

**Studies on effect of salicylic acid, putrescine and
modified atmospheric packaging of guava (*Psidium
guajava* L.) cultivar Hisar Safeda**

By

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**MASTER OF SCIENCE
IN
HORTICULTURE-FRUIT SCIENCE**



**COLLEGE OF AGRICULTURE
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2021

CERTIFICATE-I

This is to certify that this thesis entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda**” submitted for the degree of **Master of Science** in the subject of Horticulture (Fruit - Science) to the Chaudhary Charan Singh Haryana Agricultural University, Hisar is a bonafide research work carried out by **Mr. Gurpreet Singh**, Admission Number **2017A49M** under my supervision and that no part of the thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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LIST OF ABBREVIATIONS

%	:	Per cent
/	:	Per
@	:	at the rate of
°Brix	:	Degree brix
°C	:	Degree celsius
μM	:	Micromolar
CD	:	Critical difference
CFB	:	Corrugated fibre board
CRD	:	Completely randomized design
cv.	:	Cultivar
<i>et al.</i>	:	<i>et alia</i> (and others)
<i>etc</i>	:	<i>etcetra</i>
g	:	Gram
ha	:	Hectare
HDPE	:	High density polyethylene
<i>i.e.</i>	:	<i>id. est.</i> (that is)
kg	:	Kilogram
l	:	Litre
LDPE	:	Low density polyethylene
MAP	:	Modified atmospheric packaging
mg	:	Milligram
ml	:	Millilitre
mM	:	Millimolar
mm	:	Millimetre
MT	:	Metric ton
N	:	Normality
NS	:	Non-significant
PLW	:	Physiological loss in weight
ppm	:	Parts per million
RH	:	Relative humidity
SA	:	Salicylic acid
TA	:	Titratable acidity
TSS	:	Total soluble solids
<i>viz.</i>	:	<i>videlicet</i> (namely)

CHAPTER- I

INTRODUCTION

Guava (*Psidium guajava* L.) belongs to the family Myrtaceae which is native to tropical America. It was introduced in India by Portuguese in 17th century and cultivated since then. Despite being an introduced crop in India, great genetic diversity of guava is available in the Indo-gangetic plains (Rajan *et al.*, 2007). It is commonly known as ‘Apple of tropics’. Guava is highly remunerative fruit crop of North India due to its high adaptability to wide range of climate and soil conditions. Owing to its hardy nature, it grows well even under neglected condition of the country. In India, guava ranked 5th among the fruit crops following mango, banana, citrus and apple. It occupies an area of 276 thousand ha with an annual production of 4,253 thousand MT fruits (Anonymous, 2019a). The most important guava growing states in India are Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra. Haryana itself occupies the area of 12,595 ha and produces 2,47,449 MT with 21.34 MT/ha productivity (Anonymous, 2019b).

Fruit, botanically it is berry, round or oval in shape with rough to smooth green skin and many small, hard or semi hard seeds embedded in the centre of the pulp, contains high amount of vitamin A, B₁ (Thiamine), B₂ (Riboflavin) and ascorbic acid. The ascorbic acid content ranges from 75 to 260 mg/100g, which is 2-5 times more than any citrus fruit. Ascorbic acid and phenol content vary with colour and quantity of seed in the fruits. Red fleshed cultivars have less phenols and ascorbic acid content as compared to white-fleshed cultivars (Bashir and Abu-Goukh, 2003). Ascorbic acid found higher in seeded cultivars, whereas total phenols are higher in seedless cultivars (Lim *et al.*, 2007), whereas pulp and peel contain extractable polyphenols (2.62-7.79%) and high content of dietary fiber (48.55-49.42%) (Escrig *et al.*, 2001). The fruit is also a good source of pectin, calcium and phosphorus and their content varies with cultivar, season, location and stage of maturity, whereas pectin content ranges between 0.5% and 1.8% (Bose and Mitra, 2001). The flavor compounds may accumulate in different proportions during ripening depending on the cultivar and due to this fact, guava fruits present distinct aroma and taste. It is commended as “Super fruit” owing to its high nutritional and nutraceutical profile.

Guava, being a climacteric fruit is harvested at the physiologically mature stage and is allowed to ripen under ambient conditions. Guava has great commercial potential due to its delicious taste, aroma, sweet flavour and fine balance of acid, sugar and pectin. High concentration of pectin in guava fruit may play a significant role in the reduction of human body cholesterol and thereby decreases the risk of cardiovascular disease (Singh, 2005). The fruits of guava have several uses and can be eaten raw or can be processed into some products

like jam, jellies, juices etc. (Singh *et al.*, 2016). During fruit ripening many physiological and biochemical changes occur which encourage starch degradation and other polysaccharides to produce sugars, synthesis of pigments, volatile compounds and solubilization of cell walls (Jain *et al.*, 2003).

Although guava has wider adaptability and higher nutritional value, yet the trade at the world level is limited due to its short post-harvest life, susceptibility to chilling injury and delicate pulp and post-harvest rotting during cold storage (Rai *et al.*, 2010 and Mahajan *et al.*, 2009). It is highly prone to bruising and mechanical injuries and shelf-life ranges from 2-3 days at room temperature. So, it makes transportation and storage difficult (Bassetto *et al.*, 2005). Because of perishability, slow down of fruit ripening is fundamental, necessitating the development of new technologies to extend shelf-life, enter new markets and improve the marketing process. During the last decades, various viable technology for improving shelf-life and storage of fruits have been evolved. Besides available techniques, the post-harvest losses are still high. Guava undergoes rapid ripening and senescence even after few days under ambient conditions. Thus, rate of respiration and ethylene production inversely proportional to shelf-life of guava fruits (Killadi *et al.*, 2007). So, it necessitates its immediate consumption or marketing after harvest. Although India is 2nd largest producer of fruits in the world but per capita availability of fruits in India is still low. Post-harvest loss of fruits considered as the main reason for gap between the gross production and net availability. There is a need to develop safe and affordable post-harvest practices to increase its life and maintaining the quality.

Ripening and senescence reflect the deterioration of cellular structures and in particular the cell membranes, further leading to the loss of tissue structure and ultimately homeostatis due to events that occur during storage and post-harvest handling (Paliyath and Subramaniam, 2008). Most of the techniques meant for enhancing the post-harvest life of fruits aims at reducing the respiration rate and thereby the catabolism. Other approaches to achieve this goal may be disruption of ethylene production, application of antioxidants such as salicylic acid, n-propyl gallate and calcium supplementation as it maintains the membrane integrity.

Salicylic acid (SA), 2-hydroxybenzoic acid, $C_7H_6O_3$, is a simple phenolic compound which is frequently disseminated in plants, involved in regulating stress responses as well as many processes regarding plant growth and development (Asgharia and Aghdam, 2010). Salicylic acid also plays an important role in post-harvest decay resistance and delaying fruit ripening (Srivastava and Dwivedi, 2000). Hence, SA treatment is used to control fruit ripening during shelf-life as SA decreases ethylene production. The inhibition of ethylene production in fruit may be by decreasing both of amino cyclopropane-1-carboxylic acid synthase (ACS) and oxidase (ACO) production and activity during early stage of fruit

ripening (Zhang *et al.*, 2003). Brar *et al.* (2014) also reported that the salicylic acid has potential to maintain the post-harvest life of peach fruits.

Polyamines (PAs) are a group of natural compounds with a low molecular weight and an aliphatic nitrogen structure that are found in all living organisms and play critical roles in a variety of physiological processes including cell growth and development and stress response. The term polyamines collectively apply to spermidine (triamine), spermine (tetramine) and putrescine (diamine) are found in every plant cell (Galston and Sawhney, 1990). Putrescine is the first polyamine in the biosynthetic pathway followed by spermidine and spermine which is formed by successive addition of aminopropyl groups derived from decarboxylated S-adenosyl methionine (dSAM). The universal occurrence of putrescine, spermidine and spermine in plant organs suggests that they perform important functions in regulating plant growth. The exogenous application of PAs inhibits ethylene production in fresh climacteric produce (Serrano *et al.*, 2003). These molecules have been reported to slow down the ripening phenomenon, while maintaining the firmness of fruits during storage (Khan *et al.*, 2008). PAs have been shown to extend the post-harvest life of various types of fruit such as mangoes, apples, peaches and plums through their active participation in fruit ripening.

Packaging plays a vital role to prolong shelf-life of fruits by preventing moisture loss and also serve as attractant to the consumer. Among various packaging technique used in fruits, modified atmospheric packaging (MAP) using different films can be illustrated as one of the best and low cost technology to have a better shelf-life with proper quality fruits. Modified atmosphere (MA) refers to alter atmospheric composition around the fruit which delays senescence by altering the biochemical and physiological processes. A well-known benefit of MAP is to prevent high moisture loss by creating high humidity inside the packaging and with that the fruit maintains freshness comparatively for a longer duration. Modified atmospheric packaging is done with various types of packaging materials like low density polyethylene (LDPE), High density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC), Cellophane paper etc.

Hence, considering the above importance the present investigation entitled “Effect of salicylic acid, putrescine and modified atmospheric packaging on shelf-life of guava cv. Hisar Safeda” has been planned with the following objective:

1. To evaluate the effect of different chemicals on the shelf-life of guava cv. Hisar Safeda.
2. To evaluate the effect of different packaging films on the shelf-life of guava cv. Hisar Safeda.
3. To determine the optimum storage conditions for a better shelf-life of guava cv. Hisar Safeda.

CHAPTER- II

REVIEW OF LITERATURE

In the following chapter, an attempt has been made to review, update and collect literature on research topic and thereby provide an overview of the subject. The present investigation entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda**” was executed during the period 1st to 3rd week of December 2020. The relevant research work done on these aspects has been reviewed in this chapter under following headings:

2.1 Effect of different chemicals on the shelf-life of fruits:

Abd El-Aziz (2020) studied the effect of hydrocooling, salicylic acid and citric acid as post-harvest applications on guava (*Psidium guajava* L.) fruit during storage at 10°C and 90-95% RH for 28 days and observed lowest per cent physiological weight loss, decay, total sugars, soluble solid content, pectin methyl esterase activity and retarded fruit colour changes when fruits treated with hydro-cooling technique combined with dipping in salicylic acid at 4 mM. This treatment also maintained higher fruit firmness, acidity % and vitamin C content during storage and increased shelf-life of fruits over control.

Ennab *et al.* (2020) reported that post-harvest application of salicylic acid and putrescine had significantly reduced the weight loss and decay in ‘Murcott’ mandarin fruit. During storage, both materials were effective in preserving fruit firmness, total soluble solids (TSS), acidity, TSS: acid ratio and ascorbic acid. However, salicylic acid at 400 ppm was more effective to reduce weight loss and decay and to maintain fruit quality in comparison to putrescine treatments.

Haider *et al.* (2020) experimented on evaluation of effects of salicylic acid on post-harvest fruit quality of “Kinnow” mandarin under cold storage. Different concentrations of salicylic acid (4, 8 and 12 mM) were applied in the first year, while 2, 4 and 6 mM during the second year. The fruits were stored at $5 \pm 1^\circ\text{C}$ and $90 \pm 5\%$ RH for 90 days. Results revealed that maximum antioxidant activity, total phenolic contents, activities of peroxidases (POD) and superoxide dismutase (SOD) enzymes were found in the fruit treated with 4 mM salicylic acid. As a result, pre-storage application of 4 mM salicylic acid can be used safely to reduce the percentage of decay and preserve the highest amount of bioactive compound in ‘Kinnow’ mandarin fruit for three months in cold storage.

Arafat (2019) found that salicylic acid with a concentration at 4 mmol/l decreased TSS and Weight loss after 15 days of treatment for guava cv. White Balady fruits.

Fawole *et al.* (2020) concluded that for short term storage of pomegranate cv. Wonderful fruits should be treated with putrescine 2 mM concentration for maintaining fruit quality. However, for longer storage period, a higher concentration as 3 mM should be recommended for alleviating storage disorder and maintaining physio-chemical attributes.

Kaur & Kaur (2019) revealed that the quality and storability of peach cv. Florida prince was improved by salicylic acid and putrescine treatments as a result of their ability to slow down the ripening process. However, the salicylic acid 3 mmol reduced significantly the physiological weight loss and retained fruit's firmness, colour and palatability. Treatments with putrescine 3 mmol and control had the highest and lowest sugar content, respectively.

Abbasi *et al.* (2019) reported that spray of putrescine significantly reduced the incidence of chilling injury and rates of fruit softening, loss in fruit weight, soluble solid content, titratable acidity, ascorbic acid content and skin colour fading during storage, regardless of the doses of putrescine applied. However, the positive effects on the quality characteristics of peach fruit, including chilling injury, were more pronounced with the higher doses of putrescine, specifically when applied at 2 mM.

Singh *et al.* (2019) investigated the effect of post-harvest dip treatment of putrescine (PUT) @ 1 mM, 2 mM and 3 mM on pear fruit cv. Punjab Beauty to reduce softening and maintain quality of pear fruit. PUT treatment @ 2 mM and 3 mM effectively reduced the weight loss (WL), retained higher firmness, suppressed the degradation of starch and titratable acidity (TA) and maintained the higher quality of fruit. Moreover, the 2 mM and 3 mM PUT exhibited the lower spoilage of fruit.

Kaur *et al.* (2019) conducted an experiment to evaluate the effect of CaCl₂ (1% and 2%), CaNO₂ (1% and 2%), NAA (100 ppm and 200 ppm) and salicylic acid (100 ppm and 200 ppm) in improving shelf-life of guava cultivar Allahabad Safeda. Results revealed that CaNO₂ (2%) was effective to maintain highest palatability rating, specific gravity, maximum firmness and ascorbic acid. Minimum decay was noted in salicylic acid (200 ppm) treated fruits. CaNO₂ (2%) treated fruits showed minimum physiological loss in weight.

Lo'ay and Taher (2018) reported that treatment of fruits with edible coatings chitosan/PVP blending with salicylic acid with 2 mM concentration indicated the stability of soluble solid content (SSC), total acidity (TA) and SSC/TA ratio up to end of experiment as compared to that concentration level of 0 mM and 1 mM in guava cv. Banati.

Amanullah *et al.* (2017) experimented to study the efficacy of post-harvest treatment of salicylic acid on guava to enhance the shelf-life. Guava fruits were treated with various concentrations of salicylic acid (0, 400, 500, 600, and 700 µmol) and stored at room temperature to evaluate various attributes. Results depicted those fruits treated with 600 µmol had lower values for colour loss 1.5, fruit decay 14.97% and weight loss 20.03% as compared to other salicylic acid concentrations. Utmost values for TSS 7.24°Brix, total titratable acidity

0.35%, total sugars 20.08%, non-reducing sugars 11.37%, reducing sugars 6.05%, ascorbic acid contents 7.95(mg/100g), total phenolic compound 304.82 ($\mu\text{g}/\text{ml}$ FW) and total antioxidants 161.18 (IC $50\mu\text{g}/\text{ml}$) were noted in fruits that were treated with Salicylic Acid 600 μmol . The study indicates that 600 μmol Salicylic acid concentration is effective post-harvest treatment for guava fruit to extend its shelf-life during short-term storage.

Kasnazany *et al.* (2017) conducted a trial to evaluate the effect of salicylic acid (0, 3, and 6 mmol/L) and potassium metabisulfite (0, 0.5, 1.0, 1.5, and 2.0%) on post-harvest quality of plum cv. Qadri. Results revealed that fruits treated with 6 mmol/l salicylic acid significantly had more titratable acidity, hardness, and moisture content, while water loss and anthocyanin were less. On the other hand, 2% potassium metabisulfite increased the total soluble solids, titratable acidity, hardness and total phenol, whereas moisture content and anthocyanin were decreased in fruits.

Madhav *et al.* (2016) studied impact of salicylic acid on the physiological and quality attributes of guava fruits during storage at low temperature and observed that fruits treated with salicylic acid at 2 mM concentration showed minimum weight loss during entire storage.

Exogenous application of putrescine and salicylic acid were found to be effective for maintaining titratable acidity, ascorbic acid, total phenolics and antioxidant activity in plum cv. Santa Rosa during storage at 4°C. Hence, these chemicals can be used commercially to extend the shelf-life of plum fruit with acceptable quality (Davarynejad *et al.*, 2015).

Jahromi and Ramazani (2015) observed that 500 mg/l salicylic acid as post-harvest application on ber fruits cv. Seb significantly enhanced the TSS and vitamin C as compared to control treatment.

Yeganeh *et al.* (2013) observed that TSS, titratable acidity and TSS: Acidity were maximum when 'Bidaneh Sefid' grapes treated with at 2 and 4 mM salicylic acid as compared to all other treatments. However, Minimum fruit pH was reported in control and maximum in 2 mM as well as 4 mM salicylic acid concentration.

Khademi and Ershadi (2013) assessed the post-harvest treatment of salicylic acid for improving storability of peach cv. Elberta fruits. Four salicylic acid concentration viz., 0 (as control), 1, 2 and 4 mM were applied for evaluation of different quality parameters of fruit during seven weeks of storage at weekly intervals. Salicylic acid at a concentration of 2 mM had a positive effect on fruit firmness, total phenolic content and antioxidant capacity, while having no negative impact on fruit taste and appearance. Salicylic acid at 4 mM concentration slightly damaged the fruits.

Fatemi *et al.* (2013) studied the effect of salicylic acid (SA) at different concentrations (0, 1, 2, 4 and 5 mM SA) on fungal decay and some quality factors of kiwi fruit (*Actinidia deliciosa* cv. Hayward) in post-harvest conditions. Treated and untreated (control) fruits were placed in cold storage (6°C) for 60 days. It was observed that fruits

treated with salicylic acid at concentration 5 mM had the highest TSS, titratable acidity, ascorbic acid and antioxidant content and it had the lowest decay and acidity, whereas grey mould growth inhibited by salicylic acid at all applied concentrations.

Jawandha *et al.* (2012) reported that fruits of mango cv. Langra had high palatability rating, good blend of total soluble solids (TSS) and acidity and low physiological loss in weight and spoilage percentage when treated with putrescine at 2.0 mmol/l.

Tareen *et al.* (2012) concluded that application of 2.0 mmol/l salicylic acid had significant effect on quality attributes of peach fruits cv. 'Florida king' during five weeks of storage. Fruits treated with 2.0 mmol/l salicylic acid concentration retained maximum firmness, higher levels of SSC, increased contents of ascorbic acid and total phenolics and reduced REC. Whereas, lower salicylic acid concentrations did not affect significantly and performed nearly to that of control fruits.

Lo'ay and El Khateeb (2011) investigated the effect of exogenous salicylic acid treatments (water, 100, 300 and 500 μ M) on fruit guava cv. Baladi during 12 days storage at room temperature. Fruits immersed in high level of salicylic acid (500 μ M) had less Ion leakage %, degradation in total phenol, fruit browning and maintained the amount of vitamin C. Moreover, it had higher fruit firmness and colour as compared to other concentrations of salicylic acid and water-control.

Abbasi *et al.* (2010) observed that weight loss was lowest in 1 mM salicylic acid treated fruits of Peach cv. Maria Delicia during storage. TSS and pH were low in the salicylic acid treated fruits but titratable acidity and ascorbic acid concentrations were high. Sugars (non-reducing, reducing and total) were maintained in 1 mM salicylic acid treated fruit than other treatments. According to organoleptic assessment, 1 mM salicylic acid substantially maintained eating efficiency with higher quality attributes than other treatments.

Khosroshahi *et al.* (2008) studied the effect of exogenous putrescine on post-harvest life and quality of sweet cherry fruit cultivar 'Surati-e Hamedan' at 2°C. Putrescine application significantly reduced softening and loss of titratable acidity and increased the soluble solids content of cherries. Furthermore, cherries treated with higher putrescine concentrations had a lower rate of ethylene production.

