect of heat treatment and salicylic acid on alleviating internal browning in cold-stored peach fruit. *Postharvest Biol. Technol.* 58(2): 93-97.

Carrillo-Lopez, A., Chavez-Sanchez, I., Vega-García, M., and Yahia, E. M. 2013. The effect of antifungal hot-water treatments on papaya postharvest quality and activity of pectinmethylesterase and polygalacturonase. *J. Food Sci. Technol*. 50(1): 101-107.

Castro, M., Mantuano, M. I., Coloma, J. L., and Santacruz, S. 2017. Utilisation of Cassava starch edible films containing salicylic acid on papaya (*Carica papaya* L.) preservation. *Polytechnic Mag.* 39(1): 7-12.

Chandran, T. T. 2018. Aloe vera based film coating for shelf life extension in tomato *(Solnum lycopersicum* L.). M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 280p.

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.

Chavez-Sanchez, I., Carrillo-Lopez, A., Vega-Garcia, M., and Yahia, E. M. 2013. The effect of antifungal hot-water treatments on papaya postharvest quality and activity of pectinmethylesterase and polygalacturonase. *J. Food Sci. Technol.* 50(1): 101-107.

Chonhenchob, V. and Singh, S. P. 2005. Packaging performance comparison for distribution and export of papaya fruit. *Packaging Technol. Sci. An Int. J.* 18(3): 125-131.

Choudhury, M. L. 2006. Recent developments in reducing postharvest losses in the Asia-Pacific region. *Environ. Ecol*. 23(4): 49-58.

Chutichudet, B. and Chutichudet, P. 2014. Effects of chitosan or calcium chloride on external postharvest qualities and shelf-life of 'Holland'papaya fruit. *J. Agric. Sci.* 6(11): 160p.

Coltro, S., Broetto, L., Rotilli, M. C. C., deMoraes, A. J., Bearp, F. K., and Braga, G. C. 2014. Heat shock and salicylic acid on postharvest preservation of organic strawberries. *Rev. Ceres*. 61(3): 306-312.

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 (3a): 1037-1040.

Desai., R. J. 2008. Studies on shelf life and quality of papaya cv. Red lady Taiwan as influenced by some ripening retardants under ambient condition. M. Sc. (Hort.) thesis, ASPEE College of Horticulture and Forestry Gujarat Agricultural University, Navsari, 114p.

Desai, V. N. 2016. Influence of pre-harvest spraying treatments of chemicals and plant growth regulators on quality parameters and shelf life of sapota [*Manilkara achras* (Mill.) Forsberg] fruits cv. Kalipatti. M. Sc. (Hort.) thesis, Anand Agricultural University, Anand (Gujarat), 111p.

Devarakonda, S., Madhumathi, C., Umamahesh, V., Mukunda, L., Lakshmi, M., Bhaskar, V. V., and Rajasekharam, T. 2020. Influence of pre-harvest spray of salicylic acid and Jasmonic acid on fruit quality and postharvest behaviour of papaya (*Carica papaya* L.) cv. Red Lady. *J. Pharmacognosy Phytochem.* 9(3): 622-626.

Devi, A., Sharma, N., Wali, V. K., Bakshi, P., Jamwal, M., and Kumar, R. 2016. Effects of preharvest bioregulator application on shelf-life and disease incidence during storage of Kinnow Mandarin. *Bangladesh J. Bot.* 45(5): 1091-1099.

Dhatt, A. S. and Mahajan, B. V. C. 2004. Studies on postharvest calcium chloride application on storage behaviour and quality of Asian pear during cold storage. *J. Food Agric. Environ*. 2(3-4): 157-159.

Dhillon, B. S. and Kaur, S. 2013. Effect of post harvest application of calcium chloride on storage life of mango var. Dashehari fruits. *Hortic. Flora Res. Spect.* 2(3): 265-267.

Dikki, K., Singh, D. B., Yadav, M., Roshan, R. K., and Pebam, N. 2010. Effect of wax coating and NAA on storage behaviour of papaya (*Carica papaya* L.). *Acta Hortic.* 851: 533-536.

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.

Dubey, S., Sahu, G. D., Kumar, V., Saxena, R. R., and Hota, D. 2020. Effect of plant growth regulators on chemical quality of papaya (Carica papaya) cv. Red Lady. *Int. J. Chem. Stud*. 8(3): 197-199.

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. Current Res. Rev.* 6(23): 63-69.

Erkan, M., Pekmezci. M., and Wang, C. Y. 2005. Hot water and curing treatments reduce chilling injury and maintain post-harvest quality of ‘Valencia’ oranges. *Int. J. Food Sci. Technol*. 40: 91-96.

Ezzat, A., Ammar, A., Szabo, Z., Nyeki, J., and Holb, I. J. 2017. Postharvest treatments with methyl jasmonate and salicylic acid for maintaining physico-chemical characteristics and sensory quality properties of apricot fruit during cold storage and shelf-life. *J. Food Nutr. Sci.* 67(2): 159-166.

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.

Figueroa, C. R., Opazo, M. C., Vera, P., Arriagada, O., Diaz, M. M., and Moya-leon. 2012. Effect of postharvest treatment of calcium and auxin on cell wall composition and expression of cell wall-modifying genes in the Chilean strawberry (*Fragaria chiloensis*) fruit. *Food Chem.* 132: 2014-2022.

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

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.

George, G. M. 2015. Postharvest handling studies for extending shelf life of amaranthus (*Amaranthus tricolor* L.). M. Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 128p.

Gerailoo, S. and Ghasemnezhad, M. 2011. Effect of salicylic acid on antioxidant enzyme activity and petal **senescence** in ‘Yellow Island’ cut rose flowers. *J. Fruit Ornamental Plant Res*. 19: 183–193.

Ghadage, V. R. 2011. Effect of post harvest application of calcium chloride and wax emulsion on ripening and storage behavior of papaya (*Carica papaya* L.) cv. Taiwan Red Lady. M. Sc. (Hort.) thesis, ASPEE College of Horticulture and Forestry Navsari Agricultural University, 169p.