Khosroshahi *et al.* (2007) concluded that soluble solid content, pH and titratable acidity of fruits were not affected significantly by the use of putrescine in strawberry cv. Selva. However, overall qualities of fruits were improved by the use of 2 mM putrescine application.

Serrano *et al.* (2003) treated four cultivars of plum (Santa Rosa, Black Diamond, Golden Japan and Black Star) with 1 mM putrescine and then stored at 20°C. Putrescine had a noticeable impact on all cultivars in terms of increased shelf-life, delayed ripening and higher quality attributes as compared to controls. Furthermore, putrescine-treated plums produced

less ethylene and had higher fruit firmness, lower soluble solids concentration and titratable acidity evolution, reduced weight loss and delayed colour changes during storage.

2.2 Effect of different packaging materials on the shelf-life of fruits:

Nagaraju and Banik (2019) reported that Low Density Polyethylene (LDPE) and High-density polythene (HDPE) with varying degree of perforation (0%, 1% and 2%) and one ethylene absorbent sachets (4g KMnO₄/Kg of fruit) was very effective in maintaining fruit quality of guava cv. Khaja. Highest acidity (0.38%) and ascorbic acid (5.82mg/100g pulp) was reported in un-perforated HDPE on 12th day of storage. However, TSS, reducing and total sugars were maximum in 2% perforated HDPE treatment.

Avesh *et al.* (2019) reported that guava fruits packed in sealed poly bags had minimum physiological and decay loss, while the fruits packed in corrugated fibreboard box with newspaper cuttings retained maximum firmness with minimum injury. However, the guava fruits packed in perforated poly bags, wooden box lined with paddy straw and corrugated fibreboard boxes lined with newspaper cuttings maintained their colour in acceptable limit at the end of storage.

Asati *et al.* (2017) reported that fruits of ber cv. Gola and Chhuhara packed in gunny bags were rated best for overall acceptability followed by fruits packed in perforated polythene film bags. The lowest loss in weight and spoilage percentage was observed in card board box followed by wooden box. Gunny bags showed the highest organoleptic scores, followed by perforated polythene. Fruits stored in wooden box showed maximum TSS followed by card board baskets. The maximum loss in per cent acidity and ascorbic acid content was observed in wooden box, whereas minimum loss was found in gunny bags. However, maximum ascorbic acid retention was found in gunny bag followed by perforated polythene bag. Perforated polythene bag and gunny bag were found to be the most suitable and economically viable packing containers for ber fruits storage at ambient conditions.

Taduri *et al.* (2017) reported that fruits of mango cv. Amrapali maintained lower PLW, desirable firmness, minimum spoilage, highest total soluble solids (21.92%) and TSS: Acid (109.44), maximum reducing sugar (9.23%) and total sugars (8.36%) and better quality as compared to other treatments when packed in 5% perforated LDPE film after 12 days of storage.

Panda *et al.* (2016) carried out an experiment to evaluate the shelf-life of strawberry cv. Sweet Charlie at room temperature (18-25°C and 80-90% RH) in modified atmospheric packaging. The result revealed that LDPE 50 micron packaging material was most effective to control the weight loss (5.49%) and all of the LDPE films along with the PP and cling films appeared best to minimize decay loss. The total soluble solids (6.35-5.78%) and titratable acidity (0.91-0.70%) decreased with the prolongation of storage periods. Higher level of

ascorbic acid in strawberry fruits packed with LDPE 50 (31.56 mg/100 g) and 75 micron (29.86 mg/100 g) was retained. The organoleptic rating was found best in fruits packed with LDPE 50 micron (7.90) packaging films.

Lee *et al.* (2016) noticed that atemoya fruits packed in a low density polyethylene bag (LDPE) and in polyvinylchloride (PVC) film after treating with 1000 ppm of ethrel at 25°C for three days showed least chilling injury, maximum total soluble solids to acid ratio (97.0 ± 1.2) and minimum titratable acidity at 5°C temperature for eleven days.

Ferreira *et al.* (2016) reported that fruits of Bengal litchi packed in polyethylene terephthalate tray (PET) with lid showed maximum total soluble solids to acid ratio when kept under refrigeration for nine days at 5°C.

Venkatesh *et al.* (2016) reported that sweet orange fruits packed in polyolefin and polyolefin shrink-wrapped had the lowest physiological loss in weight during storage at ambient and refrigerated conditions, respectively in comparison to other treatments.

Meena and Meena (2016) reported black polythene packaging have lowest value for physiological loss in weight of Allahabad Safeda (11.45%) and Lalit (10.18%) fruits after 16 days of storage.

Azene *et al.* (2014) studied the effects of packaging materials and storage environments on shelf-life of papaya fruit and reported that polyethylene bag packaging (HDPE & LDPE) with evaporative cooler storage were more effective compared to newspaper, banana leaf and the control fruits in retaining the quality as well as extending shelf-life and marketability of papaya. HDPE and LDPE bags retained higher concentration of total and reducing sugars when compared with different packaging treatments.

Kaur *et al.* (2014) observed after two weeks of storage, guava fruits packed in perforated LDPE maintained higher organoleptic rating (8.63), lower physiological loss in weight (0.91%) and minimum spoilage (0%) as compared to other treatments viz., LDPE, polypropylene and control. The study revealed that guava fruits packed in 5% perforated LDPE polythene films can be stored for 14 days as compared to unpacked fruits which had storage life of 7 days.

Chandra *et al.* (2011) reported maximum pectin retention (0.26%), higher ascorbic acid (49.83 mg/100 g pulp) in guava fruits when wrapped in cling film as compared to the fruits wrapped in tissue paper, banana leaves or teak leaves after seven days of storage. However, maximum TSS of guava was observed when fruits were cushioned with neem leaves followed by the fruits wrapped in teak leaves.

Miano *et al.* (2010) investigated the effect of three packaging materials viz., tissue papers, newspapers and plastic bags at room temperature and fridge temperature on different attributes of guava cv. Allahabd Safeda. At room temperature, fruits wrapped in tissue papers retained the fruit weight (241 g) at green mature and yellow stage (242 g), while at fridge

temperature, weight (244.20 g) was reported at green stage fruits wrapped with newspapers after 4 days of storage. After 8 days of storage at room temperature, yellow fruits with plastic bags had the highest moisture percentage (87.63%) followed by green fruits (87.51%) at fridge temperature. After 4 days of storage under newspapers, the highest TSS percentage (13.20%) was observed in green mature fruits at fridge temperature followed by room temperature (12.23%) in yellow fruits after 8 days of storage under tissue papers. At room temperature, fruits wrapped in tissue wrappers were more acidic than fruits held in the fridge. Under tissue papers, fruits at room temperature had the highest specific gravity followed by fruits at fridge temperature. Tissue papers performed better as guava wrapping materials both at room temperature and in the refrigerator.

Parihar and Kumar (2007) concluded that guava fruits packed in HDPE bags had highest total sugar (12.2%) as compared to other treatments viz., bamboo basket, corrugated boxes, wooden boxes and polyethylene bags.

Bhushan *et al.* (2002) concluded that kiwifruits packed in polyethylene packages (200 gauge thick with 0.5% ventilation) had overall better quality at the end of 8 weeks storage. However, control treatment reported faster changes in some physio-chemical characteristics thus had poorest quality after 8 weeks of storage.

Sandhu and Singh (2000) assessed the efficiency of HDPE and LDPE bags of different thickness for pear cv. Le Conte fruits storage. Fruits were first individually wrapped and sealed in bags then refrigerated (at 0-3.3°C). Higher physiological weight loss (PLW) and spoilage were observed in LDPE than HDPE bags. In LDPE bags, total soluble solids were higher than in HDPE bags, while starch and total acids were higher in HDPE bags.

Venkatesha and Reddy (1994) recorded maximum total soluble solids, ascorbic acid and acidity in guava fruits wrapped in polyethylene bags of 300 gauge thickness as compared to control after 9 days of storage.

Sharma *et al.* (1994) observed that guava fruits cv. L-49 retained maximum total soluble solids and vitamin C for long period when packed in polythene bag. However, acidity of guava fruits was not affected by any of packaging materials.

Singh *et al.* (1993) observed that polythene packed guava fruits retained maximum total soluble solids and ascorbic acid as compared to control fruits after 10 days of storage.

Kahlon and Bajwa (1991) observed least weight loss of litchi fruit when fruits were packed in perforated polyethylene bags with paper cutting as cushioning material as compared to control fruits.

Wavhal and Athale (1988) reported higher acidity in mango fruits treated with KMnO_4 and wrapped in polyethylene, whereas minimum in control fruits after 20 days of storage.

Kalra *et al.* (1986) conducted an experiment for improving quality of Dashehari mangoes through pre-packing material viz., newspaper, polyethylene, brown paper and butter paper pouches. Results reported that physiological loss in weight (PLW) in polyethylene packed mangoes was very less (5%) as compared to other packing materials (15-20%) after 8 days of storage. Polyethylene reported no ripening. The other treatments showed complete ripening, optimum level of total soluble solids (TSS) and acidity.

Adsule and Tandon (1983) observed minimum physiological loss of weight, maximum ascorbic acid and TSS in guava fruits packed in 600 gauge low density polyethylene film as compared to control.

Jain and Chitkara (1980) reported minimum loss in weight when fruits of ber cv. Umran were stored in polyethylene bags.

2.3 Effect of storage conditions on shelf-life of fruits.

Dhara *et al.* (2016) studied effect of Storage Conditions on Shelf-Life and Quality of Guava cv. Allahabad Safeda and concluded that fruits pre-cooled at 10°C for 8 hours, packed in 200 gauge polyethylene without vent and stored at 10°C were found best in maintaining Reducing sugar, Total sugar, TSS, Acidity, Ascorbic Acid and Firmness and also showed minimum physiological loss in weight during storage.

Fawole and Opara (2013) studied the effects of storage temperature and duration on physiological responses of pomegranate fruit and observed the physiological responses and quality of the fruit influenced by storage conditions with the highest levels of respiration occurring at higher temperatures and extended storage period. It was observed that fruit stored at 5°C and 92% RH had significantly reduced physiological weight loss, low incidence of physiological disorders and best results in maintaining total soluble solids (TSS), titratable acidity (TA) and TSS: TA.

Hong *et al.* (2013) studied the influences of storage temperature on quality parameters and internal browning of summer pineapple fruit and results indicates that there was decrease in TSS in fruit stored at 25°C, whereas TSS remained relatively constant in fruits stored at 10 and 6°C. The maximum retentions of sugars were observed with storage of fruits at 6°C rather than storage at 10 or 25°C. Vitamin C and titratable acidity degradation rate significantly slowed down when fruits were kept at 6°C followed by 10 and 25°C. Throughout the storage period, the content of soluble proteins decreased as storage temperature increased and after 12 days in storage, substantial differences were observed between fruit stored at low temperature and fruit stored at room temperature. Internal browning development was also influenced by storage temperature. In fruits stored at 25°C, internal browning incidence was more rapid and with greater intensity than in fruits stored at 10°C and internal browning intensity was marginal in fruit stored at 6°C. The study found that

lower storage temperature is useful in maintaining quality and prevent the development of internal browning in pineapple.

Kishore *et al.* (2011) studied the effect of storage temperature on physio-chemical and sensory attributes of purple passion fruit and observed that after 5 days of storage at $25\pm 1^{\circ}\text{C}$, fruits developed off-flavour in juice, while fruits stored at $8\pm 1^{\circ}\text{C}$ produced no off-flavour even up to 21 days. At $25\pm 1^{\circ}\text{C}$, fruits can be stored only for 5 days as the overall sensory quality of juice significantly reduced afterwards, while at $8\pm 1^{\circ}\text{C}$, fruits maintained the optimum overall quality up to 21 days.

Mahajan *et al.* (2009) conducted a trail to Optimization of storage temperature for maintaining quality of guava. Fruits were harvested at green mature stage, packed in polythene bags (perforated) and stored at 0°C , 3°C , 6°C , 9°C and 90-95% RH. Results revealed that fruits stored below 6°C developed chilling injury and bland taste after 7 days of storage, whereas fruits at 9°C developed faster ripening and over softening. The optimum temperature for guava fruit storage was 6°C and 90-95% relative humidity, since the fruits had an attractive colour, good flavour and satisfactory quality at this temperature and could be stored for up to 2-3 weeks.

Marcilla *et al.* (2006) studied the effect of different storage temperatures (5, 15, 20 and 25°C) on the flavour of cv. Valencia and observed reduction of orange-like flavour and increased the presence of off-flavours at higher temperatures during storage.

Huang and Wang (1989) concluded that optimum storage temperature was about 5°C for litchi at which fruits showed acceptable fruit colour, TSS, acidity and less incidence of physiological disorder throughout the storage duration.

Abou Aziz *et al.* (1976) studied effect of storage temperature on quality and decay percentage of 'Pairi' and 'Taimour' mango fruits and observed that most suitable storage temperature for both cultivars was 5°C or slightly higher followed by 10°C due to maintenance of better quality and minimum spoilage.

CHAPTER- III

MATERIALS AND METHODS

The details of the materials methods used during investigation are presented in this chapter under following headings:

3.1 Experimental site

The present study entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda**” was conducted at post-harvest laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during the period 1st to 3rd week of December 2020. The guava fruits were collected from the experimental orchard, CCS Haryana Agricultural University, Hisar which is situated at 215.2 m above sea level with coordinates of 29°10' N latitude and 75°46' E longitudes.

3.2 Climate and weather conditions

Hisar has semi-arid and subtropical climate with hot and dry winds during summer months while extremely cold winters. The common climate characteristics of this region are dryness and scanty rainfall (450 mm). Mean monthly maximum and minimum temperature of both during summer and winter months shows wide ranges of variations. A maximum temperature ranged from 44°C to 48°C during summer and in winter, temperature as low as to freezing point accompanied with chilling frost.

3.3 Experimental details

The present investigation entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of Guava (*Psidium guajava* L.) cultivar Hisar Safeda**” was performed in two experiments. The guava fruits were harvested by hand picking early in the morning at physiological maturity during 1st week of December from the experimental orchard, CCS Agricultural University, Hisar. Disease free and uniform sized fruit were collected in plastic crates.

Experiment 1: Effect of salicylic acid and putrescine on the shelf-life of guava under different storage conditions.

In the first experiment, the fruits were dipped in salicylic acid and putrescine solutions for 5 minutes and then packed in CFB boxes and stored at room temperature and refrigeration temperature (7°C).

No. of treatments	9
Experimental Design	CRD
Replications	3

Sample size 2 kg

Details of treatments are given below-

Treatments:

T₁: Salicylic acid 1 mM

T₂: Salicylic acid 2 mM

T₃: Salicylic acid 3 mM

T₄: Salicylic acid 4 mM

T₅: Putrescine 2 mM

T₆: Putrescine 3 mM

T₇: Putrescine 4 mM

T₈: Putrescine 5 mM

T₉: Control

Time of dipping: 5 min

Experiment 2: Effect of different packaging films on the shelf-life of guava fruit under different storage conditions.

In the second experiment, the fruits were wrapped with different packaging films and then packed in CFB boxes and stored at room temperature and refrigeration temperature (7°C).

No. of treatments	5
Experimental Design	CRD
Replications	3
Sample size	2 kg

Details of treatments are given below-

Packaging material:

T₁: LDPE 25 micron

T₂: HDPE 25 micron

T₃: Polypropylene 25 micron

T₄: Cellophane Paper

T₅: Control

3.4 Methodology

Uniform size fruits were harvested at the physiological mature stage and physio-chemical parameters were recorded on the same day of harvesting. The treated fruits (2.0 kg/replication) for the experiment were packed in corrugated fibre board (CFB) boxes and kept in refrigerator as well at room temperature under ambient condition in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar.

The freshly harvested fruits were analyzed and subsequent stored fruits samples were taken out from the refrigerator and ambient storage at alternate days and analyzed for various physio-chemical attributes.

3.5 Observations to be recorded:

The observations were recorded on alternate days as per standard procedures. The various parameters along with the methodology followed for their assessment are discussed below:

- Physiological loss in weight (%)
- Decay loss (%)
- Total soluble solid (%)
- Titratable acidity (%)
- TSS: Acid Ratio
- Juice pH
- Pectin content (%)
- Ascorbic acid content (mg/100 g pulp)
- Total sugars (%)
- Reducing sugars (%)
- Non-reducing sugars (%)
- Organoleptic rating

3.5.1 Physiological loss in weight (%)

The Physiological loss of weight (PLW) of fruit was determined on the basis of initial weight. After each interval of storage, the weight of fruits was recorded and percent physiological loss in weight (PLW) was calculated by subtracting final weight from the initial weight of fruits, as per formula given below:

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

3.5.2 Decay loss (%)

Decay loss (%) of fruits was decided on the basis of visual observations. Decay loss was evaluated by simply counting the number of spoiled fruits displaying fungal infection and subsequent rotting in a replication and expressed in percentage.

$$\text{Decay loss (\%)} = \frac{\text{Number of spoiled fruits}}{\text{Total number of fruits}} \times 100$$

3.5.3 Total soluble solid (%)

Total soluble solids was determined by using ERMA hand refractometer of the range of 0-32 °Brix. In each replication, the juice was extracted from randomly selected fruit and filtered through muslin cloth. From extracted juice, one drop was placed on dry refractometer prism and the readings were recorded. After every observation, the prism of refractometer was cleaned with the help of double-distilled water. The values of the total soluble solids were expressed in per cent after making the temperature correction at 20°C.

3.5.4 Titratable acidity (%)

Titratable acidity was measured with the help of titration method given in A.O.A.C. (1990).

Reagents prepared

The following reagents were prepared for further use:

Sodium hydroxide	0.1 N
Phenolphthalein indicator	1%

Procedure

5 g of fruit pulp was crushed with small amount of distilled water then the juice was filtered through muslin cloth. An aliquot of 2 ml of filtrate was pipette out into a beaker and titrated against 0.1 N sodium hydroxide solution using phenolphthalein (1-2 drops) as an indicator. Titration was carried out drop by drop till the colour change to light pink. Acidity was expressed in terms of per cent citric acid and calculated by using the following formula:

$$\text{Titratable Acidity (\%)} = \frac{\text{Titrate value} \times \text{Normality of NaOH} \times \text{Equivalent weight of citric acid}}{\text{Juice taken (ml)} \times 1000} \times 100$$

3.5.5 Total soluble solids to acid ratio

The total soluble solids to acid ratio was determined by dividing total soluble solids by acidity. Formula used was written below:

$$\text{TSS: Acid ratio} = \frac{\text{Total soluble solids (\%)}}{\text{Titratable acidity (\%)}}$$

3.5.6 Juice pH

A microprocessor-based pocket pH meter (Eutech instrument Pvt. Ltd. Singapore) was used to determine the pH of fruit juice. The pH meter was standardized with the standard solution (pH 4) before use. The pH of the juice was determined by dipping the bulb of cell of pH meter into it for few seconds. The reading was noted after stabilization. The pH meter's bulb was washed with double-distilled water before each observation.

3.5.7 Pectin content (%)

Ranganna (1979) described the method used for the estimation of total pectin as calcium pectate in fresh fruits.

Reagents

1) 1N Acetic acid

Glacial acetic acid	30 ml
Volume	200 ml

2) 1N Calcium chloride

Anhydrous calcium chloride	27.5 g
Volume	500 ml

3) 1N Sodium hydroxide

Sodium hydroxide	20 g
Volume	500 ml

4) 1% Silver nitrate

Silver nitrate	1 g
Volume	100 ml

Extraction

For the estimation of pectin content, mashed 25 g of fruit pulp was taken in a flask and 200 ml distilled water was added to it and placed on hot plate for an hour. The water lost during boiling was restored back concurrently. The flask was then further cooled and final volume was made up to 250 ml. After that, the contents of the flask were filtered using Whatman filter paper no. 4.