Ghebreslassie, B. M. 2017. Effect of GA_3, waxing and micro perforated bags on shelf life and selected quality attributes of papaya fruit. *J. Postharvest Technol.* 5(4): 10-24.

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.

Goulao, L. F. and Oliveira, C. M. 2008. Cell wall modifications during fruit ripening: when a fruit is not the fruit. *Trends Food Sci. Technol*. 19: 4–25.

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: 108843p.

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.

Han, T., Wang, Y., Li, L., and Ge, X. 2002. August. Effect of exogenous salicylic acid on post harvest physiology of peaches. In *XXVI Int. Hortic. Cong. Issues Adv. Postharvest Hortic.* 22-25 May. 2002, Italy 628: 583-589.

Hazarika, T. K., Sangma, B. D., Mandal, D., Nautiyal, B. P., and Shukla, A. C. 2016. Effect of plant growth regulators on growth, yield and quality of tissue cultured papaya (*Carica papaya* L.) cv. Red Lady. *Indian J. Agric. Sci.* 86(3): 404-408.

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

Hodges, D. M. 2003. *Postharvest oxidative stress in horticultural crops*. CRC Press, New York, 238p.

Hong, K., Gong, D., Xu, H., Wang, S., Jia, Z., Chen, J., and Zhang, L. 2014. Effects of salicylic acid and nitric oxide pretreatment on the expression of genes involved in the ethylene signalling pathway and the quality of postharvest mango fruit. *N. Z. J. Crop Hortic. Sci.* 42(3): 205-216.

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, 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 sinenisis* L. Osbeck). *J. Sci. Food Agric*. 88(2): 229-236.

Hussain, P. R., Dar, M. A., Meena, R.S., Mir, M.A., shafi, F. and Wani, A.M. (2008). Changes in quality of apple (malus domestica) cultivars due to gamma irradiation and storage conditions. *J. Food Sci. Technol*. 45: 444-449.

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

Jashvantlal, B. P. 2012. Effect of ripening retardants and storage conditons of shelf life of papaya (*Carica papaya* L.) cv. Taiwan Red Lady. M. Sc. (Hort.) thesis, ASPEE College of Horticulture and Forestry Navsari Agricultural University, 214p.

Jawandha S. K., Gupta N., and Randhawa, S. 2012 Effect of post-harvest treatments on enzyme activity and quality of cold stored Ber fruit. *Sci. Biol.* 4: 86-89.

Jayasheela, D. S., Sreekala, G. S., Meenakumari, K. S., and Subba, A. 2015. Effect of different sanitising agents on reducing the post harvest loss in papaya (*Carica papaya* L.) variety Coorg Honeydew for local market. *Int. J. Trop. Agric.* 33(2): 405-408.

Kader, A. A. 2013. Postharvest technology of horticultural crops-An overview from farm to fork. *Ethiop. J. Appl. Sci. Technol*. 1: 1-8.

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.

Karaca, H. and Velioglu, Y. S. 2007. Ozone applications in fruit and vegetable processing. *Food Rev. Int.* 23(1): 91-106.

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.

Kechinski, C. P., Montero, C. R. S., Norena, C. P. Z., Tessaro, I. C., Marczak, L. D. F., and Bender, R. J. 2012. Effects of ozone in combination with hydrothermal treatment and wax on physical and chemical properties of papayas. *Ozone: Sci. Eng.* 34(1); 57-63.

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.

Khader, S. E. S. A., Singh, B. P., and Khan, S. A. 2002. Effect of GA_3 as a post-harvest treatment of mango fruit on ripening, amylase and peroxidase activity and quality during storage. *Sci. Hortic.* 36(3-4): 261-266.

Khandaker, M. M., Hossain, A. S., Osman, N., Mat, N., and Boyce, A. N. 2015. Growth, yield and postharvest quality of wax apple as affected by Naphthalene Acetic Acid application. *Mag. Brasileri de Fruticultura* 37(2): 410-422.

Khandaker, M. M., Boyce, N. A., Osman, N., and Hossain, S. A. B. M. 2012. Physiochemical and phytochemical properties of wax apple (*Syzygium samarangense* [Blume] Merrill & LM Perry var. Jambu Madu) as affected by growth regulator application. *Sci. World J.* 12(1): 201-215.

Koraddi, V. V. and Devendrappa, S. 2011. Analysis of physiological loss of weight of vegetables under refrigerated conditions. *Int. J. Farm Sci.* 1(1): 61-68.

Kumar, S. and Bhatnagar, T. 2014. Studies to enhance the shelf life of fruits using Aloe vera based herbal coatings: A Rev. *Int. J. Agric. Food Sci. Technol.* 5(3): 211-218.

Kumar, A., Singh, O., and Kohli, K. 2017. Post-harvest changes in functional and sensory properties of guava (*Psidium guajava* L. cv. Pant Prabhat) fruits as influenced by different edible coating treatments. *J. Pharmacognosy Phytochemistry* 6(6): 1109-1116.

Lanka, B. S., Jayathunge, K. G. L. R., Prasad, H. U. K. C., Fernando, M. D., and Palipane, K. B. 2011. Prolonging the postharvest life of papaya using modified atmosphere packaging. *J. Agric. Technol.* 7(2): 507-518.

Lata, D. 2017. Minimizing fruit decay in papaya *(Carica papaya* L.*)* through postharvest treatments. M. Sc. (Hort.) thesis, BAU, Sabour, 92p.

Lata, D., Aftab, M. A., Homa, F., Ahmad, M. S., and Siddiqui, M. W. 2018. Effect of eco-safe compounds on postharvest quality preservation of papaya (*Carica papaya* L.). *Acta Physiol. Plant* 40(1): 8p.

Li, X., Zhu, X., Zhao, N., Fu, D., Li, J., Chen, W., and Chen, W. 2013. Effects of hot water treatment on anthracnose disease in papaya fruit and its possible mechanism. *Postharvest Biol. Technol*. 86: 437-446.

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

Lokesh, Y. and Varu, D. K. 2013. Effect of pre harvest spray and post harvest dipping of fruit on shelf life and quality of papaya. *Asian J. Hortic*. 8(2): 581-587.

Lu, X., Sun, D., Li, Y., Shi, W., and Sun, G. 2011. Pre and post- harvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit. *Sci. Hortic*. 130: 97-101.

Lurie, S. 1998. Postharvest heat treatments. *Postharvest Biol. Technol.* 14(3): 257-269.

Mahajan, B. V. C., Dhatt, A. S., and Sandhu, K. S. 2005. Effect of different post-harvest treatments on the storage life of Kinnow. *J. Food Sci. Technol.* 42(4): 296-299.

Maharaj, R. and Sankat, C. K. 1990. Storability of papayas under refrigerated and controlled atmosphere. *Acta Hortic*. 269: 375-386.

Mandal, D., Lalrindika, E., Hazarika, T. K., and Nautiyal, B. P. 2016. Post-harvest 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., Thamawizuali, Z. R., Hazarika, T. K., and Shukla, A. C. 2017. Effect of salicylic acid as papaya post-harvest treatment in ambient condition. *Environ. Ecol.* 35(4c): 3149-3153.

Manganaris, G. A., Vasilakakis, M., Diamantidis, G., and Mignani, I. 2007. The effect of postharvest calcium application on tissue calcium concentration, quality attributes, incidence of flesh browning and cell wall physicochemical aspects of peach fruits. *Food Chem.* 100(4): 1385-1392.

Manivannan, K. and Rajkumar, M. 2005. Effect of chemicals and growth regulator on storage behavior of papaya (*Carica papaya* cv. CO 2). In proceedings I *Int. Symp. Papaya*, 22-24 November. 2005, Malaysia 740: 327-331.

Maqbool, M., Ali, A., Alderson, P. G., Mohamed, M. T. M., Siddiqui, Y., and Zahid, N. 2011. Post-harvest application of gum arabic and essential oils for controlling anthracnose and quality of banana and papaya during cold storage. *Postharvest Biol. Technol*. 62: 71–76.

Marpudi, S. L., Abirami, L. S. S., and Srividya, N. 2011. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera* based antimicrobial coating. *Indian J. Biotechnol.* 10: 83-89.

Martinez-Romero, D., Castillo, S., Guillen, F., Diaz-Mula, H. M., Zapata, P. J., Valero, D., and Serrano, M. 2013. *Aloe vera* gel coating maintains quality and safety of ready-to-eat pomegranate arils. *Postharvest Biol. Technol*. 86: 107-112.

Martins, D. M. S., Blum, L. E. B., Sena, M. C., Dutra, J. B., Freitas, L. F., Lopes, L. F., Yamanishi, O. K., and Dianese, A. C. 2004. September. Effect of hot water treatment on the control of papaya (*Carica papaya* L.) post harvest diseases. In *III Int. Symp. Tropic. Subtropical Fruits*, 23-26 September. 2004, Brazil 864: 181-185.

Martins, D. M. S., Blum, L. E. B., Sena, M. C., Dutra, J. B., Freitas, L. F., Lopes, L. F., Yamanishi, O. K., and Dianese, A. C. 2010. Effect of hot water treatment on the control of papaya (*Carica papaya* L.) post harvest diseases. *Acta Hortic*. 864: 181-185.

Masalkar, S. D. and Garande, V. K. 2005. Effect of post-harvest treatments and packaging materials on shelf life and quality of custard apple fruits. *Acta Hortic*. 682 (2): 1037-1040.

Mendy, T. K., Misran, A., Mahmud, T. M. M., and Ismail, S. I. 2019. Application of *Aloe vera* coating delays ripening and extend the shelf life of papaya fruit. *Sci. Hortic*. 246: 769-776.

Misir, J., Brishti, H. F., and Hoque, M. M. 2014. *Aloe vera* gel as a novel edible coating for fresh fruits: A Rev. *Am. J. Food Sci. Tech*. 2(3): 93-97.

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.

Mohamed, S. A., Awad, M. A., and Al-Qurashi, A. D. 2014. Antioxidant activity, antioxidant compounds, antioxidant and hydrolytic enzymes activities of 'Barhee'dates at harvest and during storage as affected by pre-harvest spray of some growth regulators. *Sci. Hortic.* 167: 91-99.

Molamohammadi, H., Pakkish, Z., Akhavan, H. R., and Saffari, V. R. 2020. Effect of salicylic acid incorporated chitosan coating on shelf life extension of fresh in-hull pistachio fruit. *Food Bioprocess Technol.* 13(1): 121-131.

Montanaro, G., Dichio, B., Xiloyannis, C., and Celano, G. 2006, Light influences transpiration and calcium accumulation in fruit of Kiwifruit plants (*Actinidia deliciosa* var. *deliciosa*). *Plant Sci.* 170: 520-527.

Moreno, J. J., Cerpa-Calderon, F., Cohen, S. D., Fang, Y., Qian, M., and Kennedy, J. A. 2008. Effect of postharvest dehydration on the composition of pinot noir grapes (*Vitis vinifera* L.) and wine. *Food Chem.*109(4): 755-762.

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.

NHB [National Horticultural Board]. 2012. Indian Horticultural Board [online]. Available:http://nhb.go.in.area-pro/database-2013.pdf. [17 May 2013].

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

Ong, K. C., Cash, J. N., Zabik, M. J., Siddiq, M., and Jones, A. L. 1996. Chlorine and ozone washes for pesticide removal from apples. *Food Chem.* 55(2): 153-160.

Ong, M. K., Kazi, F. K., Forney, C. F., and Ali, A. 2013. Effect of gaseous ozone on papaya anthracnose. *Food Bioprocess Technol.* 6(11): 2996-3005.

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.