Estimation

50 ml of the filtrate was taken in the beaker and then 50 ml of distilled water and 5.0 ml of 1 N NaOH was added in it and kept overnight. The following day, 25 ml of acetic acid solution was added and after 5 minutes 12.5 ml of 1 N calcium chloride solution was added by continuous stirring. After an hour of still stand, it was boiled for a minute and filtered through oven dried previously weighed Whatman filter paper no. 4. The precipitates were washed with distilled water until they were free from chloride (test with 1% silver nitrate solution). Used filter paper was dried overnight at 100°C cooled in desiccators and weighed on next day. The amount of pectin was measured as per cent calcium pectate.

$$\text{Calcium pectate (\%)} = \frac{\text{Weight of calcium pectate} \times \text{volume of content}}{\text{Volume of filtrate} \times \text{weight of sample for estimation}} \times 100$$

3.5.8 Ascorbic acid content (mg/100 g pulp)

The method used for estimation ascorbic acid was mentioned in A.O.A.C. (1990).

Reagents

- **Metaphosphoric acid solution (3%)**

Metaphosphoric acid (HPO ₃)	15 g
Glacial acetic acid	40 ml
Final volume adjusted	500 ml

- **2, 6 dichlorophenol indophenol dye**

2, 6-dichlorophenol indophenol dye	50 mg
Sodium bicarbonate	42 mg
Volume adjusted	200 ml

- **Standard ascorbic acid solution**

50 mg of ascorbic acid (C₆H₈O₆) was dissolved in 50 ml metaphosphoric acid (3%).

Estimation

Grinding of 5 g of fruit pulp was done using 25 ml of 3% metaphosphoric acid and filtered through muslin cloth. 2 ml of filtrate was titrated against 2, 6-dichlorophenol dye until end point (distinctly rose pink colour) appeared. Simultaneously, 1.0 ml of standard ascorbic acid was also titrated against the dye. The results were expressed as mg of ascorbic acid per 100 g of fruit pulp. It was calculated using the following formula:

$$\text{Ascorbic acid (mg/100 g fruit pulp)} = \frac{\text{Titrate value} \times \text{total volume}}{\text{Standard reading} \times \text{ml of sample}} \times 100$$

3.5.9 Sugars (%)

The method used for the estimation of sugars was described by Hulme and Narain (1931).

Reagents

- 1) **Potassium ferricyanide solution**

Potassium ferricyanide	8.25 g
Anhydrous sodium carbonate	10.6 g
Final volume adjusted	500 ml

- 2) **Potassium iodide solution**

Potassium iodide	12.5 g
Zinc sulphate	125 g
Final volume adjusted	500 ml

3) 5% acetic acid solution

Glacial acetic acid	50 ml
Final volume adjusted	1000 ml

4) Sodium thiosulphate solution (0.01N)

Sodium thiosulphate	2.482 g
Final volume adjusted	1000 ml

5) Starch (indicator)

Soluble starch	1 g
Sodium chloride	20 g
Final volume adjusted	100 ml

Extraction

With the help of pipette, 0.2 ml juice was taken in a test tube and final volume was adjusted to 20 ml (100 times dilution) with distilled water. These test tubes were covered with aluminum foil and kept in boiling water bath for 30 minutes.

3.5.9.1 Total sugars (%)

5.0 ml of aliquot was taken in a test tube, in which 4 ml of HCl (Hydrochloric acid) was added to it and kept in boiling water bath for 15 minutes by covering with aluminium foil. It was neutralized completely till effervesce stopped by adding anhydrous Na₂CO₃ (Sodium carbonate). Final volume was made to 50 ml in a volumetric flask with distilled water. From this, 5.0 ml of aliquot was taken and the same procedure was repeated as used in estimation of reducing sugar.

3.5.9.2 Reducing sugar (%)

5 ml of aliquot was taken along with 5 ml of potassium ferricyanide solution in a test tube and it was covered with aluminium foil and kept in a water bath for 15 minutes. Test tubes were cooled under running tap water, thereafter, 5 ml of potassium iodide and 3 ml of acetic acid solution were added so that it turned into orange yellow coloured solution. This solution was titrated against the sodium thiosulphate using starch solution as indicator and the end point was milky white colour. The amount of sodium thiosulphate solution was recorded at this point. At the same time, a blank was run simultaneously. The results were calculated by using the formula given below and expressed in gram of sugars per 100 g fresh weight.

$X = [(ml \text{ of sodium thiosulphate used in blank} - ml \text{ of sodium thiosulphate used for blank}) + 0.05] \times 0.338 = \text{mg of sugar per 5 ml extract}$

$$\text{Reducing sugar (\%)} = \frac{\text{'X' x dilution factor}}{5 \times 1000} \times 100$$

3.5.9.3 Non-reducing sugars

Non-reducing sugar was estimated from the calculated values of total and reducing sugar (%) of the fruit samples by using the following formula:

$$\text{Non-reducing sugar (\%)} = \text{Total sugars} - \text{Reducing sugar}$$

3.5.10 Organoleptic rating

As described by Ranganna (1977) it was determined on the basis of colour and appearance, taste, flavour and overall acceptability of the randomly selected fruits by panel of five judges as per 'Hedonic Scale' (1-9 points) which is as follows:

Marks	Acceptability
9	Extremely desirable
8	Very much desirable
7	Moderately desirable
6	Slightly desirable
5	Neither desirable nor undesirable
4	Slightly undesirable
3	Moderately undesirable
2	Very much undesirable
1	Extremely undesirable

3.6 Statistical Analysis

Gomez and Gomez (1981) proposed that statistical analysis of collected data during the storage experiment was done by applying the Completely Randomized Design (factorial) for analysis of variance (ANOVA). OPSTAT statistical software was used to conduct the statistical analysis.

The experiment entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda.**” was conducted in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2020-21. The results obtained for parameters under study are presented after tabulation and statistical analysis as follow:

4.1 Experiment I: Effect of salicylic acid and putrescine on the shelf-life of guava.

4.1.1 Physiological loss in weight (%)

The data presented in Table 4.1.1 reveals that post-harvest chemical treatments and storage time significantly influenced the physiological loss in weight (PLW) in guava. Under refrigerator storage, among the different treatments, minimum PLW (1.44%) was recorded in fruits treated with salicylic acid @ 4 mM (T₄) followed by salicylic acid @ 3 mM (T₃; 1.57%). Similarly, under ambient storage among the different treatments, minimum PLW (2.91%) was recorded in fruits treated with salicylic acid @ 4 mM (T₄) followed by salicylic acid @ 3 mM (T₃; 3.13%). The maximum PLW (2.32 and 4.18%) was recorded under control treatment (T₉) in refrigerator and ambient storage, respectively.

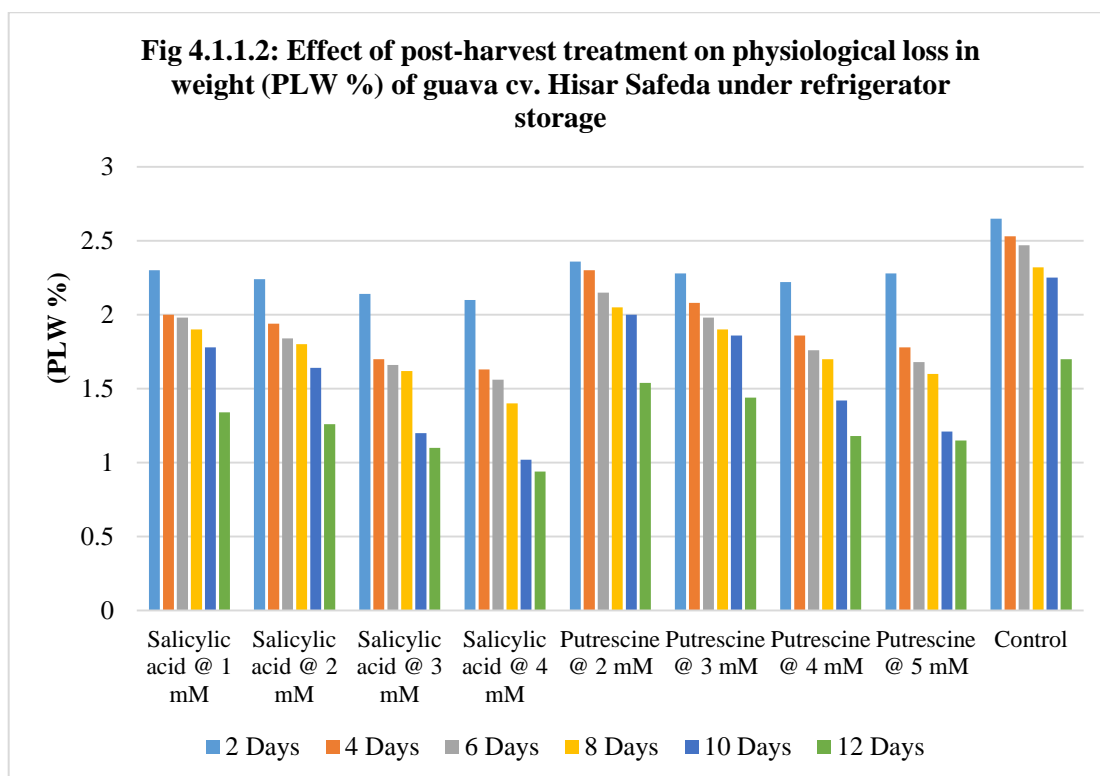
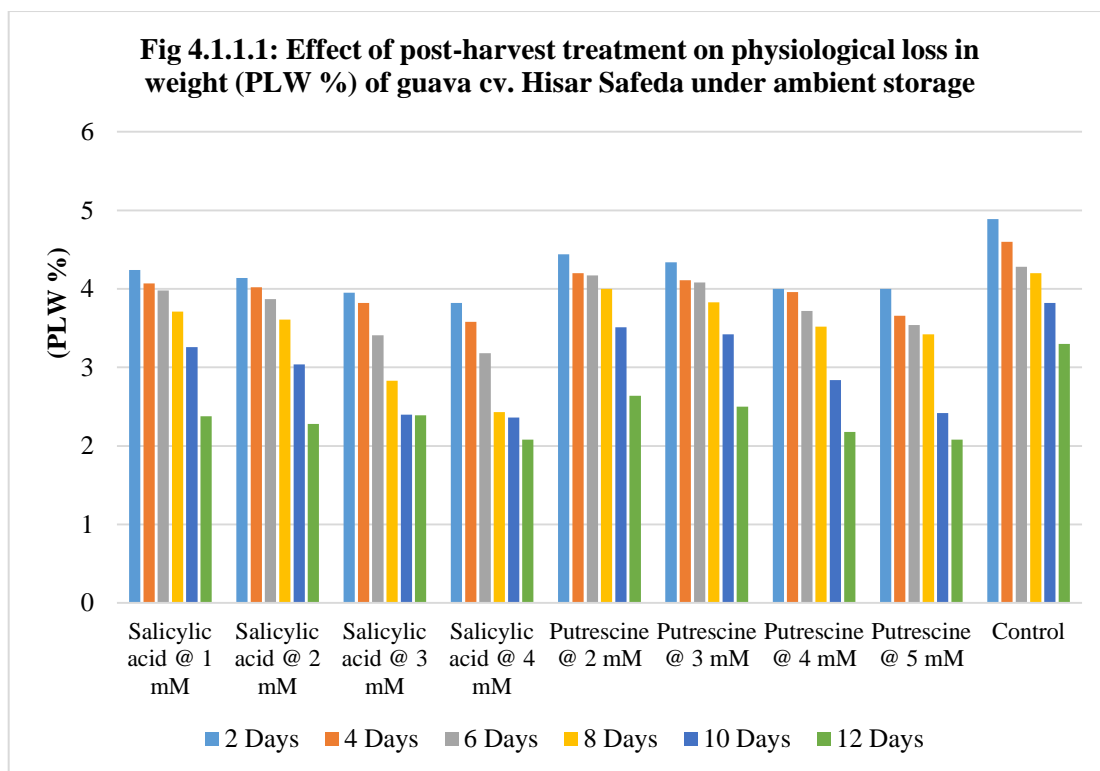
Among the storage time, PLW decreased with the passage of time during the storage studies. The minimum PLW (1.30 and 2.43%) was recorded on 12th day of storage (S₆) followed by 10th day of storage (S₅; 1.60 and 3.01%) under refrigerator and ambient storage, respectively. The maximum PLW (2.29 and 4.20%) was recorded on 2nd day of storage (S₁) under refrigerator and ambient storage, respectively. However, the interaction between chemical treatments and storage time was found non-significantly influence physiological loss in weight.

4.1.2 Decay loss (%)

The data on decay loss for different treatments and days under refrigerator and ambient storage has been presented in Table 4.1.2. It is clear from the data that all post-harvest treatments have significant effect in reducing the decay loss than control under both storage conditions. Under refrigerator storage, fruits treated with salicylic acid @ 4 mM (T₄) showed minimum decay loss (1.94%) which was statistically at par with salicylic acid @ 3 mM (T₃; 2.22%) and putrescine @ 5 mM (T₈; 2.50%), while maximum decay loss (7.78%) was recorded in control treatment (T₉). Under ambient storage, minimum decay loss (3.06%) was recorded with salicylic acid @ 4 mM (T₄) that was statistically at par with salicylic acid

Table 4.1.1: Effect of post-harvest treatment of salicylic acid and putrescine on physiological loss in weight (PLW %) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage										
			Storage Period							Storage Period										
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean				
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆					
Salicylic acid	1 mM	T ₁	4.24	4.07	3.98	3.71	3.26	2.38	3.61	2.30	2.00	1.98	1.90	1.78	1.34	1.88				
	2 mM	T ₂	4.14	4.02	3.87	3.61	3.04	2.28	3.49	2.24	1.94	1.84	1.80	1.64	1.26	1.79				
	3 mM	T ₃	3.95	3.82	3.41	2.83	2.40	2.39	3.13	2.14	1.70	1.66	1.62	1.20	1.10	1.57				
	4 mM	T ₄	3.82	3.58	3.18	2.43	2.36	2.08	2.91	2.10	1.63	1.56	1.40	1.02	0.94	1.44				
Putrescine	2 mM	T ₅	4.44	4.20	4.17	4.00	3.51	2.64	3.83	2.36	2.30	2.15	2.05	2.00	1.54	2.07				
	3 mM	T ₆	4.34	4.11	4.08	3.83	3.42	2.50	3.71	2.28	2.08	1.98	1.90	1.86	1.44	1.92				
	4 mM	T ₇	4.00	3.96	3.72	3.52	2.84	2.18	3.37	2.22	1.86	1.76	1.70	1.42	1.18	1.69				
	5 mM	T ₈	4.00	3.66	3.54	3.42	2.42	2.08	3.19	2.28	1.78	1.68	1.60	1.21	1.15	1.62				
Control		T ₉	4.89	4.60	4.28	4.20	3.82	3.30	4.18	2.65	2.53	2.47	2.32	2.25	1.70	2.32				
Mean			4.20	4.01	3.80	3.51	3.01	2.43	4.20	2.29	1.98	1.90	1.82	1.60	1.30					
C.D. at 5%			Treatment (T) = 0.20			Days (D) = 0.17			T×D = NS			Treatment (T) = 0.11			Days (D) = 0.09			T×D = NS		



@ 3 mM (T_3 ; 3.89%) and putrescine @ 5 mM (T_8 ; 4.17%), while maximum decay loss (10.83%) was observed in control treatment (T_9).

Storage period also had significant influence on decay loss as it increased with prolongation of storage time. There was no decay incidence till 2nd day of storage under both conditions in all treatments including control. On 4th day of storage (S_2)

Table 4.1.2: Effect of post-harvest treatment of salicylic acid and putrescine on decay loss (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage										
			Storage Period							Storage Period										
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean				
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆					
Salicylic acid	1 mM	T ₁	0.00	5.00	6.67	6.67	11.67	13.33	7.22	0.00	0.00	3.33	5.00	6.67	8.33	3.89				
	2 mM	T ₂	0.00	3.33	5.00	6.67	8.33	10.00	5.56	0.00	0.00	5.00	5.00	5.00	6.67	3.61				
	3 mM	T ₃	0.00	0.00	1.67	5.00	8.33	8.33	3.89	0.00	0.00	0.00	3.33	5.00	5.00	2.22				
	4 mM	T ₄	0.00	0.00	1.67	5.00	5.00	6.67	3.06	0.00	0.00	0.00	1.67	5.00	5.00	1.94				
Putrescine	2 mM	T ₅	0.00	6.67	10.00	11.67	13.33	13.33	9.17	0.00	0.00	6.67	6.67	10.00	11.67	5.83				
	3 mM	T ₆	0.00	5.00	8.33	10.00	11.67	13.33	8.06	0.00	0.00	5.00	5.00	8.33	10.00	4.72				
	4 mM	T ₇	0.00	1.67	5.00	6.67	10.0	15.0	6.11	0.00	0.00	3.33	5.00	5.00	8.33	3.61				
	5 mM	T ₈	0.00	0.00	1.67	6.67	8.33	8.33	4.17	0.00	0.00	0.00	3.33	5.00	6.67	2.50				
Control		T ₉	0.00	8.33	10.00	13.33	16.67	16.67	10.83	0.00	1.67	8.33	11.67	11.67	13.33	7.78				
Mean			0.00	3.33	5.74	7.78	10.19	12.04		0.00	0.19	3.52	5.19	6.85	8.33					
C.D. at 5%			Treatment (T) = 1.7			Days (D) = 1.4			T×D = 4.2			Treatment (T) = 1.1			Days (D) = 0.9			T×D = 2.7		

minimum decay loss (0.19 and 3.3%) followed by 6th day of storage (S₃; 3.52 and 5.74%) under refrigerator and ambient storage, respectively. Maximum decay loss (8.33 and 12.04%) was observed on 12th day of storage (S₆) under refrigerator and ambient storage, respectively.