Othman, Z. 2008. Effect of post harvest coatings and heat treatment on quality of stored pineapple fruits. Ph. D. thesis, *Univ. Putra*, Malaysia, 309p.

Ovando-Martinez, M., Lopez-Teros, M.V., Tortoledo-Ortiz, O., Astiazarán-García, H., Ayala-Zavala, J. F., Villegas-Ochoa, M. A., and González-Aguilar, G. A. 2018. Effect of ripening on physico-chemical properties and bioactive compounds in papaya pulp, skin and seeds. *Indian J. Nat. Prod. Resour.* 9(1): 47-59.

Pandiselvam, R., Subhashini, S., Banuu Priya, E. P., Kothakota, A., Ramesh, S.V., and Shahir, S. 2019. Ozone based food preservation: A promising green technology for enhanced food safety. *Ozone: Sci. Eng.* 41(1): 17-34.

Parker, T. L., Esgro, S. T., Miller, S. A., Myers, L. E., Meister, R. A., Toshkov, S. A., and Engeseth, N. J. 2010. Development of optimized papaya pulp nectar using a combination of irradiation and mild heat. *Food Chem*. 118(3): 861-869.

Parven, A., Sarker, M. R., Megharaj, M., and Meftaul, I. M. 2020. Prolonging the shelf life of Papaya (*Carica papaya* L.) using *Aloe vera* gel at ambient temperature. *Sci. Hortic.* 265: 109-228.

Patel, N., Naik, A. G., and Arbat, S. S. 2011. Response of post-harvest chemical treatments on shelf-life and quality of custard apple cv. Balanagar. *Indian J. Hortic.* 68(4): 547-550.

Patel, P. S., Kumar, V. B. S., Kumar, N. K., Chandrappa, P., and Lingaraj, B. 2019. Eco-friendly post-harvest management of papaya black spot disease caused by *Asperisporium caricae*. *Int. J. Chemical Stud.* 7(5): 68-71.

Paull, R. E. and Chen, N. J. 2011. December. Recent advances in postharvest management of papaya. In *Int. Symp. Tropic. Subtropical Fruits* 1024: 321-327.

Pila, N., Neeta, B. Gol., and Rao, T. V. 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.

Premalata, 2009. Post Harvest Management in Papaya *(Carica papaya L.*) Cv. Taiwan Red Lady. M. Sc. (Hort.) thesis, ASPEE College of Horticulture and Forestry Gujarat Agricultural University, Navsari, 164p.

Priyanka, B.S., Rastogi, N.K., and Tiwari, B.K. 2014. Opportunities and challenges in the application of ozone in food processing. In: *Emerging technologies for food processing*. Academic Press. pp.335-358.

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.

Rai, K. M., 2014. Studies on integrated nutrient management in mango (*Mangifera indica* L.) cv. Dashehari. Ph.D thesis, GB Pant University of Agriculture and Technology, Pantnagar, Uttarkhand, 164p.

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. CO2). *Acta Hortic.* 740: 327-331.

Ram, H. 2017. Effect of plant growth regulators on growth, yield and quality of papaya *(Carica papaya l.) cv.* Red Lady under net house M. Sc. (Hort.) thesis, Indira Gandhi Krishi Vishwavidhyalaya, Raipur, 156p.

Ramakrishna, M., Haribabu, K., and Purushotham, K. 2002. Effect of post-harvest application of growth regulators on storage behaviour of papaya (*Carica papaya* L.) cv.'Co-2'. *J. Food Sci. Technol.* 39(6): 657-659.

Ramesh, D., Kumar, B. P., Rajasekhar, M., and Suneetha, D. S. 2014. Effect of chemicals and growth regulators on post-harvest shelf-life and quality in papaya (*Carica papaya* L.) cv. Red Lady. *J. Hortic. Sci.* 9(1): 66-73.

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

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

Rao, Y. S. 2004. Biochemical studies on post harvest treatments and packing materials at different storage temperatures in papaya *(Carica papaya L.)* cv. Red Lady. M.Sc. (Hort.) thesis, Acharya N. G. Ranga Agricultural University, Hyderabad 122p.

Ramos, A. P., Zanardi, A. M., Amarante, C. V. T. D., Steffens, C. A., and Pereira-Netto, A. B. 2019. Effects of an Auxin and a brassinosteroid on physical, chemical and biochemical attributes of ‘Galaxy’ apples. *Ciencia Rural* 49(4): 73-85.

Reddy, P. V. K. and Gowda, V. N. 2014. Influence of greenhouse cultivation on fruit quality of ‘Red Lady’ papaya. *Acta Hortic.*1024**:** 109-114.

Renhua, H., Renxue, X., Yunnel, L., Liming, H., and Yongjie, X. 2008. Effect of pre-harvest salicylic acid spray treatment on postharvest antioxidant in the pulp and peel of Cara navel orange (*Citrus sinensis* L. Osbeck*). J. Sci. Food Agric*. 88: 229-236.

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

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.

Santos, C. E. M. D., Couto, F. A., Salomao, L.C.C., Cecon, P. R., Wagner Junior, A., and Bruckner, C. H. 2008. Comportamento pos-colheita de mamoes Formosa'Tainung 01'acondicionados em diferentes embalagens para o transporte. *Mag. Brasileri de Fruticultura* 30(2): 315-321.

Sarikhani, H., Sasani-Homa, R., and Bakhshi, D. 2010. Effect of salicylic acid and SO_2 generator pad on storage life and phenolic contents of grape (*Vitis vinifera* L. 'Bidaneh Sefid' and 'Bidaneh Ghermez'). *Acta Hortic.* 877: 623–1630.

Saxsena, P., Singh, V. K., and Neelam, P. 2014. Antioxidative enzymes and biochemical changes in paclobutrazole induced flowering in mango (*M. indica*) cultivars. *J. Environ. Biol*. 35: 1061-1066.

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.

Sayyari, M., Babalar, M., Kalantari, S., Martínez-Romero, D., Guillén, F., Serrano, M., and Valero, D. 2011. Vapour treatments with methyl salicylate or methyl jasmonate alleviated chilling injury and enhanced antioxidant potential during postharvest storage of pomegranates. *Food Chem.* 124(3): 964-970.

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.

Serrano, M., Valverde, J. M., Guillen, F., Castillo, S., Martínez-Romero, D., and Valero, D. 2006. Use of *Aloe vera* gel coating preserves the functional properties of table grapes. *J. Agric. Food chem.* 54(11): 3882-3886.

Shadmani, N., Ahmad, S. H., Saari, N., Ding, P., and Tajidin, N. E. 2015. Chilling injury incidence and antioxidant enzyme activities of *Carica papaya* L.'Frangi'as influenced by postharvest hot water treatment and storage temperature. *Postharvest Biol. Technol.* 99: 114-119.

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.

Shahia, M., Rastegarb, S., and Khankahdanic, H. H. 2015. Effects of essential oil and calcium chloride on quantitative and qualitative features of ber (*Ziziphus mauritiana* L.) during storage. *Postharvest Biol. Technol*. 34(2): 923-932.

Sharma, K. 2017. Effect of different post-harvest treatments on quality and shelf life of papaya. *J. Pharmacognosy Phytochemistry* 6(5): 1788-1792.

Sharma, S. K. and Zote, K. K. 2010. Effect of adoption of papaya ring spot virus management technology on economic of papaya cultivation. *Indian J. Hortic.* 67: 456-462.

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

Shamrez, A., Shukla, R. N., and Mishra, A. 2013. Study on drying and quality characteristics of tray and microwave dries guava slices. *Int. J. Sci. Eng. Technol*. 3(4): 2348-4098.

Sharmin, M. R., Islam, M. N., and Alim, M. A. 2015. Shelf-life enhancement of papaya with aloe vera gel coating at ambient temperature. *J. Bangladesh Agric. Univ*. 13(1): 131-136.

Shetty, M. J .2017. Postharvest handling studies for extending shelf life of rambutan (*Nephelium lappaceum* L.). MSc (Hort.) thesis, Kerala Agricultural University, Thrissur, 170p.

Shipra, B., Shubhranshu, S., and Bikash, D. 2016. Effect of GA_3 and carbendazim as pre-harvest and salicylic acid and 1-MCP as post-harvest treatment on storage and post-harvest life of mango cv Amrapali. *Environ. Ecol.* 34(2): 683-685.

Shivendra, K. and Singh, R. P. 2015. Salicylic acid delayed ripening of mango fruits during storage in wooden crates. *Green Farming* 6(2): 396-399.

Sihag, R. P., Beniwal, L. S., and Mehta, P. K. 2005. Effect of post harvest application of potassium permanganate on shelf life of peach fruits. *Haryana J Hortic. Sci.* 34(3/4): 259.

Silva Neto, O. P. D., Pinto, E. V. D. S., Ootani, M. A., Silva Junior, J. L. D., Lima, J. L. D. S. B., and Sousa, A. E. D. D. 2019. Ozone slows down anthracnose and increases shelf life of papaya fruits. *Mag. Brasileri de Fruticultura* 41(5): 45-67.

Singh, A., and Singh, H. K. 2015. Application of plant growth regulators to improve fruit yield and quality in Indian gooseberry (*Emblica officinalis* Gaertn.). *J. AgriSearch* 2(1): 123-131.

Singh, S. P. and Rao, D. S., 2005. Effect of modified atmosphere packaging (MAP) on the alleviation of chilling injury and dietary antioxidants levels in 'Solo'papaya during low temperature storage. *European J. Hortic. Sci.* 70(5): 246-252.

Singh, S., Singh, A. K., Joshi, H. K., Bagle, B. G., and Dhandar, D. G. 2008. Storability of ber (*Zizyphus mauritiana* Lamk) fruit in semi arid environment. *J. Food Sci. Technol*. 45: 65–69.

Singh, P., Kumar, S., and Maji, S. 2012. Effect of ethrel on postharvest changes in papaya (*Carica papaya* L.) fruits. *Hortic. Flora Res. Spect* 1: 225—230.

Singh, P., Kumar, S., Maji, S., Kumar, A., and Yadav, Y. C. 2012. Effect of calcium chloride on post harvest changes in papaya fruits. *Asian J. Hortic*. (1): 113-117.

Singh, G., Bakshi, M., and Kaur, M. 2019. Post-harvest treatment for improvement of shelf life in guava (*Pisidium guajava*. L) cultivar 'Allahabad Safeda' under ambient storage condition. *Plant Arch.* 19(2): 3005-3010.

Singh, H., Jawandha, S. K., and Arora, A. 2019. Ripening behaviour of papaya at different temperature regimes. *Indian J. Hortic.* 76(1): 195-197.

Singh, J., Prasad, N., and Singh, S. K. 2018. Postharvest application of Boric Acid and NAA in guava to improve shelf-life and maintain quality under cold storage. *Adv. Biores.* 9(1): 451-454.

Skog, C. L. and Chu, L. J. 2001. Effect of ozone on qualities of fruits and vegetables in cold storage. *Can. J. Plant Sci.* 81(4): 773-778.

Srinu, B., Rao, M. A., Joshi, V. K., Reddy, N. S., and Sharma, H. K. 2017. Effect of different post harvest treatments on quality and shelf life of papaya. *J. Pharmacognosy Phytochemistry* 6(5): 1788-1792.

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

Sultana, M. S., Islam, M. Z., Shamim, A. H. M., and Mondal, M. F. 2012. Effect of growth regulators on physical changes and shelf life of banana during storage. *Int. J. Sustain. Crop Prod*. 7(3): 31-35.

Supapvanich, S. 2015. Effects of salicylic acid incorporated with lukewarm water dips on the quality and bioactive compounds of rambutan fruit (*Nephelium lappaceum* L.). *CMU J. Nat. Sci.* 14(1): 23-27.