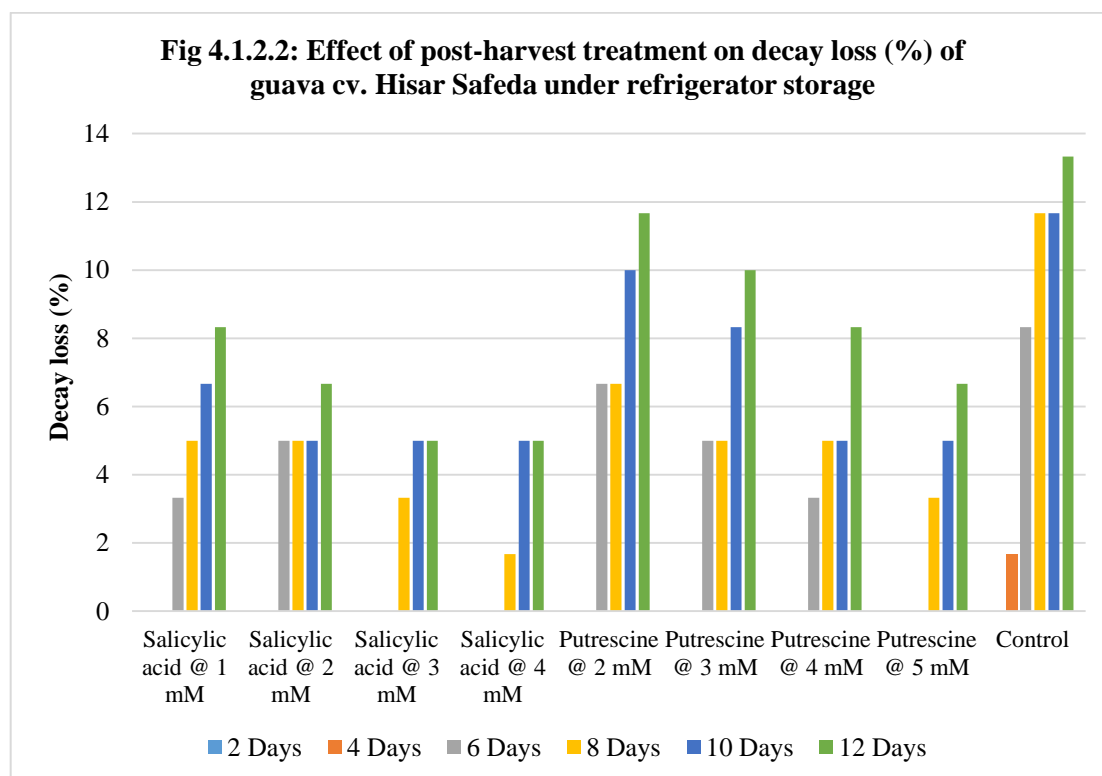
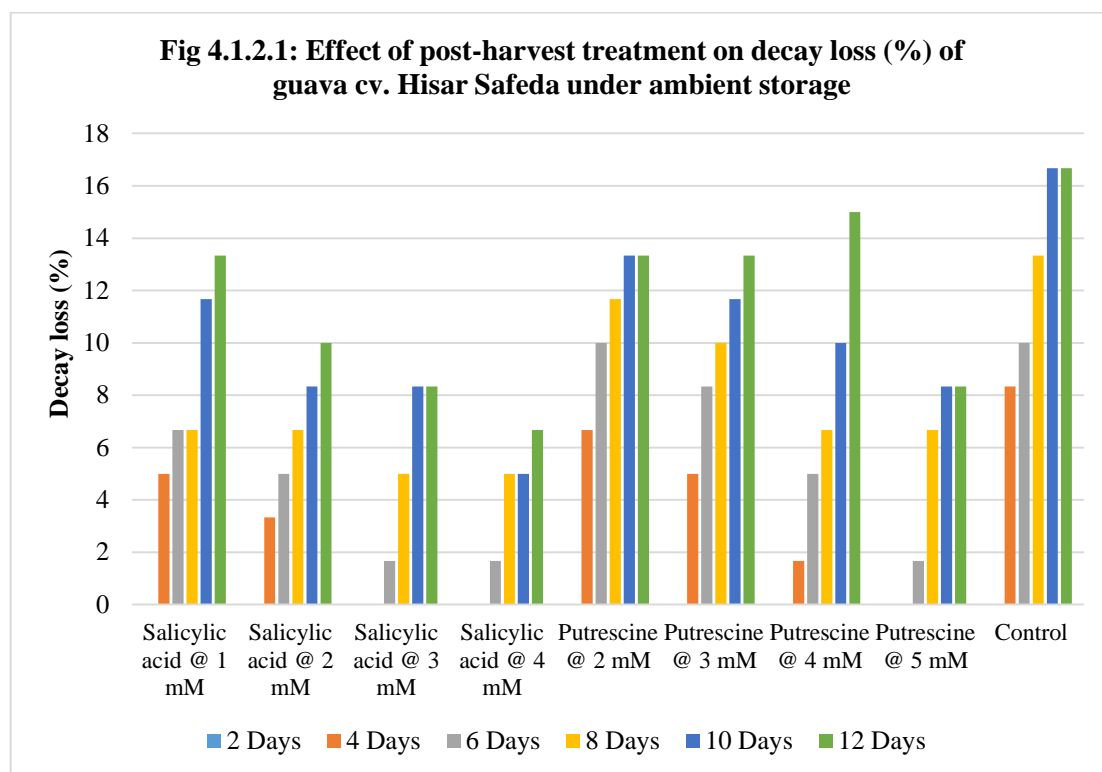


Table 4.1.3: Effect of post-harvest treatment of salicylic acid and putrescine on total soluble solids (TSS; %) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	11.79	12.02	12.34	11.35	10.53	9.65	11.28	11.76	11.89	12.30	11.80	10.62	9.96	11.39
	2 mM	T ₂	11.83	12.03	12.41	11.52	10.81	9.95	11.43	11.73	11.73	12.33	12.07	10.98	10.28	11.52
	3 mM	T ₃	11.73	12.13	12.53	12.63	11.57	10.77	11.90	11.67	11.80	12.10	12.40	12.63	11.95	12.09
	4 mM	T ₄	11.65	12.07	12.46	13.14	11.99	11.35	12.11	11.63	11.73	12.07	12.70	13.10	12.71	12.32
Putrescine	2 mM	T ₅	11.98	12.18	11.60	10.90	10.20	9.09	10.99	11.87	12.23	11.93	11.34	10.26	9.51	11.19
	3 mM	T ₆	11.89	12.10	11.98	11.21	10.47	9.38	11.17	11.80	12.11	12.13	11.60	10.43	9.70	11.30
	4 mM	T ₇	11.76	11.98	12.30	12.05	11.10	10.25	11.57	11.67	11.80	12.09	12.30	11.78	10.88	11.75
	5 mM	T ₈	11.77	12.20	12.55	12.26	11.35	10.54	11.78	11.70	11.83	11.99	12.67	11.97	11.21	11.90
Control		T ₉	12.07	12.26	11.19	10.27	9.68	8.67	10.69	11.97	12.45	11.50	10.68	10.07	9.26	10.99
Mean			11.83	12.11	12.15	11.70	10.86	9.96		11.76	11.95	12.05	11.95	11.32	10.61	
C.D. at 5%			Treatment (T) = 0.19			Days (D) = 0.15		T×D = 0.47		Treatment (T) = 0.19			Days (D) = 0.15		T×D = 0.41	

Under refrigerator, there was no decay loss till 6th day of storage in fruits treated with salicylic acid @ 4 mM, salicylic acid @ 3 mM and putrescine @ 5 mM, while maximum decay loss (13.33%) was recorded in fruit under control treatment on 12th day of storage (T₉S₆). Under ambient condition, no decay loss was observed in fruits treated with salicylic acid @ 4 mM, salicylic acid @ 3 mM and putrescine @ 5 mM till 4th day of storage, while fruits on 10th and 12th day of storage under control treatment (T₉S₆ and T₉S₅) showed maximum decay loss (16.67%).

4.1.3 Total soluble solid (%)

Data related to total soluble solids (TSS) has been presented in Table 4.1.3. Highest TSS (12.32 and 12.11%) was recorded in fruits treated with salicylic acid @ 4 mM (T₄) followed by salicylic acid @ 3 mM (T₃; 12.09 and 11.90%) under refrigerator and ambient storage, respectively. Lowest TSS (10.99 and 10.69%) was reported in fruits under control treatment (T₉) in refrigerator and ambient storage, respectively.

It was observed that TSS content initially increased upto different days of storage in different treatments and then often decreased with prolongation of storage time. Among storage time, maximum TSS (12.05%) was observed on 6th day of storage (S₃) that was statistically at par with 4th (S₂; 11.95%) and 8th day of storage (S₄; 11.95%), while minimum TSS (10.61%) was recorded 12th day of storage (S₆) under refrigerator. Under ambient condition, maximum TSS (12.15%) was observed on 6th day of storage (S₃) that was statistically at par with 4th day of storage (S₂; 12.11%), while minimum TSS (9.96%) was recorded on 12th day of storage (S₆).

TSS was also significantly influenced by the combined effect of post-harvest treatments and storage time. In refrigerator storage, highest TSS (13.10%) was recorded in the fruits treated with salicylic acid @ 4 mM on 10th day of storage (T₄S₅) that was statistically at par with salicylic acid @ 4 mM on 8th day (T₄S₄; 12.70%) and 12th day of storage (T₄S₆; 12.71%), whereas lowest TSS (9.26%) was recorded in fruits under control treatment on 12th day of storage (T₉S₆). At ambient condition, highest TSS (13.14%) was observed in fruits treated with salicylic acid @ 4 mM followed by salicylic acid @ 3 mM (12.63%) on 8th day of storage, while lowest TSS (8.67%) was recorded in fruits under control treatment 12th day of storage (T₉S₆).

4.1.4 Titratable acidity (%)

The data given in Table 4.1.4 reveals that post-harvest treatments, storage period and interaction of treatment and storage period non-significantly influence the titratable acidity (TA) of the guava under both storage conditions.

Fig 4.1.3.1: Effect of post-harvest treatment on total soluble solids (TSS; %) of guava cv. Hisar Safeda under ambient storage

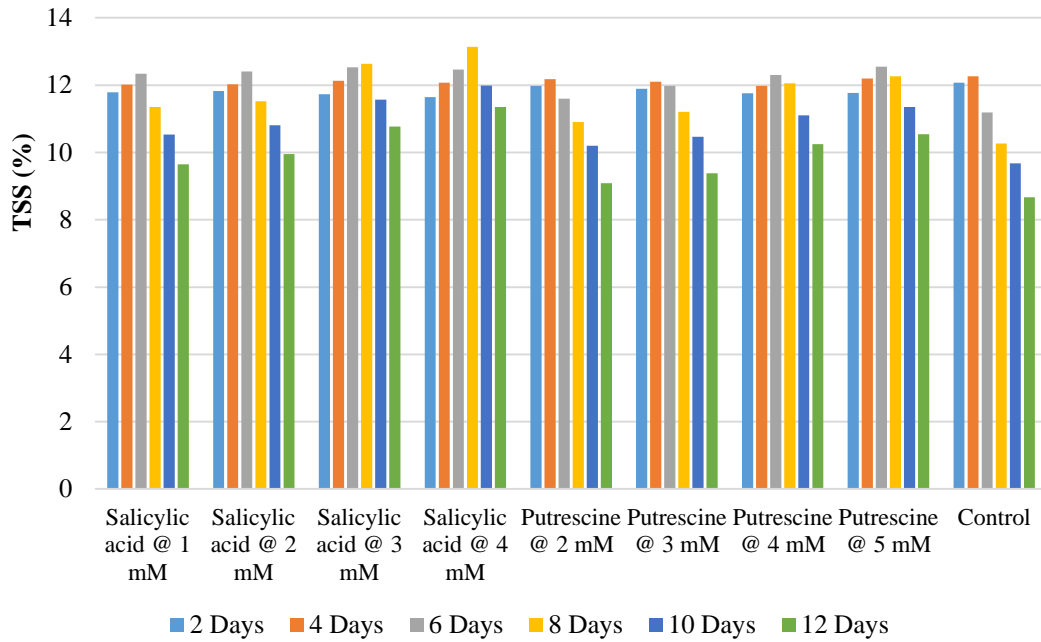


Fig 4.1.3.2: Effect of post-harvest treatment on total soluble solids (TSS; %) of guava cv. Hisar Safeda under refrigerator storage

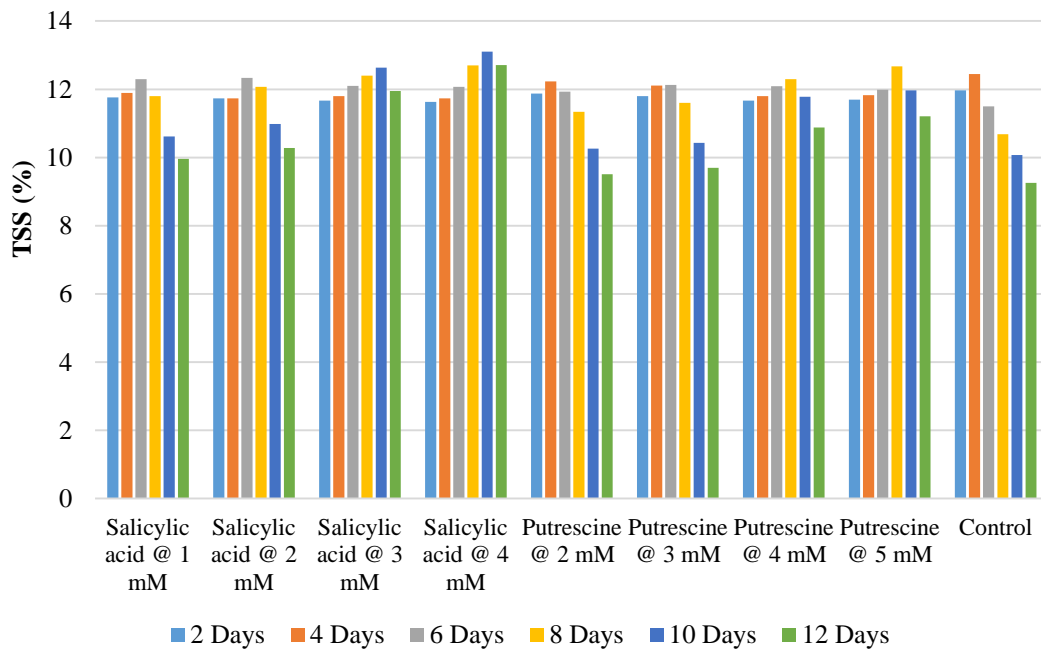


Table 4.1.4: Effect of post-harvest treatment of salicylic acid and putrescine on titratable acidity (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage										
			Storage Period							Storage Period										
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean				
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆					
Salicylic acid	1 mM	T ₁	0.33	0.32	0.30	0.29	0.28	0.27	0.30	0.34	0.32	0.31	0.30	0.28	0.27	0.30				
	2 mM	T ₂	0.34	0.32	0.30	0.29	0.28	0.27	0.30	0.34	0.32	0.31	0.30	0.29	0.27	0.30				
	3 mM	T ₃	0.34	0.33	0.31	0.30	0.29	0.28	0.31	0.34	0.33	0.31	0.30	0.29	0.28	0.31				
	4 mM	T ₄	0.34	0.33	0.31	0.30	0.30	0.28	0.31	0.35	0.33	0.32	0.31	0.30	0.29	0.31				
Putrescine	2 mM	T ₅	0.33	0.31	0.30	0.29	0.28	0.26	0.29	0.33	0.32	0.30	0.29	0.28	0.26	0.30				
	3 mM	T ₆	0.33	0.32	0.30	0.29	0.28	0.26	0.30	0.33	0.32	0.30	0.29	0.28	0.27	0.30				
	4 mM	T ₇	0.34	0.32	0.31	0.30	0.29	0.27	0.30	0.34	0.32	0.31	0.30	0.29	0.28	0.31				
	5 mM	T ₈	0.34	0.33	0.31	0.30	0.29	0.28	0.31	0.34	0.33	0.31	0.30	0.29	0.28	0.31				
Control		T ₉	0.33	0.31	0.29	0.28	0.27	0.26	0.29	0.33	0.31	0.30	0.29	0.28	0.26	0.29				
Mean			0.34	0.32	0.30	0.29	0.28	0.27		0.34	0.32	0.31	0.30	0.29	0.27					
C.D. at 5%			Treatment (T) = NS			Days (D) = NS			T×D = NS			Treatment (T) = NS			Days (D) = NS			T×D = NS		



Plate 1: Fruits treated with Salicylic acid @ 4mM on 12th day of storage



Plate 2: Fruits under control treatment on 12th day of storage

4.1.5 TSS: Acid ratio

The data pertaining to TSS: Acid ratio of guava fruits with different post-harvest treatments and days has been presented in Table 4.1.5. Under refrigerator storage, salicylic acid @ 4 mM (T_4) showed maximum TSS: Acid ratio (39.58) that was statistically at par with salicylic acid @ 3 mM (T_3 ; 39.08) and putrescine @ 5 mM (T_8 ; 38.77), while minimum TSS: Acid ratio (37.36) was estimated in control treatment (T_9). Under ambient storage, maximum TSS: Acid ratio (39.07) was observed in T_4 that was statistically at par with T_3 (38.69) and T_8 (38.52), whereas minimum TSS: Acid ratio (36.74) was observed in T_9 (control).

It is evident from the data that TSS: Acid ratio initially increased, thereafter declined with the advancement of storage period and maximum TSS: Acid ratio (40.23) manifested on 8th day of storage (S_4) followed by 10th day of storage (S_5 ; 39.49), whereas minimum TSS: Acid ratio (34.79) was estimated on 2nd day of storage (S_1) under refrigerator condition. In ambient condition, maximum TSS: Acid ratio (40.04) estimated on 6th day of storage (S_3) that was statistically at par with 8th day of storage (S_4 ; 39.84) followed by 10th day of storage (S_5 ; 38.31), while minimum TSS: Acid ratio (35.21) was estimated on 2nd day of storage (S_1).

TSS: Acid ratio was also significantly influenced by the integrated effect of both post-harvest treatments and storage period. Highest value of TSS: Acid ratio (44.47) was recorded in T_4S_5 that was statistically at par with T_3S_5 (42.97), T_3S_6 (42.20) and T_4S_6 (44.37), whereas lowest value was observed in T_4S_1 (33.63) under refrigerator storage. In ambient storage, highest value of TSS: Acid ratio (43.24) was recorded in T_4S_5 that was statistically at par with T_3S_5 (41.99), whereas lowest value was observed in T_4S_1 (33.86).