Supapvanich, S., Pimsaga, J., and Srisujan, P. 2011. Physicochemical changes in fresh-cut wax apple (*Syzygium samarangenese* [Blume] Merrill & L.M. Perry) during storage. *Food Chem.*127: 912–917.

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

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.

Swati, G. and Bisen, B. P. 2012. Effect of different coating material on the storage behavior of custard apple (*Annona squamosa* L.). *Int. J. Life Sci.* 7(4): 637-640.

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.

Tehrani, M., Chandran, S., Hossain, A. B. M. S., and Boyce, A. N. 2011. Postharvest physico-chemical and mechanical changes in jambu air (*Syzygium aqueum* Alston) Fruits. *Aust. J. Crop Sci.*5: 32-38.

Terao, D., de Nechet, L, K., Frighetto, R. T. S., and Sasaki, F. F. C. 2019. Ozonated water combined with heat treatment to control the stem-end rot of papaya. *Sci. Hortic.* 257: 722p.

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

Vanaei, M., Sedaghat, N., Abbaspour, H., Kaviani, M., and Azarbad, H. R. 2014. Novel edible coating based on *Aloe Vera* Gel to maintain pistachio quality. *Int. J. Sci. Eng. Technol*. 3(8): 1016-1019.

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 caid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. *J. Agric. Food Chem*. 59(10): 5483-5489.

Wang, L., Chen, S., Kang, W, Li S, Aschbold DD. 2006. Salicylic acid pre-treatments alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. *Postharvest Biol. Technol*. 41: 244-251.

Wei, Y., Liu, Z., Su, Y., Liu, D., and Ye, X. 2011. Effect of salicylic acid treatment on postharvest quality, antioxidant activities, and free polyamines of asparagus. *J. Food Sci*. 76 (2): 126–S132.

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

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.

Yadav, L., Varu, D. K., Patel, V. K., Mor, V. B., and Ganvit, S. 2016. Study of pre and post harvest treatment on post harvest quality of Papaya. *Eco. Env. Cons*. 22: 517-522.

Yadav, S. J., Bhatia, S. K., Godara, R. K., and Rana, G. S. 2001. Effect of growth regulators on the yield and quality of winter season guava cv. L-49. *Haryana J. Hortic. Sci*. 30: 1–2.

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: 253–262.

Zaman, W., Biswas, S. K., Helali, M. O. H., Ibrahim, M., and Hassan, P. 2006. Physicochemical composition of four papaya varieties grown at Rajshahi. *J. Bio-Sci.* 14: 83-86.

Zeng, K. and Weibo, J. 2008. Effects of salicylic caid applied at growing stage on mango fruit quality and disease. *Acta Bot. Sin*. 35(3): 427-432.

Zeng, K. F., Cao, J. K., and Jiang, W. B. 2006. Enhancing disease resistance in harvested mango (*Mangifera indica* L. cv. 'Matisu') fruit by salicylic acid. *J. Sci. Food Agric.* 86: 694–698.

Zhao, N., Li, X., Chen, W., and Shi, J. 2013. Effect of hot water treatment on the inhibition of anthracnose, PG, PME activity and PGIP gene expression in harvested papaya fruits. *Acta Hortic.* 975: 487-493.

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

Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Score card for papaya skin colour

Title: Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady

Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Skin colour							

Score:

0: Green skin without yellow stripe

1: Green skin with light yellow stripe

2: Green skin with well-defined yellow stripe

3: One or more orange-coloured stripes in skin

4: Clearly orange-coloured skin with some light green areas

5: Characteristic orange-coloured skin of papaya

6: Fruit colour similar to stage 5, but more intense

Date   Name:

Signature:

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Score card for sensory evaluation of ripe Red Lady papaya fruits

Sample: Papaya cv. Red Lady

Instructions : You are given 7 samples of ripe papaya fuits. Evaluate them and give scores for each criterion

Criteria	Samples						
	1	2	3	4	5	6	7
Appearance							
Flavour							
Texture							
Taste							
Flesh colour							
Overall acceptability							
Any other remarks							

<u>Score:</u>

Like extremely -9

Like very much -8

Like moderately -7

Like slightly -6

Neither like or dislike -5

Dislike slightly -4

Dislike moderately -3

Dislike very much -2

Dislike extremely -1

Date Name:

Signature:

POSTHARVEST QUALITY MANAGEMENT OF PAPAYA (*Carica papaya* L.) CV. RED LADY

by

MENAKA M.

(2018-12-026)

ABSTRACT

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2020

ABSTRACT

The present study entitled "Postharvest quality management of papaya (*Carica papaya* L.) cv. Red Lady" was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellayani, Thiruvananthapuram during the year 2018-2020. The objective of the experiment was to standardize postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss through postharvest handling practices.

Papaya fruits (cv. Red Lady) of uniform size, shape and maturity at colour break stage were procured from the field of progressive farmers of Farmer Producer Organisation, at Pallichal, Thiruvananthapuram. Harvested fruits were sanitized (ozonisaton 2 ppm) and subjected to hot water treatment (50^0C for 20 minutes) followed by postharvest dipping of fruits for 5 minutes using different treatments *viz.*, Naphthalene Acetic Acid (NAA 250 ppm), Edible coating (Papaya Leaf Extract Aloe Gel), Gibberellic Acid (GA_3 100 ppm), Calcium chloride ($CaCl_2$ 2%), Salicylic Acid (SA 2 mM), hot water treatment alone and fruits without any postharvest treatment as absolute control. Treated fruits, after removal of surface moisture, were stored in corrugated fibre board boxes at room temperature (30±2 ºC, RH 80-85%) till the end of shelf life.

Superiority of postharvest treatments on papaya cv. Red Lady was assessed based on physiological, biochemical, physical, and sensory attributes during storage at an interval of 3 days. Papaya fruits treated with Salicylic Acid (2 mM) recorded the lowest percentage of physiological loss in weight (6.55%), and respiration rate (74.99 mL CO_2 kg^{-1} h^{-1}) after 9th day of storage where as fruits without any postharvest treatment recorded a weight loss of 16.65% with a respiration rate of 101.92 mL CO_2 kg^{-1} h^{-1}. Fruits with salicylic acid treatment recorded 8.72% total sugars, 6.39% reducing sugars, 7.66 ˚Brix of total soluble solids with a carotenoid content of 2.09 mg $100g^{-1}$, and antioxidant activity of 48.35% after 9 days of storage which increased with the storage period and the values were significantly lower than the untreated fruits indicating the delayed ripening of treated fruits. Red Lady papaya fruits without any postharvest treatment (control) recorded the lowest storage life of 7.38 days due

to high rate of physiological, biochemical and physical changes which indicated faster ripening and senescence.

The treatment of fruits with salicylic acid (SA) recorded the lowest respiration rate of 95.63 mL CO_2 kg^{-1} h^{-1} and physiological loss in weight (13.10%) after 14 days of storage at room temperature with the highest fruit firmness (19.89 N) and 8.26% reducing sugar, 12.73% total sugar, 11.52 ˚Brix of total soluble solids, 0.14% titratable acidity, 2.55 mg $100g^{-1}$ of carotenoid content, and 64.53% of antioxidant activity. The salicylic acid treatment recorded the highest shelf life of 14.56 days with acceptable sensory parameters where as fruits without any treatment (control) recorded a shelf life of 7.38 days.

Papaya fruits cv. Red Lady, harvested at colour break stage were sanitized using ozonation (2 ppm) and subjected to hot water treatment (50 ˚C for 20 minutes) followed by dipping for 5 minutes in postharvest treatment with salicylic acid at 2 mM was standardised as the best postharvest treatment for delayed ripening which recorded the longest shelf life of 14.56 days at room temperature as compared to 7.38 days for fruits without any postharvest treatment.

kw{Klw

shÅm-bWn ImÀjnItImtf-Pnse hnf-sh-Sp-¸m-\-´c kmt¦-Xn-I-hnZym hn`m-K-¯nÂ 2018- – 2020 Ime-b-f-hnÂ ‘]¸mb (*carica papaya* L) C\-amb sdUvte-Un-bpsS hnf-sh-Sp-¸m-\-´c KpW-\n-e-hmc \nb-{´W amÀ¤-§Ä’]T-\-hn-t[-b-am-¡n. sdUvte-Un]¸mbpsS hnf-sh-Sp-¸n\pti-j-apÅ]cn-N-c-W-¯n-eqsS]g-§-fpsS KpW-\n-e-hmcw \ne-\nÀ¯n-s¡m-v]gp-¯p-In-«p-hm-\pÅ Ime-ssZÀLyhpw kq£n-¸p-Im-ehpw Iq«p-¶-Xn-\pÅ amÀ¤-§Ä {IaoIcn¡pI F¶-Xm-bn-cp¶p Kth-j-W-]-T-\-¯nsâ e£yw.

Xncph\´]pcs¯]Ån¨ense IÀjI DÂ]mZIkwLS\bnse AwK§fmb]ptcm-K-a\ IÀj-I-cpsS sdUvte-Un]¸mb tXm«-§-fnÂ \n¶pw Htc aq¸n-epÅXpw (\ndwamdp¶ L«w) Htc BIr-Xnbpw hen-¸hpÅ]¸mb]g§fmWv]T-\-¯n-\mbn XncsªSp¯Xv. hnf-sh-Sp¯]¸mb]g-§Ä ipNn-Xz-hÂ¡-cn-¨-tijw (HmtkmssW-tk-j³. 2]n]nFw) NqSp-shÅ]cn-N-c-W-¯n\v hnt[-b-am-¡n (50°c, 20 an\näv t\c-t¯¡v ap¡n h¨p). C¯-c-¯nÂ]cn-N-cn¨]¸mb (sdUvteUn)]g-§sf 5 an\näv ka-b-t¯¡v hnhn[ ]cn-N-cW emb-\n-I-fnÂ ap¡nsh¨p.]cn-N-cW eb-\n-I-Ä \m^v¯-eo³ Ak-änIv BknUv (NAA – 250 ppm). `£y-tbmKy Bh-cWw (]-¸mb Ce-k¯vþIämÀhm-g-sPÂ) Pn{_-enIv BknUv (G_{A3}- 100 ppm), ImÂkyw t¢mssdUv ($CaCl_2$ 2%), kmen-kn-enIv BknUv (SAA -2 mM) F¶n-hbpw NqSp-shÅ]cn-N-cWw am{Xw \S-¯nb]g-§fpw tIh-e-\n-b-{´-W-¯n-\mbn bmsXmcp]cn-N-c-W-ap-d-IÄ IqSm-sX-bpÅ]g-§fpw D]-tbm-Kn-¨p.]cn-N-cn¨]g-§Ä CuÀ¸w \o¡w sNbvX-tijw km[m-cW Xm]-\n-e-bnÂ (30±2°c, BÀ{ZX 80 apXÂ 85%) kq£n-¸p-Imew Ah-km-\n-¡p-¶-Xp-hsc tImdp-tK-äUv ss^_À t_mÀUv t_mIvkp-I-fnÂ kq£n-¨p.