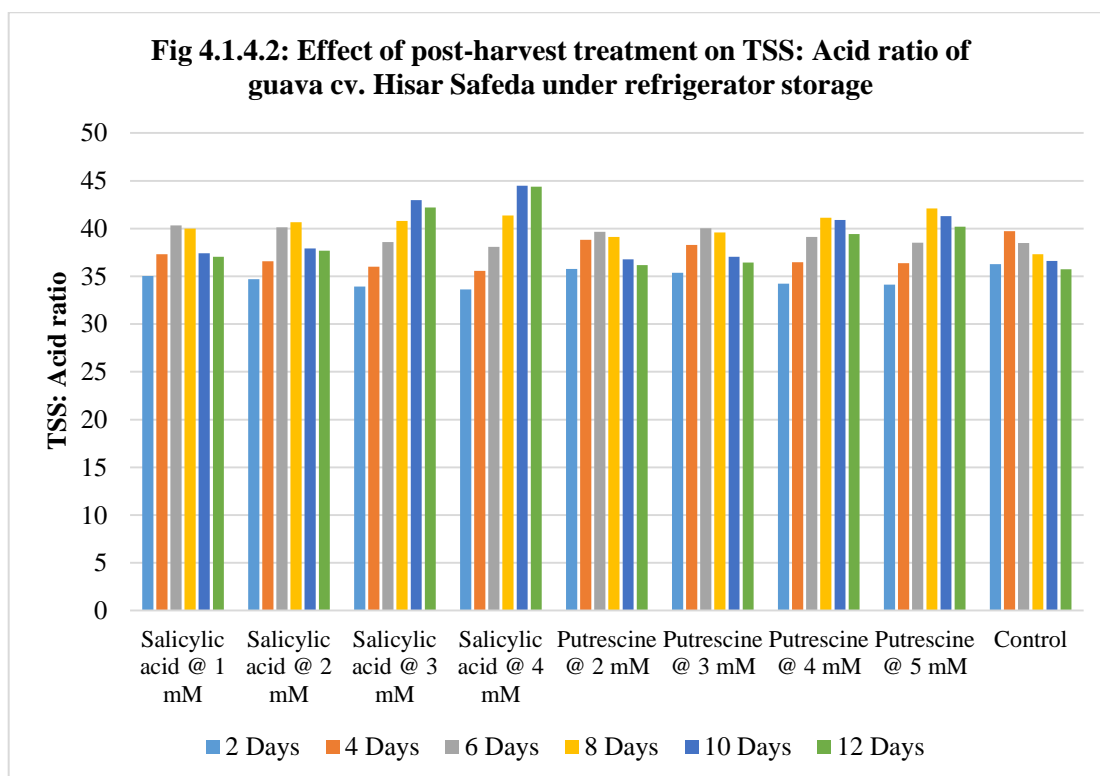
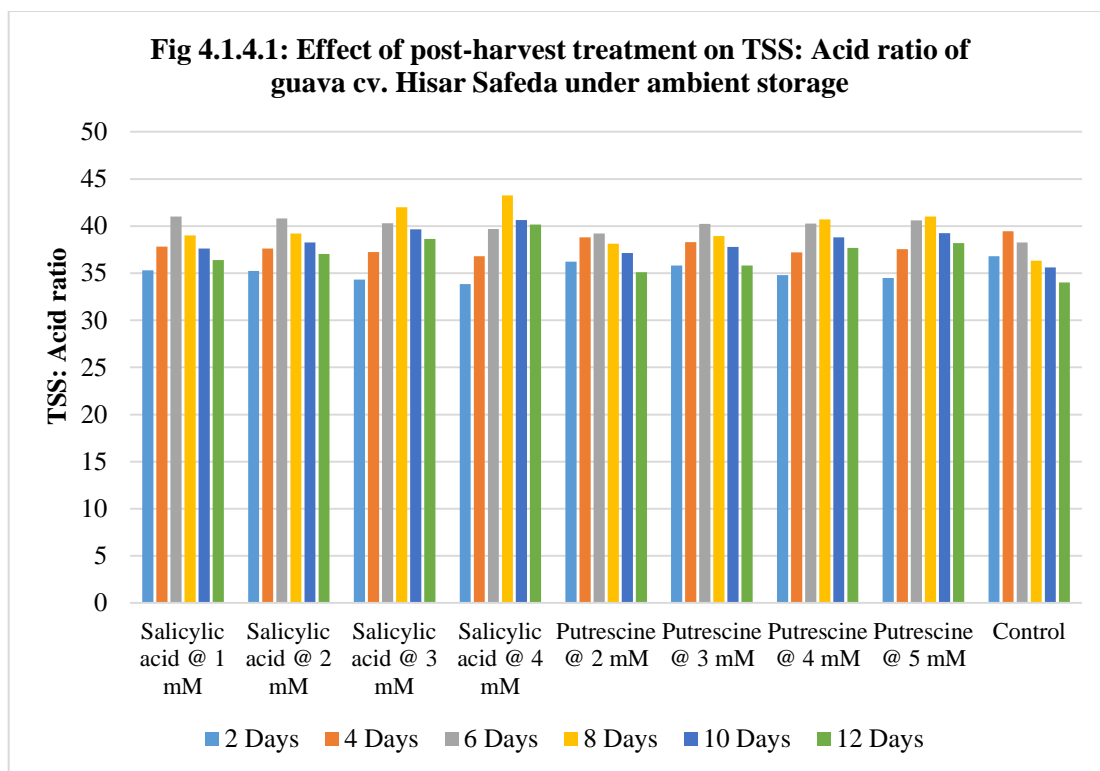
4.1.6 Juice pH

The data related to juice pH has been presented in Table 4.1.6. It is obvious from the data that pH of juice increased including control under both storage conditions. Lowest value of juice pH (5.06 and 5.11) was recorded in fruits treated with salicylic acid @ 4 mM (T_4) which was statistically at par with salicylic acid @ 3 mM (T_3 ; 5.10 and 5.15), while highest value (5.43 and 5.48) was recorded in control treatment (T_9) under refrigerator and ambient storage, respectively.

Among the storage intervals, a significant difference in pH of fruit juice was observed. There was gradual increase in pH of fruit juice with the prolongation of storage period. Lowest juice pH (4.94 and 4.92) was observed on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 5.06 and 5.10), while highest juice pH (5.42 and 5.49) was observed 12th day of storage (S_6) under refrigerator and ambient storage, respectively.

Table 4.1.5: Effect of post-harvest treatment of salicylic acid and putrescine on TSS: Acid ratio of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	35.30	37.81	41.01	39.02	37.60	36.40	37.86	35.03	37.30	40.33	40.00	37.43	37.03	37.86
	2 mM	T ₂	35.24	37.61	40.80	39.21	38.27	37.04	38.03	34.70	36.57	40.13	40.67	37.93	37.67	37.94
	3 mM	T ₃	34.33	37.23	40.30	41.99	39.65	38.64	38.69	33.93	36.00	38.60	40.80	42.97	42.20	39.08
	4 mM	T ₄	33.86	36.79	39.70	43.24	40.65	40.16	39.07	33.63	35.57	38.07	41.37	44.47	44.37	39.58
Putrescine	2 mM	T ₅	36.22	38.81	39.20	38.14	37.13	35.11	37.43	35.77	38.83	39.67	39.13	36.77	36.17	37.72
	3 mM	T ₆	35.80	38.31	40.24	38.94	37.80	35.80	37.81	35.37	38.27	40.03	39.60	37.03	36.43	37.79
	4 mM	T ₇	34.80	37.20	40.25	40.70	38.81	37.70	38.24	34.23	36.47	39.13	41.13	40.90	39.43	38.55
	5 mM	T ₈	34.50	37.55	40.61	41.00	39.25	38.19	38.52	34.13	36.37	38.53	42.10	41.30	40.20	38.77
Control		T ₉	36.81	39.46	38.25	36.31	35.60	34.01	36.74	36.27	39.73	38.50	37.30	36.60	35.73	37.36
Mean			35.21	37.86	40.04	39.84	38.31	37.01		34.79	37.23	39.22	40.23	39.49	38.80	
C.D. at 5%			Treatment (T) = 0.8			Days (D) = 0.7		T×D = 2.1		Treatment (T) = 0.9			Days (D) = 0.7		T×D = 2.2	

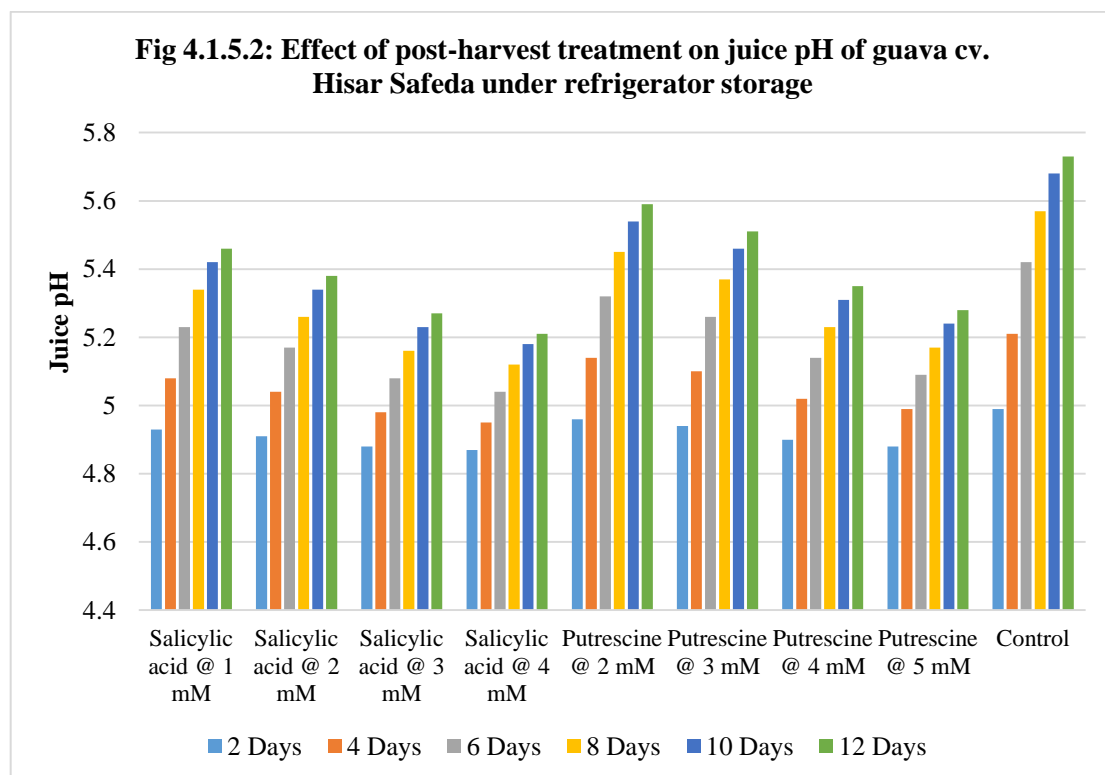
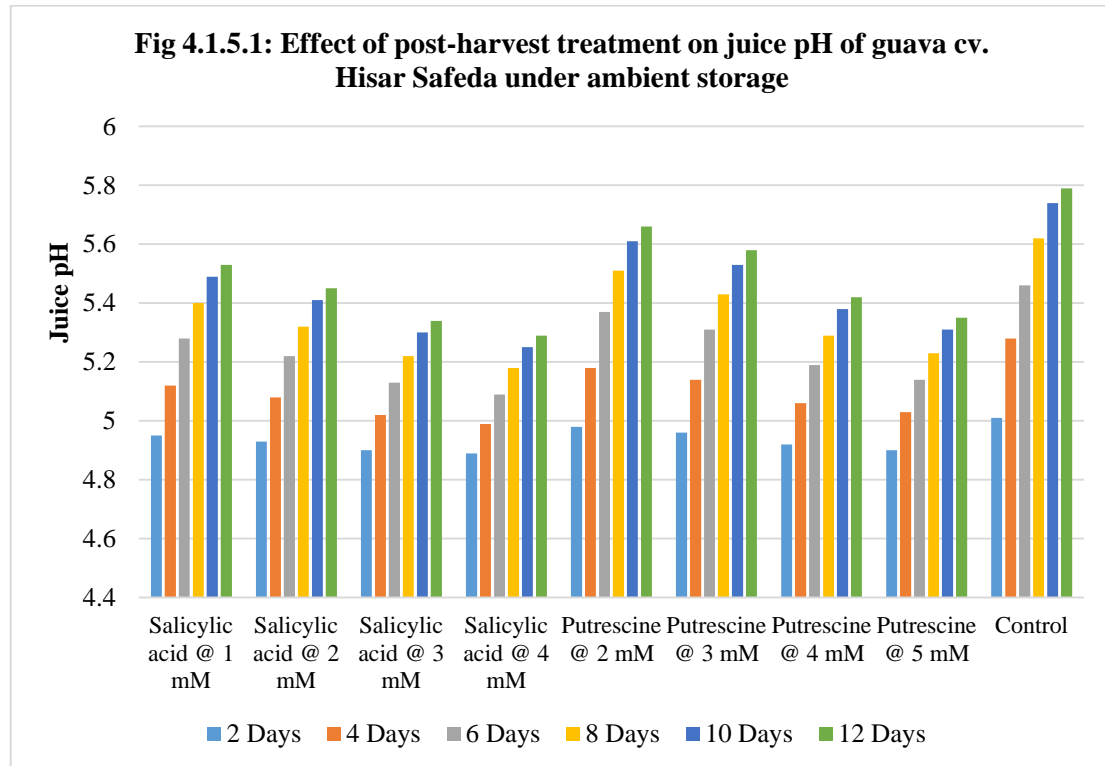


Up to 6th day of storage, no significant difference had been observed in juice pH among different treatments. Minimum pH (5.12 and 5.18) was recorded in fruits treated with salicylic acid 4mM on 8th of storage (T_4S_4) that was statistically at par with T_3S_4 (5.16 and 5.22), T_8S_4 (5.17 and 5.23) and T_4S_5 (5.18 and 5.25), whereas maximum pH (5.73 and 5.79)

Table 4.1.6: Effect of post-harvest treatment of salicylic acid and putrescine on juice pH of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	4.95	5.12	5.28	5.40	5.49	5.53	5.30	4.93	5.08	5.23	5.34	5.42	5.46	5.24
	2 mM	T ₂	4.93	5.08	5.22	5.32	5.41	5.45	5.23	4.91	5.04	5.17	5.26	5.34	5.38	5.18
	3 mM	T ₃	4.90	5.02	5.13	5.22	5.30	5.34	5.15	4.88	4.98	5.08	5.16	5.23	5.27	5.10
	4 mM	T ₄	4.89	4.99	5.09	5.18	5.25	5.29	5.11	4.87	4.95	5.04	5.12	5.18	5.21	5.06
Putrescine	2 mM	T ₅	4.98	5.18	5.37	5.51	5.61	5.66	5.39	4.96	5.14	5.32	5.45	5.54	5.59	5.33
	3 mM	T ₆	4.96	5.14	5.31	5.43	5.53	5.58	5.32	4.94	5.10	5.26	5.37	5.46	5.51	5.27
	4 mM	T ₇	4.92	5.06	5.19	5.29	5.38	5.42	5.21	4.90	5.02	5.14	5.23	5.31	5.35	5.16
	5 mM	T ₈	4.90	5.03	5.14	5.23	5.31	5.35	5.16	4.88	4.99	5.09	5.17	5.24	5.28	5.11
Control		T ₉	5.01	5.28	5.46	5.62	5.74	5.79	5.48	4.99	5.21	5.42	5.57	5.68	5.73	5.43
Mean			4.94	5.10	5.24	5.36	5.45	5.49		4.92	5.06	5.19	5.30	5.38	5.42	
C.D. at 5%			Treatment (T) = 0.04			Days (D) = 0.03		T×D = 0.10		Treatment (T) = 0.04			Days (D) = 0.03		T×D = 0.10	

was observed in control treatment on 12th day of storage (T_9S_6) under refrigerator and ambient storage, respectively.



4.1.7 Pectin content (%)

Results on pectin content of guava fruits as affected by different post-harvest treatments during different period of storage has been presented in Table 4.1.7. It is clearly illustrated that all the post-harvest treatments have significant influence in retaining the pectin content with respect to the control. Among the different treatments, maximum pectin content (1.01 and 0.99%) was observed in fruits treated with salicylic acid @ 4 mM (T_4) that was statistically at par with fruits treated with salicylic acid @ 3 mM (T_3 ; 1.00 and 0.98%) followed by putrescine @ 5 mM (T_8 ; 0.99 and 0.97%), while minimum (0.93 and 0.91%) was observed in control (T_9) under refrigerator and ambient storage, respectively.

Among the storage time, pectin content gradually declined with the advancement of storage period. Maximum pectin content (1.06 and 1.05%) was recorded on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 1.02 and 1.01%) under refrigerator and ambient conditions, respectively. However, minimum pectin content (0.88 and 0.84%) was recorded on 12th day of storage (S_6) under refrigerator and ambient conditions, respectively.

No significant variation has been observed in pectin content among different treatments up to 6th day of storage. Maximum pectin content (1.00 and 0.98%) was recorded in fruits treated with salicylic acid @ 4 mM on 8th of storage (T_4S_4) that was statistically at par with T_3S_4 (0.99 and 0.97%) and T_8S_4 (0.99 and 0.96%), while minimum pectin content (0.81 and 0.77%) was observed in control treatment on 12th day of storage (T_9S_6) under refrigerator and ambient conditions, respectively.

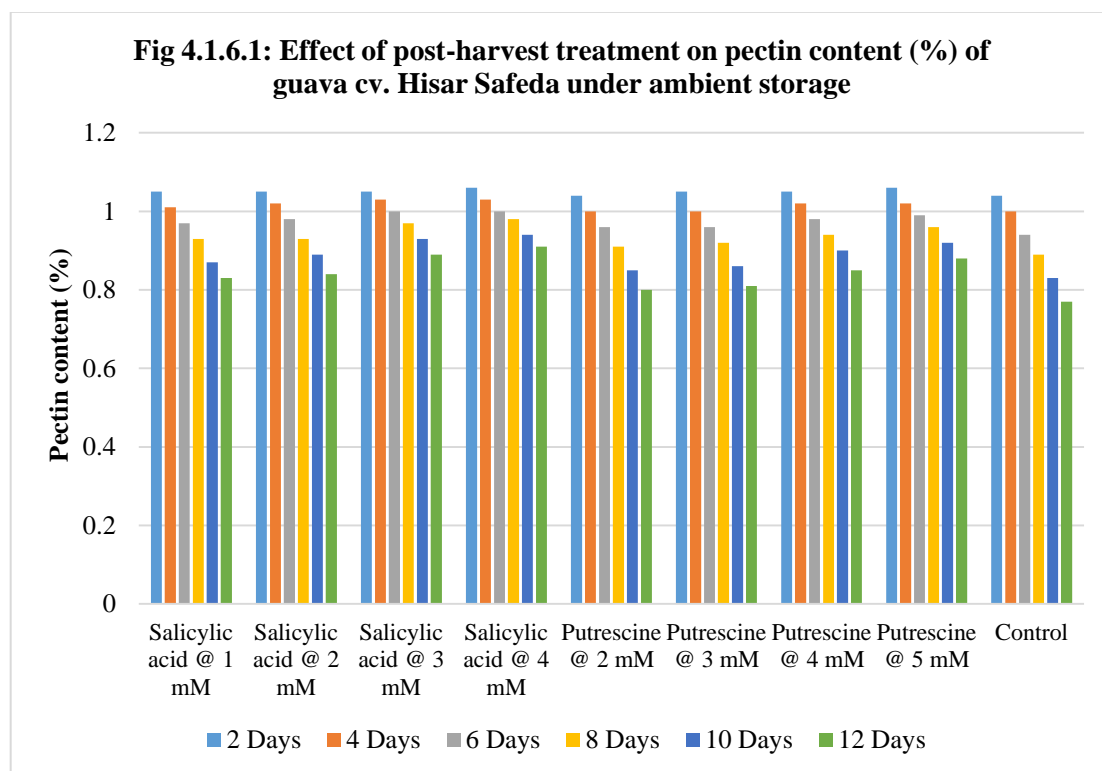
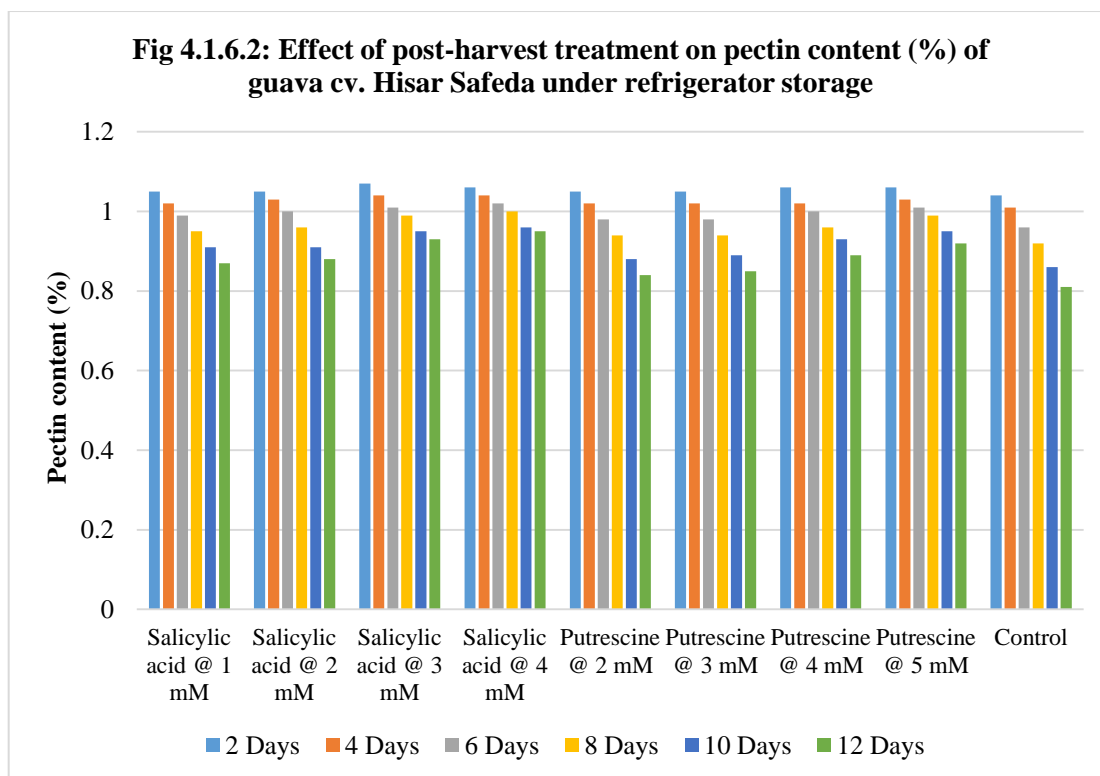


Table 4.1.7: Effect of post-harvest treatment of salicylic acid and putrescine on pectin content (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	1.05	1.01	0.97	0.93	0.87	0.83	0.94	1.05	1.02	0.99	0.95	0.91	0.87	0.96
	2 mM	T ₂	1.05	1.02	0.98	0.93	0.89	0.84	0.95	1.05	1.03	1.00	0.96	0.91	0.88	0.97
	3 mM	T ₃	1.05	1.03	1.00	0.97	0.93	0.89	0.98	1.07	1.04	1.01	0.99	0.95	0.93	1.00
	4 mM	T ₄	1.06	1.03	1.00	0.98	0.94	0.91	0.99	1.06	1.04	1.02	1.00	0.96	0.95	1.01
Putrescine	2 mM	T ₅	1.04	1.00	0.96	0.91	0.85	0.80	0.93	1.05	1.02	0.98	0.94	0.88	0.84	0.95
	3 mM	T ₆	1.05	1.00	0.96	0.92	0.86	0.81	0.93	1.05	1.02	0.98	0.94	0.89	0.85	0.96
	4 mM	T ₇	1.05	1.02	0.98	0.94	0.90	0.85	0.96	1.06	1.02	1.00	0.96	0.93	0.89	0.98
	5 mM	T ₈	1.06	1.02	0.99	0.96	0.92	0.88	0.97	1.06	1.03	1.01	0.99	0.95	0.92	0.99
Control		T ₉	1.04	1.00	0.94	0.89	0.83	0.77	0.91	1.04	1.01	0.96	0.92	0.86	0.81	0.93
Mean			1.05	1.01	0.98	0.94	0.89	0.84		1.06	1.03	0.99	0.96	0.92	0.88	
C.D. at 5%			Treatment (T) = 0.01			Days (D) = 0.01		T×D = 0.03		Treatment (T) = 0.01			Days (D) = 0.01		T×D = 0.03	



4.1.8 Ascorbic acid content (mg/100 g pulp)

The results of ascorbic acid content in guava with different treatments and storage time are shown in Table 4.1.8. It was observed that all the post-harvest treatments had significant effect in maintaining the higher level of ascorbic acid as compared to control. Among the different treatments, fruits treated with salicylic acid @ 4 mM (T_4) showed highest ascorbic content (155.4 mg/100 g pulp) that was statistically at par with salicylic acid @ 3 mM (T_3 ; 154.8 mg/100 g pulp) followed by putrescine @ 5 mM (T_8 ; 154.2 mg/100 g pulp), while control treatment (T_9) showed lowest ascorbic acid (146.8 mg/100 g pulp) under refrigerator storage. Similarly, at ambient storage, T_4 showed highest ascorbic content (151.0 mg/100 g pulp) that was statistically at par with T_3 (150.4 mg/100 g pulp) followed by T_8 (149.8 mg/100 g pulp), while it was lowest (142.9 mg/100 g pulp) in T_9 (control).

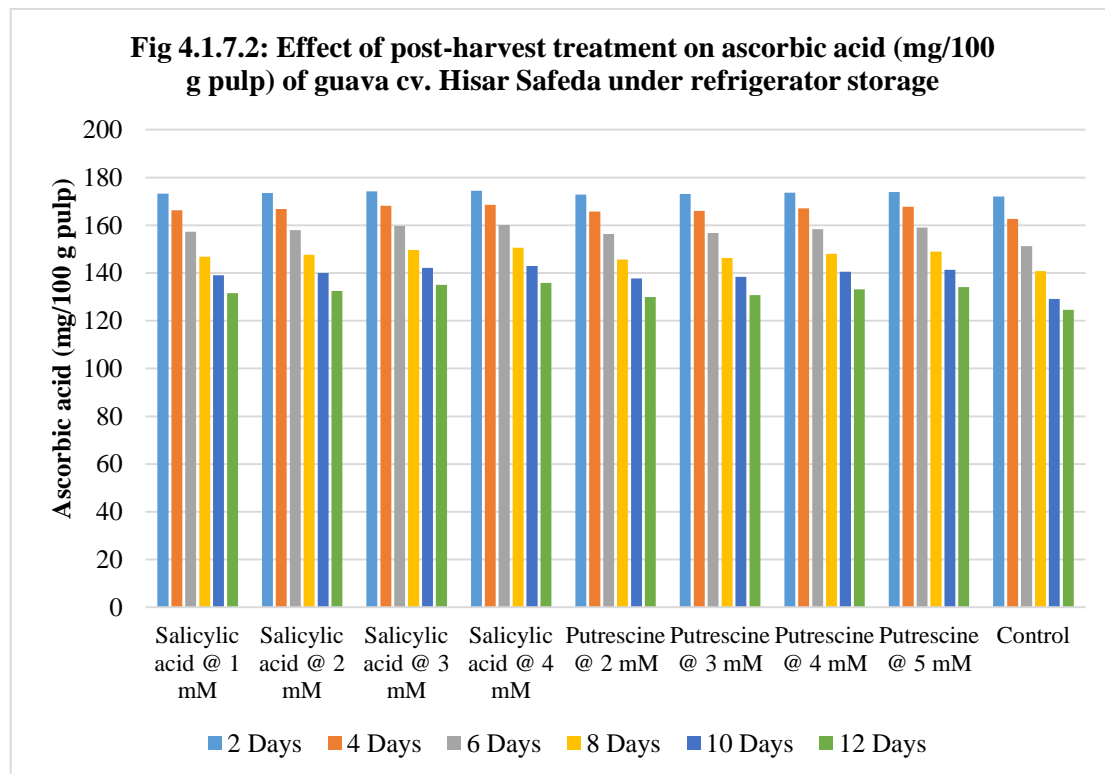
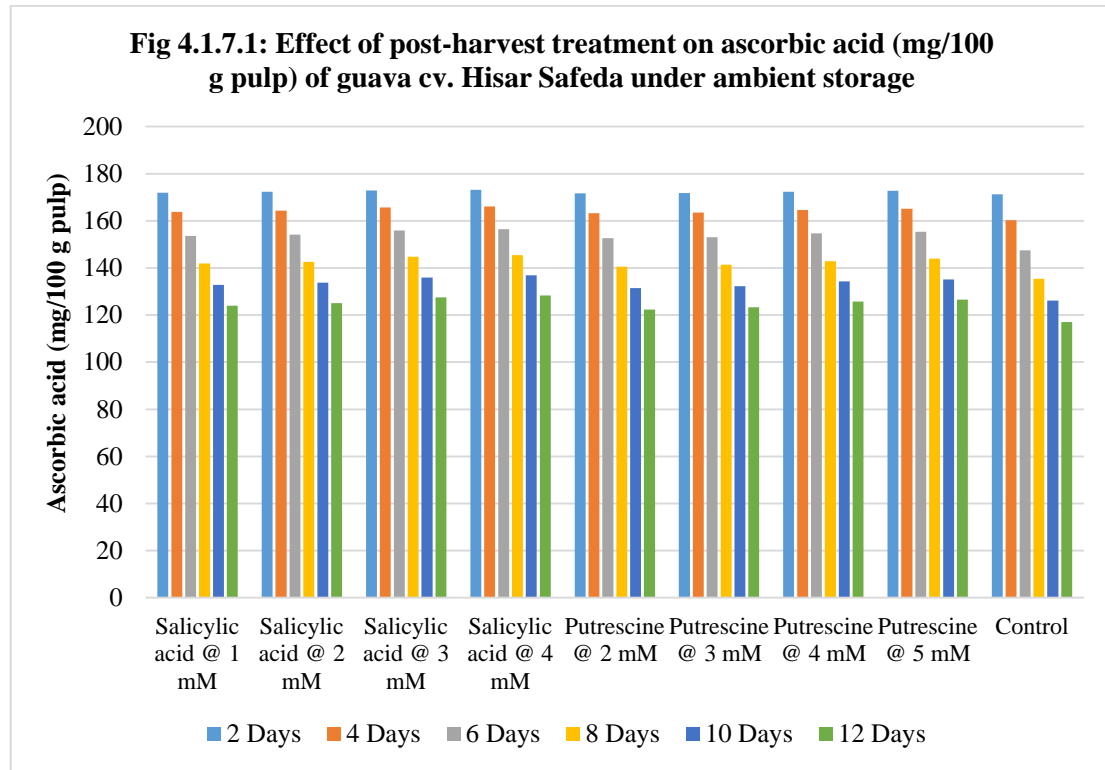
Among the storage time period, ascorbic acid content of the fruits decreased with the advancement of storage time period. Highest ascorbic acid content (173.5 mg/100 g pulp) was recorded on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 166.6 mg/100 g pulp), whereas lowest ascorbic acid content (131.9 mg/100 g pulp) was recorded on 12th day of storage (S_6) under refrigerator condition. Likewise, at ambient condition, highest ascorbic acid content (172.2 mg/100 g pulp) was recorded in S_1 followed by S_2 (164.1 mg/100 g pulp), whereas minimum ascorbic acid content (124.4 mg/100 g pulp) was recorded in S_6 .

Up to 6th day of storage, there was no significant variation in ascorbic acid content among different treatments. Highest ascorbic acid content (150.6 mg/100 g pulp) was recorded in fruits treated with salicylic acid @ 4 mM on 8th of storage

Table 4.1.8: Effect of post-harvest treatment of salicylic acid and putrescine on ascorbic acid content (mg/100 g pulp) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	172.0	163.8	153.6	141.9	132.8	124.0	148.0	173.2	166.3	157.3	146.9	139.1	131.5	152.4
	2 mM	T ₂	172.3	164.3	154.2	142.6	133.7	125.0	148.7	173.5	166.8	158.0	147.7	140.0	132.5	153.1
	3 mM	T ₃	172.9	165.7	155.9	144.7	135.9	127.5	150.4	174.2	168.2	159.7	149.7	142.2	135.0	154.8
	4 mM	T ₄	173.2	166.1	156.4	145.4	136.9	128.3	151.1	174.5	168.6	160.1	150.6	142.9	135.8	155.4
Putrescine	2 mM	T ₅	171.7	163.2	152.6	140.6	131.5	122.4	147.0	172.9	165.7	156.4	145.6	137.7	130.0	151.4
	3 mM	T ₆	171.8	163.5	153.1	141.3	132.2	123.3	147.5	173.1	166.0	156.8	146.3	138.4	130.7	151.9
	4 mM	T ₇	172.4	164.6	154.7	142.9	134.3	125.7	149.1	173.7	167.1	158.4	148.1	140.6	133.2	153.5
	5 mM	T ₈	172.7	165.2	155.3	143.9	135.1	126.6	149.8	173.9	167.7	159.1	149.0	141.4	134.1	154.2
Control		T ₉	171.2	160.2	147.5	135.4	126.2	117.1	142.9	172.1	162.7	151.2	140.8	129.1	124.6	146.8
Mean			172.2	164.1	153.7	142.1	133.2	124.4		173.5	166.6	157.5	147.2	139.0	131.9	
C.D. at 5%			Treatment (T) = 0.9			Days (D) = 0.7		T×D = 2.2		Treatment (T) = 1.1			Days (D) = 0.9		T×D = 2.4	

(T₄S₄) that was statistically at par with T₃S₄ (149.7 mg/100 g pulp) and T₈S₄ (149.0 mg/100 g pulp), whereas lowest ascorbic acid content (124.6 mg/100 g pulp) was observed in control treatment on 12th day of storage (T₉S₆) under refrigerator condition. Likewise, at ambient temperature, highest ascorbic acid content (145.4 mg/100 g pulp) was recorded in T₄S₄ that was



statistically at par with T₃S₄ (144.7 mg/100 g pulp) and T₈S₄ (143.9 mg/100 g pulp), while lowest ascorbic acid content (117.1 mg/100 g pulp) was observed in control treatment on 12th day of storage (T₉S₆).

4.1.9 Total sugars (%)

The observations regarding effect of various post-harvest treatments and storage period on total sugars of guava fruits presented in Table 4.1.9. It was observed that total sugars initially increased, afterward declined with advancement of storage period under all treatment including control but all the treatments reduced the rate of declining and maintained higher level of total sugars as compared to control at the end of storage under both conditions. Among the different treatments, fruits treated with salicylic acid @ 4 mM (T₄) showed maximum level of total sugars (7.36 and 7.51%) followed by salicylic acid @ 3 mM (T₃; 7.24 and 7.44%), whereas control treatment (T₉) showed minimum level of total sugars (7.06 and 6.90%) under refrigerator and ambient storage, respectively.

Among the storage period, Maximum total sugars (7.47%) was recorded on 8th day of storage (S₄) that was statistically at par with 6th day of storage (S₃; 7.46%), while minimum was recorded on 2nd day of storage (S₁; 6.66%) under refrigerator condition. At ambient condition, maximum total sugars (7.56%) were recorded on 6th day of storage (S₃) that was statistically at par with 4th day of storage (S₂; 7.52%), while minimum was recorded on 12th day of storage (S₆; 6.78%).

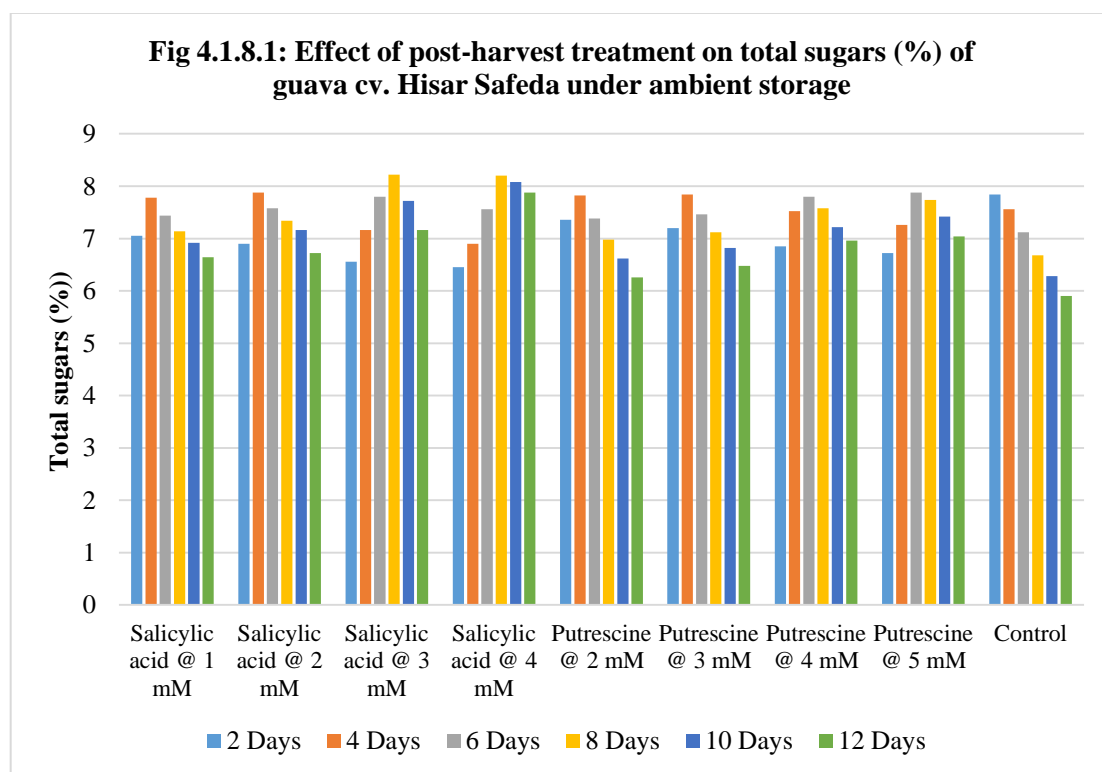
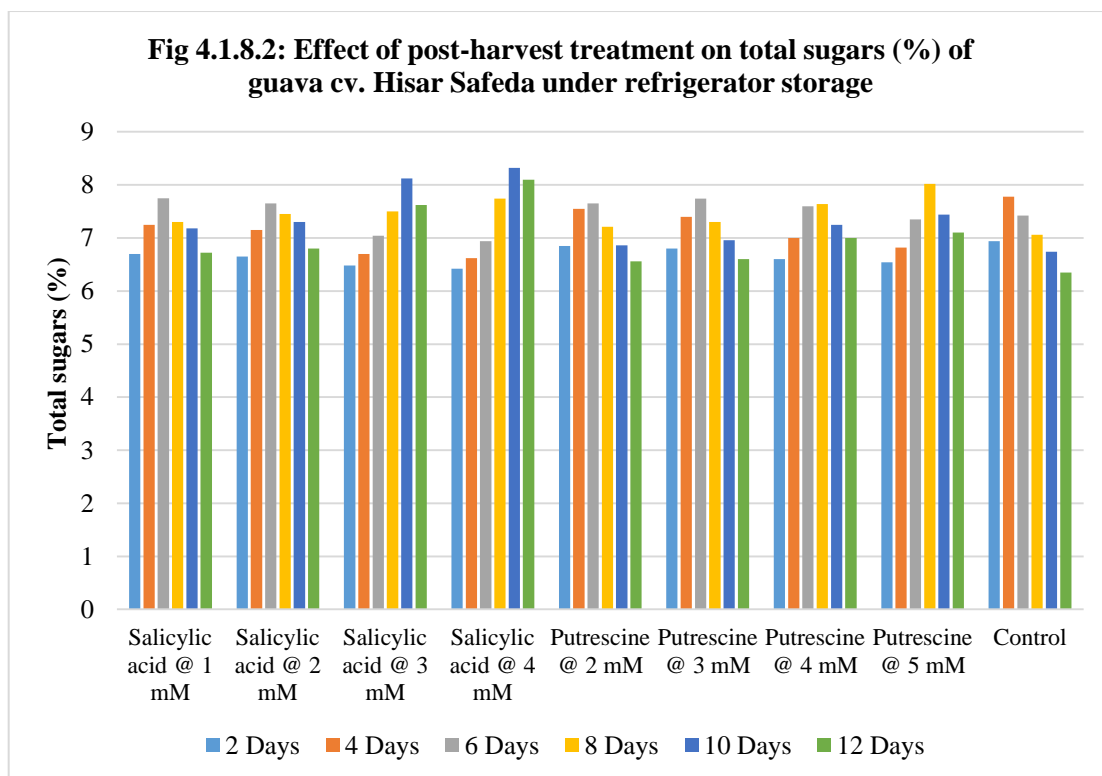


Table 4.1.9: Effect of post-harvest treatment of salicylic acid and putrescine on total sugars (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	7.05	7.78	7.44	7.14	6.92	6.64	7.16	6.70	7.25	7.75	7.30	7.18	6.72	7.15
	2 mM	T ₂	6.90	7.88	7.58	7.34	7.16	6.72	7.26	6.65	7.15	7.65	7.45	7.30	6.80	7.17
	3 mM	T ₃	6.56	7.16	7.80	8.22	7.72	7.16	7.44	6.48	6.70	7.04	7.50	8.12	7.62	7.24
	4 mM	T ₄	6.45	6.90	7.56	8.20	8.08	7.88	7.51	6.42	6.62	6.94	7.74	8.32	8.10	7.36
Putrescine	2 mM	T ₅	7.36	7.82	7.38	6.98	6.62	6.26	7.07	6.85	7.55	7.65	7.21	6.86	6.56	7.11
	3 mM	T ₆	7.20	7.84	7.46	7.12	6.82	6.48	7.15	6.80	7.40	7.74	7.30	6.96	6.60	7.13
	4 mM	T ₇	6.85	7.52	7.80	7.58	7.22	6.96	7.32	6.60	7.00	7.60	7.64	7.25	7.00	7.18
	5 mM	T ₈	6.72	7.26	7.88	7.74	7.42	7.04	7.34	6.54	6.82	7.35	8.02	7.44	7.10	7.21
Control		T ₉	7.84	7.56	7.12	6.68	6.28	5.90	6.90	6.94	7.78	7.42	7.06	6.74	6.35	7.05
Mean			6.99	7.52	7.56	7.45	7.14	6.78		6.66	7.14	7.46	7.47	7.35	6.98	
C.D. at 5%			Treatment (T) = 0.05			Days (D) = 0.04		T×D = 0.12		Treatment (T) = 0.07			Days (D) = 0.06		T×D = 0.18	



Total sugars were also significantly influenced by the integrated effect of both post-harvest treatments and storage period. Highest level of Total sugars (8.32%) was recorded in T₄S₅ followed by T₃S₅ (8.12%), whereas lowest level was observed in T₉S₆ (6.35%) under refrigerator storage condition. At ambient storage, highest level of Total sugars (8.22) was recorded in T₃S₅ that was statistically at par with T₄S₅ (8.20%), while lowest level was observed in T₉S₆ (5.90%).