]¸mb (sd-Uvte-Un) -bnÂ \S-¯n-b- hn-hn[hnfshSp-¸m-\-´c {]{In-b-I-fpsS ^e-{]m]vXn hne-bn-cp-¯p-hm³ ^nkn-tbm-f-Pn-¡Â, _tbm-sI-an-¡Â, ^nkn-¡Â, -sk³kdn F¶o KpW-§Ä aq¶v Znhk CS-th-f-I-fnÂ hni-I-e\w sNbvXp. H³]Xp Znh-ks¯ kw`-c-W-¯n-\p-tijw 2 mM kmen-kn-enIv BknUv D]-tbm-Kn¨ ]¸mb ]g-§Ä Gähpw Ipdhv `mc-\-jvShpw (6.55%) izk-\-\n-c¡pw (74.99 mL CO_2 Kg^{-1} h^{-1}) tcJs¸-Sp-¯nbt¸mÄ bmsXmcp hnf-sh-Sp-¸m-\-´c]cn-N-c-W-ap-dbpw A\p-hÀ¯n-¡m¯]¸mb]g-§Ä (16.65%) `mc-\-jvShpw (101.92 mL $CO_2$ $Kg^{-1}$ $h^{-1}$) izk-\-\n-c¡pw tcJs¸-Sp-¯n. kmen-kn-enIv BknUv D]-tbm-Kn¨v ]cn-N-cn¨ ]g-§Ä 8.72% tSm«Â jpKÀ, 6.39% sdUyq-knwKv jpKÀ, 7.66 Un{Kn {_nIvkv tSm«Â tkmeyp_nÄ tkmfn-Up-Ifpw 2.09mg $100g^{-1}$ Itcm-«n-t\m-bn-Sp-Ifpw 48.35% \ntcmIvkoIc-W-ti-jnbpw 9 Znh-ks¯ kw`-c-W-¯n\v tijw tcJ-s¸-Sp-¯p-Ibpw Ch kw`-c-W-Im-em-h[n IqSp-¶-X-\p-k-cn¨v hÀ²n-¨p-h-cp-¶-Xmbpw ImW-s¸-«p. ^nkn-tbm-f-Pn-¡Â, _tbm-sI-an-¡Â, ^nkn-¡Â hyXn-bm-\-§Ä kmen-kn-enIv BknUv

]cn-N-cW¯neqsS B¡w Ipd-¡p-¶-Xn\v klm-b-I-am-Ip-¶p-sh¶pw AXp hgn]¸m-b-bpsS]gp¡p¶Xnsâ Ime-b-fhv Iq«p-¶-Xn\pw kqjn-¸p-Imew IqSp-¶-Xmbpw kqNn-¸n-¡p-¶p DbÀ¶-tXm-Xn-epÅ C¯-c-¯n-epÅ PohÂ{]-hÀ¯-\-§fpw amä-§fpw]¸mb hfsc thK-¯nÂ]gp-¡p-¶-Xn\pw Noªp-t]m-Ip-¶-Xn\pw Imc-W-am-b-Xn-\mÂ]cn-N-c-W-ap-d-IÄ H¶pw \S-¯m-Xn-cp¶ sdUvteUn]¸mb]g-§Ä (tI-h-e-\n-b-{´-Ww) Gähpw Ipdª kqjn-¸p-Im-e-amWv (7.38 Znh-k-§Ä) tcJ-s¸-Sp-¯n-bXv.

kmen-kn-enIv BknUv D]-tbm-Kn¨v]cn-N-cWw \S-¯nb]g-§Ä Gähpw Ipdhv izk-\-\n-c¡pw (95.63 mL CO_2 Kg^{-1} h^{-1}) `mc-\-jvShpw (13.10%) 14 Znh-ks¯ kw`-c-W-¯n-\p- ti-jhpw \ne-\nÀ¯p-hm\m-bn. Cu]g-§Ä¡v DbÀ¶ ZrU-Xbpw (19.89 N) , 8.26% sdUyq-knwKv jpKÀ, 12.73 % tSm«Â jpKÀ, 16.52% Un{Kn {_nIvkv tSm«Â tkmeyp_nÄ tkmfn-Uvkv, 0.14 % A¾-Xzw, 2.55mg 100^{-1} Itcm-«n-t\m-bnSv Af-hp-w 64.53% \ntcm-Ivko-I-c-W-ti-jnbpw tcJ--s¸-Sp-¯n. kmen-kn-en¡v BknUv]cn-N-c-W-hn-t[-b-amb]g-§Ä Xr]vXn-I-c-amb sk³kdn KpW-§fpw t]mj-I-Kp-W-§-tfmsSbpw 14.56 Znhkw tISp-Iq-SmsX kq£n-¡p-hm³ km[n-¡p-sa¶v ImW-s¸-«p. F¶mÂ tIh-e-\n-b-{´Ww am{X-apÅ]¸mb]g-§-fpsS kq£n-¸p-Imew 7.38 Znh-k-§Ä am{X-am-sW¶v tcJ-s¸-Sp-¯n.

\ndw amdp¶ L«-¯nÂ hnf-sh-Sp-¡p¶ sdUvteUn]¸mb]g-§Ä 2 ppm HmtkmtWj-\n-eqsS ipNn-Xz-hÂ¡-cn¨v 50^{o}C, Xm]\nbp-Å NqSp-sh-Å-¯nÂ 20 an\näv t\cw ap¡n-h-¨-tijw 2mM kmen-kn-enIv BknUv emb-\n-bnÂ 5 an\näv t\cwIqSn ap¡n-h¨v]cn-N-cn-¡p-¶-Xp-hgn]¸m-b-bpsS]gp-¡p-¶-Xn-\pÅ Ime-ssZÀLyw Iq«p-¶-Xn\pw KpW-§Ä \ne-\nÀ¯n-s¡m-v kq£n-¸p-Imew km[m-cW Xm]-\n-e-bnÂ 14.56 Znhk§Ä hsc hÀ²n-¸n-¡m-sa-¶p-apÅ hnf-sh-Sp-¸m-\-´c]cn-N-cWw Cu]T-\-¯n-eqsS {Iao-I-cn-¡p-hm³ km[n-¨p. F¶mÂ]-cn-N-cWapd-IÄ Ah-ew_n¡m¯ (tI-h-e-\n-b-{´Ww) sdUvteUn]¸mb]g-§Ä¡v km[m-cW Xm]-\n-e-bnÂ 7.38 Znh-k-§Ä am{Xw kq£n-¸p-Im-em-h[n DÅ-Xmbn]T-\-¯nÂ hyà-ambn.