4.1.10 Reducing sugar (%)

The data pertaining to reducing sugars in guava as affected by post-harvest treatments shows an increasing-decreasing trend during the storage period as presented in Table 4.1.10. All treatments influenced the reducing sugar level. Under refrigerator storage, maximum reducing sugar content (5.14%) was observed in fruits treated with salicylic acid @ 4 mM (T₄) followed by salicylic acid @ 3 mM (T₃; 5.06%) whereas, minimum reducing sugars (4.89%) was observed in control treatment (T₉). Likewise, under ambient storage, maximum reducing sugars (5.25%) was observed in T₄ followed by T₃ (5.20%) and minimum (4.82%) in T₉ (control).

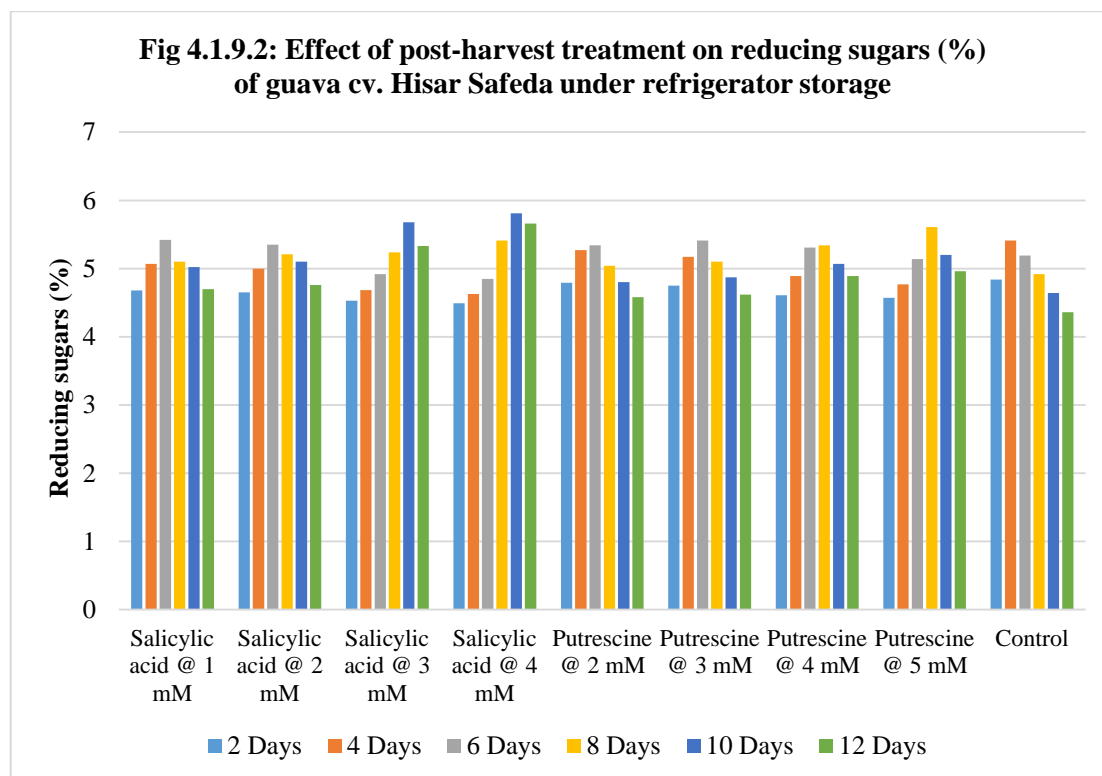
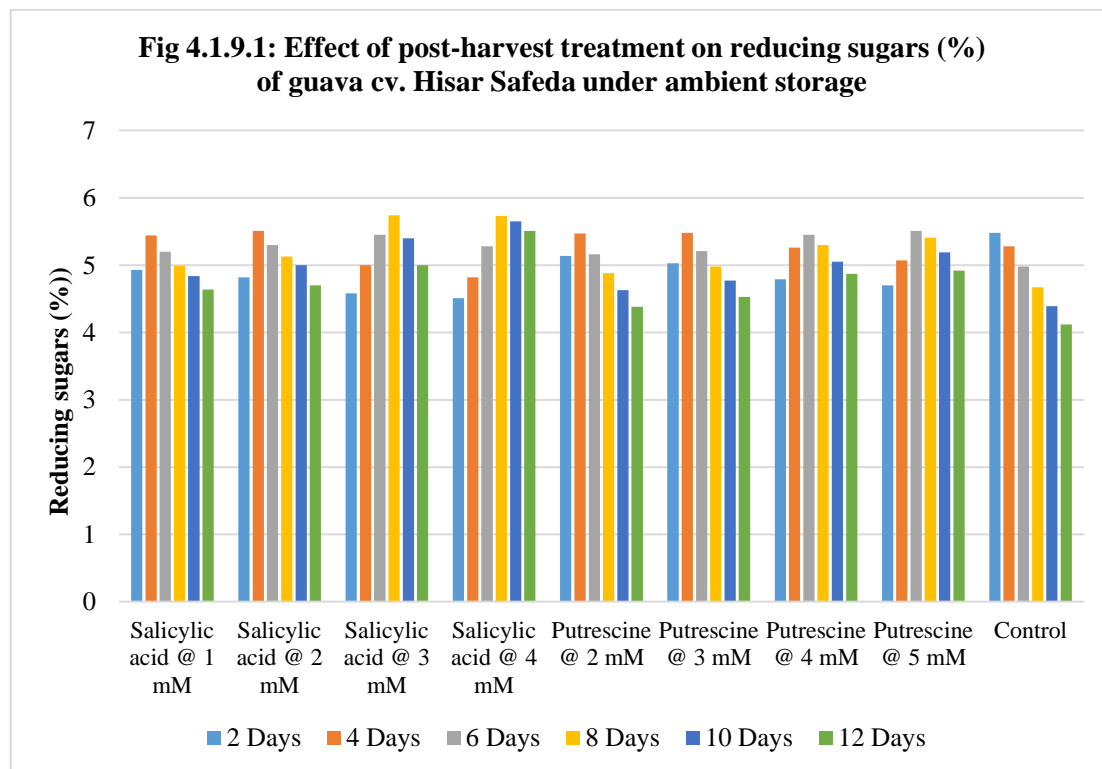
All storage intervals significantly affected the level of reducing sugar irrespective of the treatments applied. Maximum reducing sugars (5.22%) was recorded on 8th day of storage (S₄) and was statistically at par with 6th day of storage (S₃; 5.21%), while minimum was recorded on 2nd day of storage (S₁; 4.66%) under refrigerator condition. At ambient condition, maximum reducing sugars content (5.28%) was recorded on

Table 4.1.10: Effect of post-harvest treatment of salicylic acid and putrescine on reducing sugar (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage										
			Storage Period							Storage Period										
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean				
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆					
Salicylic acid	1 mM	T ₁	4.93	5.44	5.20	4.99	4.84	4.64	5.01	4.68	5.07	5.42	5.10	5.02	4.70	5.00				
	2 mM	T ₂	4.82	5.51	5.30	5.13	5.00	4.70	5.08	4.65	5.00	5.35	5.21	5.10	4.76	5.01				
	3 mM	T ₃	4.58	5.00	5.45	5.74	5.40	5.00	5.20	4.53	4.683	4.92	5.24	5.68	5.33	5.06				
	4 mM	T ₄	4.51	4.82	5.28	5.73	5.65	5.51	5.25	4.49	4.63	4.85	5.41	5.81	5.66	5.14				
Putrescine	2 mM	T ₅	5.14	5.47	5.16	4.88	4.63	4.38	4.94	4.79	5.27	5.34	5.04	4.80	4.58	4.97				
	3 mM	T ₆	5.03	5.48	5.21	4.98	4.77	4.53	5.00	4.75	5.17	5.41	5.10	4.87	4.62	4.99				
	4 mM	T ₇	4.79	5.26	5.45	5.30	5.05	4.87	5.12	4.61	4.89	5.31	5.34	5.07	4.89	5.02				
	5 mM	T ₈	4.70	5.07	5.51	5.41	5.19	4.92	5.13	4.57	4.77	5.14	5.61	5.20	4.96	5.04				
Control		T ₉	5.48	5.28	4.98	4.67	4.39	4.12	4.82	4.84	5.41	5.19	4.92	4.64	4.36	4.89				
Mean			4.89	5.26	5.28	5.20	4.99	4.74		4.66	4.99	5.21	5.22	5.13	4.87					
C.D. at 5%			Treatment (T) = 0.03			Days (D) = 0.03			T×D = 0.08			Treatment (T) = 0.05			Days (D) = 0.04			T×D = 0.12		

6th day of storage (S₃) that was statistically at par with 4th day of storage (S₂; 5.26%), while minimum was recorded on 12th day of storage (S₆; 4.74%).

Combined effect of post-harvest treatments and storage time also significantly influenced the reducing sugar level. Maximum reducing sugar (5.82%) was recorded in T₄S₅



followed by T₃S₅ (5.69%), whereas minimum was observed in T₉S₆ (4.36%) under refrigerator storage condition. In ambient storage, maximum reducing sugar (5.74%) was recorded in T₃S₅ that was statistically at par with T₄S₅ (5.73%), while minimum was observed in T₉S₆ (4.12%).

4.1.11 Non-reducing sugar (%)

The data regarding non-reducing sugars have been presented in Table 4.1.11. Non-reducing sugars varied significantly among the different post-harvest treatments. Under refrigerator storage, fruits treated with salicylic acid @ 4 mM (T₄) showed maximum non-reducing sugar content (2.21%) followed by salicylic acid @ 3 mM (T₃; 2.18%), whereas control (T₉) showed minimum non-reducing sugars (2.11%). At ambient storage, T₄ showed maximum non-reducing sugars (2.26%) followed by T₃ (2.15%), while T₉ (control) showed minimum non-reducing sugar (2.07%).

Regardless of post-harvest treatment, storage period also significantly affected the non-reducing sugar content. An increasing-decreasing pattern of non-reducing sugar was observed during the storage. Maximum non-reducing sugar content (2.25%) was recorded on 6th (S₃) and 8th day of storage (S₄) both followed by 10th day of storage (S₅; 2.21%), while minimum was recorded on 2nd day of storage (S₁; 2.01%) under refrigerator condition. In ambient condition, maximum reducing sugar content (2.28%) was recorded on 6th day of storage (S₃) that was statistically at par with 4th day of storage (S₂; 2.27%), while minimum was recorded on 12th day of storage (S₆; 2.04%).

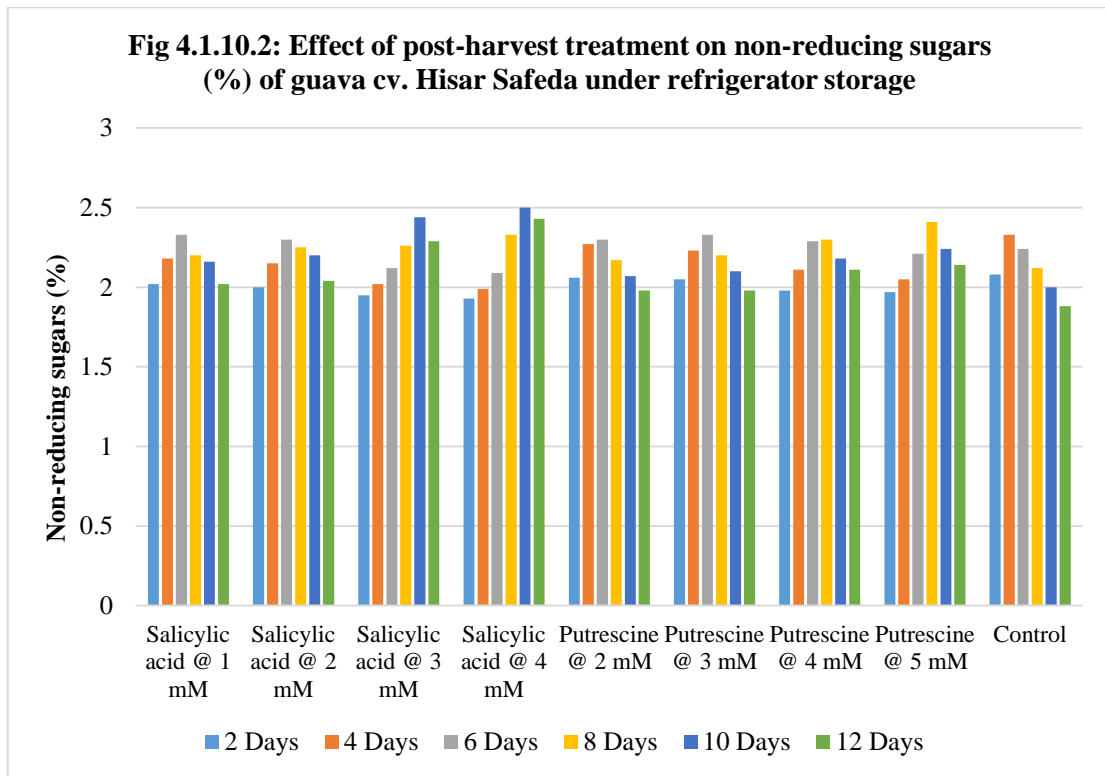
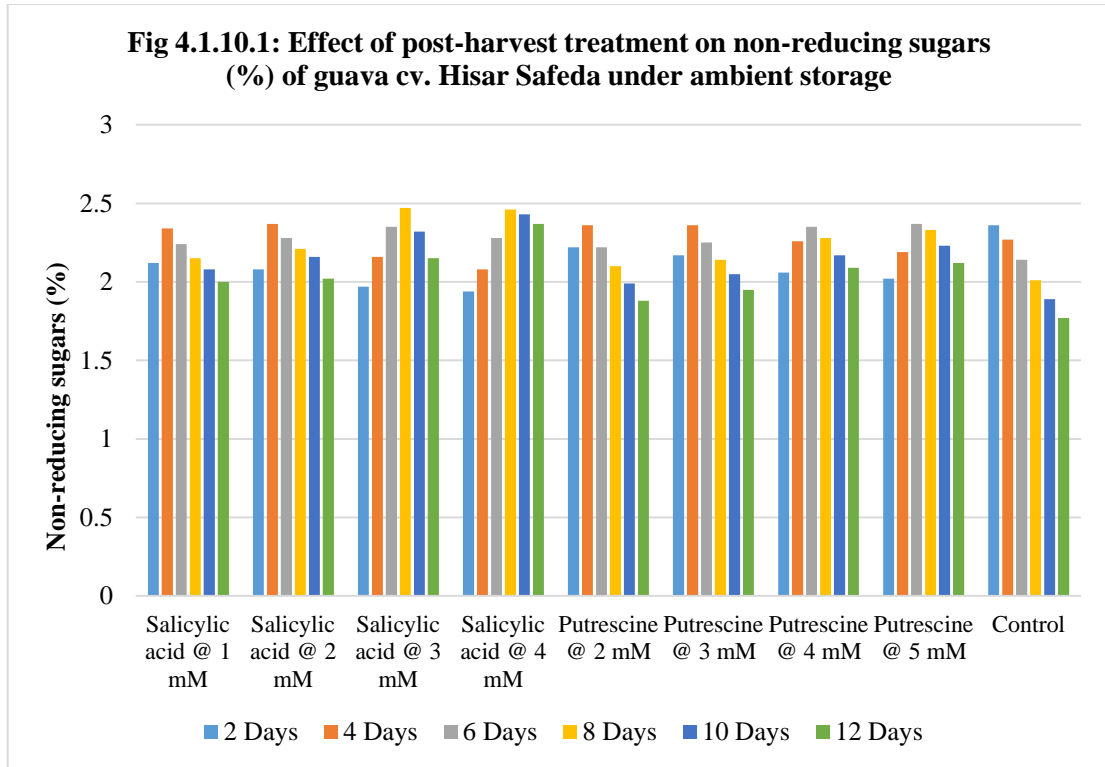
The interaction between post-harvest treatments and storage time influenced the non-reducing sugars significantly. Maximum non-reducing sugar content (2.50%) was recorded in T₄S₅ followed by T₃S₅ (2.44%), while minimum non-reducing sugar content (1.88%) was recorded in T₉S₆ under refrigerator storage. Likewise, under ambient storage, Maximum non-reducing sugar content (2.47%) was recorded in T₃S₄ which was statistically at par with T₄S₄ (2.46%) followed by T₄S₅ (2.43%), whereas minimum non-reducing sugar content (1.77%) was recorded in T₉S₆.

4.1.12 Organoleptic rating

The observations recorded on organoleptic rating of guava fruits as affected by different post-harvest treatments during different period of storage are presented in Table 4.1.12. It is evident from the data that all the post-harvest treatments had significant effect in maintaining the higher organoleptic rating as compared to control. Among the different treatments, fruits treated with salicylic acid @ 4 mM (T₄) exhibited maximum organoleptic rating (8.00) followed by salicylic acid @ 3 mM (T₃; 7.84) and putrescine @ 5 mM (T₈; 7.87), while control treatment (T₉) exhibited minimum organoleptic rating (6.93) under refrigerator

Table 4.1.11: Effect of post-harvest treatment of salicylic acid and putrescine on non-reducing sugar (%) of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	2.12	2.34	2.24	2.15	2.08	2.00	2.16	2.02	2.18	2.33	2.20	2.16	2.02	2.15
	2 mM	T ₂	2.08	2.37	2.28	2.21	2.16	2.02	2.19	2.00	2.15	2.30	2.25	2.20	2.04	2.16
	3 mM	T ₃	1.97	2.16	2.35	2.47	2.32	2.15	2.24	1.95	2.02	2.12	2.26	2.44	2.29	2.18
	4 mM	T ₄	1.94	2.08	2.28	2.46	2.43	2.37	2.26	1.93	1.99	2.09	2.33	2.50	2.43	2.21
Putrescine	2 mM	T ₅	2.22	2.36	2.22	2.10	1.99	1.88	2.13	2.06	2.27	2.30	2.17	2.07	1.98	2.14
	3 mM	T ₆	2.17	2.36	2.25	2.14	2.05	1.95	2.15	2.05	2.23	2.33	2.20	2.10	1.98	2.15
	4 mM	T ₇	2.06	2.26	2.35	2.28	2.17	2.09	2.20	1.98	2.11	2.29	2.30	2.18	2.11	2.16
	5 mM	T ₈	2.02	2.19	2.37	2.33	2.23	2.12	2.21	1.97	2.05	2.21	2.41	2.24	2.14	2.17
Control		T ₉	2.36	2.27	2.14	2.01	1.89	1.77	2.07	2.08	2.33	2.24	2.12	2.00	1.88	2.11
Mean			2.11	2.27	2.28	2.24	2.15	2.04		2.01	2.15	2.25	2.25	2.21	2.10	
C.D. at 5%			Treatment (T) = 0.02			Days (D) = 0.01		T×D = 0.04		Treatment (T) = 0.02			Days (D) = 0.02		T×D = 0.05	



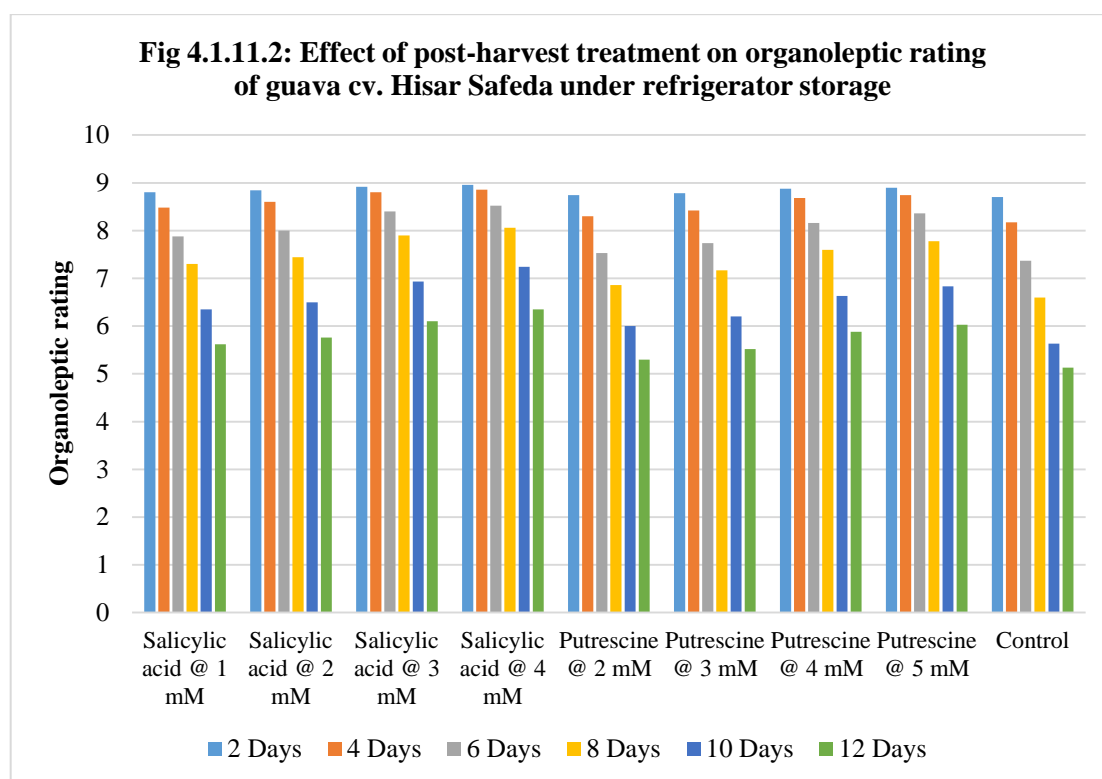
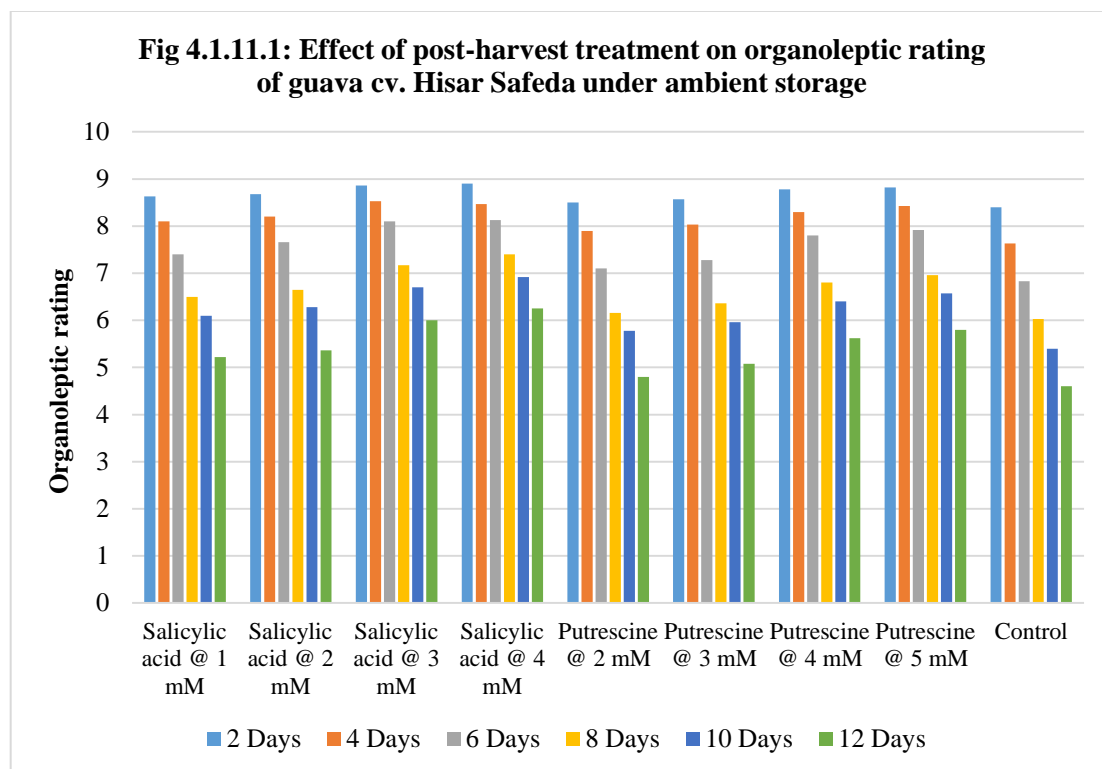
storage. Likewise, at ambient storage, T₄ exhibited maximum organoleptic rating (7.68) followed by T₃ (7.56), while it was minimum (6.48) in T₉ (control).

Storage period also had significant influence on palatability of fruits as organoleptic rating decreased with prolongation of storage time. Maximum organoleptic (8.84 and 8.64) was observed on 2nd day of storage (S₁) followed by 4th day of storage (S₂; 8.56 and 8.18),

Table 4.1.12: Effect of post-harvest treatment of salicylic acid and putrescine on organoleptic rating of guava cv. Hisar Safeda

Treatments			Ambient Storage							Refrigerator Storage						
			Storage Period							Storage Period						
			2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
			S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
Salicylic acid	1 mM	T ₁	8.63	8.10	7.40	6.50	6.10	5.22	6.99	8.80	8.48	7.88	7.30	6.35	5.62	7.41
	2 mM	T ₂	8.68	8.20	7.66	6.65	6.28	5.36	7.14	8.84	8.60	8.00	7.44	6.50	5.76	7.52
	3 mM	T ₃	8.86	8.53	8.10	7.17	6.70	6.00	7.56	8.92	8.80	8.40	7.90	6.93	6.10	7.84
	4 mM	T ₄	8.90	8.47	8.13	7.40	6.92	6.25	7.68	8.96	8.86	8.52	8.06	7.24	6.35	8.00
Putrescine	2 mM	T ₅	8.50	7.90	7.10	6.16	5.78	4.80	6.71	8.74	8.30	7.53	6.86	6.00	5.30	7.12
	3 mM	T ₆	8.57	8.03	7.28	6.36	5.96	5.08	6.88	8.78	8.42	7.74	7.17	6.20	5.52	7.30
	4 mM	T ₇	8.78	8.30	7.80	6.80	6.40	5.62	7.28	8.88	8.68	8.16	7.60	6.63	5.88	7.64
	5 mM	T ₈	8.82	8.43	7.92	6.96	6.57	5.80	7.42	8.90	8.74	8.36	7.78	6.83	6.03	7.77
Control		T ₉	8.40	7.63	6.83	6.03	5.40	4.60	6.48	8.70	8.17	7.37	6.60	5.63	5.13	6.93
Mean			8.68	8.18	7.58	6.67	6.23	5.41		8.84	8.56	8.00	7.41	6.48	5.74	
C.D. at 5%			Treatment (T) = 0.08			Days (D) = 0.07		T×D = 0.21		Treatment (T) = 0.08			Days (D) = 0.06		T×D = 0.20	

whereas minimum (5.74 and 5.41) was observed on 12th day of storage (S₆) under refrigerator and ambient condition, respectively.



Under refrigerator storage, no significant variation has been observed in organoleptic rating among different treatments up to 2nd day of storage. Maximum organoleptic rating

(8.86) was recorded in fruits treated with salicylic acid @ 4 mM on 4th of storage (T₄S₂) that was statistically at par with T₃S₂ (8.80), T₈S₂ (8.74) and T₇S₂ (8.80), while minimum organoleptic rating (5.13) was observed in control treatment on 12th day of storage (T₉S₆). Under ambient storage, maximum organoleptic rating (8.90) was recorded in T₄S₁ that was statistically at par with T₃S₁ (8.86), T₈S₁ (8.82) and T₇S₁ (8.78), while minimum organoleptic rating (4.60) was observed in control on 12th day of storage (T₉S₆).

4.2 Experiment II: Effect of different packaging films on the shelf-life of guava fruit.

4.2.1 Physiological loss in weight (%)

The data presented in Table 4.2.1 reveal that different packaging films and storage time significantly influenced the physiological loss in weight (PLW) of guava. Under refrigerator storage, among the different packaging films, minimum PLW (1.36%) was recorded in fruits packed with HDPE 25 micron (T₂) followed by LDPE 25 micron (T₁; 1.47%). Similarly, at ambient storage, minimum PLW (2.60%) was recorded in fruits packed with HDPE 25 micron (T₂) followed by fruits packed with LDPE 25 micron (T₁; 2.87%). The maximum PLW (2.32 and 4.18%) was recorded in control treatment (T₅) under refrigerator and ambient storage, respectively.

PLW decreased with the period of time during the storage studies. The minimum PLW (1.25 and 2.17%) was recorded on 12th day of storage (S₆) followed by 10th day of storage (S₅; 1.44 and 2.49%) under refrigerator and ambient conditions, respectively. The maximum PLW (2.25 and 4.00%) was recorded on 2nd day of storage (S₁) under refrigerator and ambient conditions, respectively.

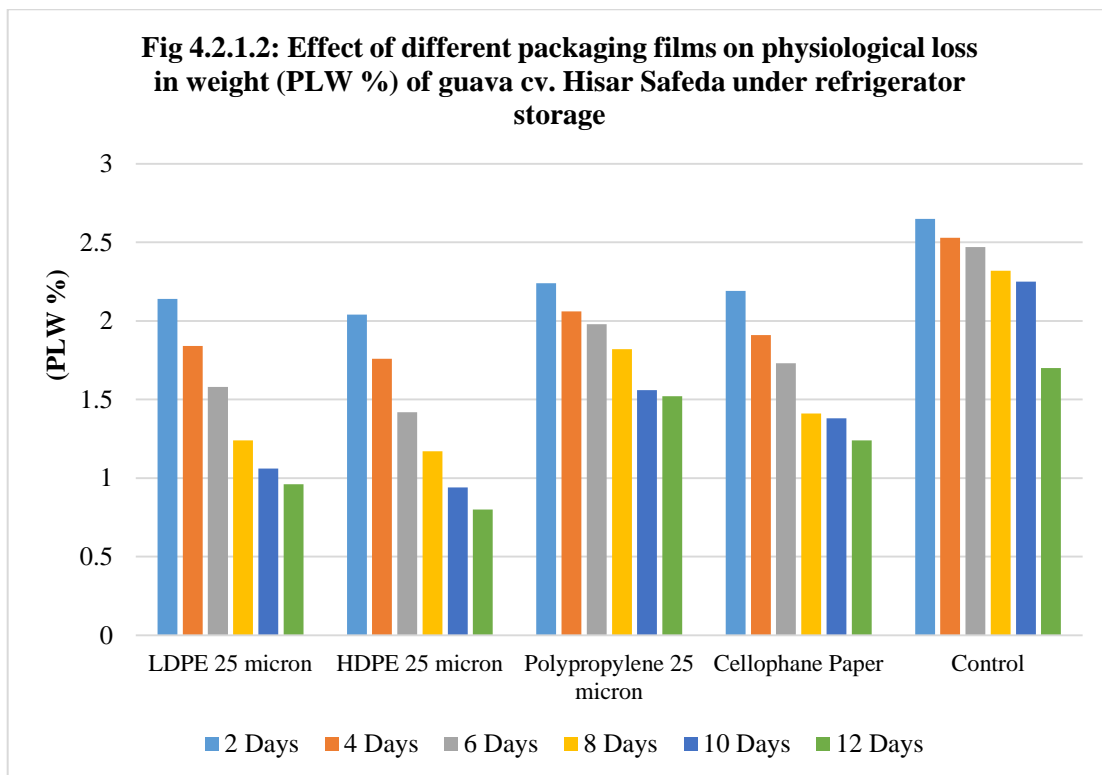
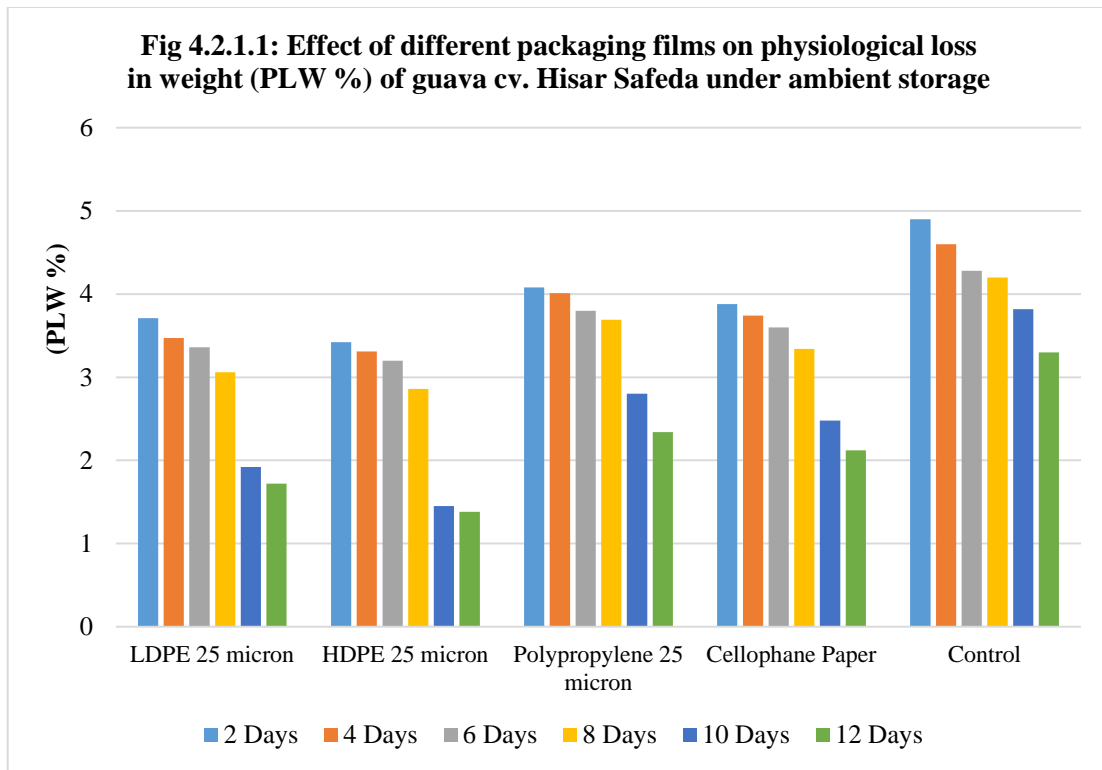
The interaction between different packaging films and storage time was found to influence physiological loss in weight significantly under refrigerator storage. Among the different packaging films in refrigerator condition, the minimum PLW (0.80%) was observed in fruits packed with HDPE 25 micron on 12th day of storage (T₂S₆) that was statistically at par with T₂S₅ (0.94%), T₁S₆ (0.96%) and T₁S₅ (1.06%) while the maximum PLW (2.65%) was observed in control treatment on 2nd day of storage (T₅S₁). In ambient storage, the interaction between different packaging films and storage time was found to non-significantly influence physiological loss in weight.

4.2.2 Decay loss (%)

The data pertaining to decay loss of guava fruits wrapped in different packaging films under refrigerator and ambient storage has been presented in Table 4.2.2. It is clear from the data that all packaging films had significant effect in reducing the decay loss than control under both storage conditions. Under refrigerator storage, minimum decay loss (2.22%) was

Table 4.2.1: Effect of different packaging films on physiological loss in weight (PLW %) of guava cv. Hisar Safeda

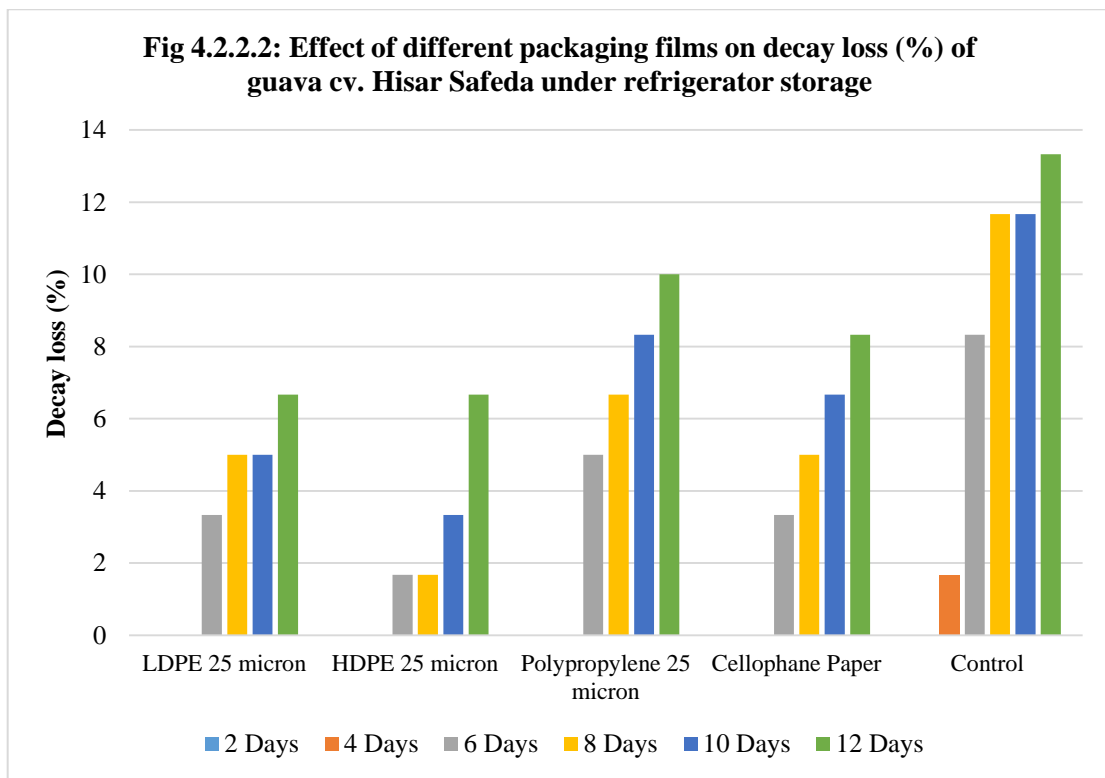
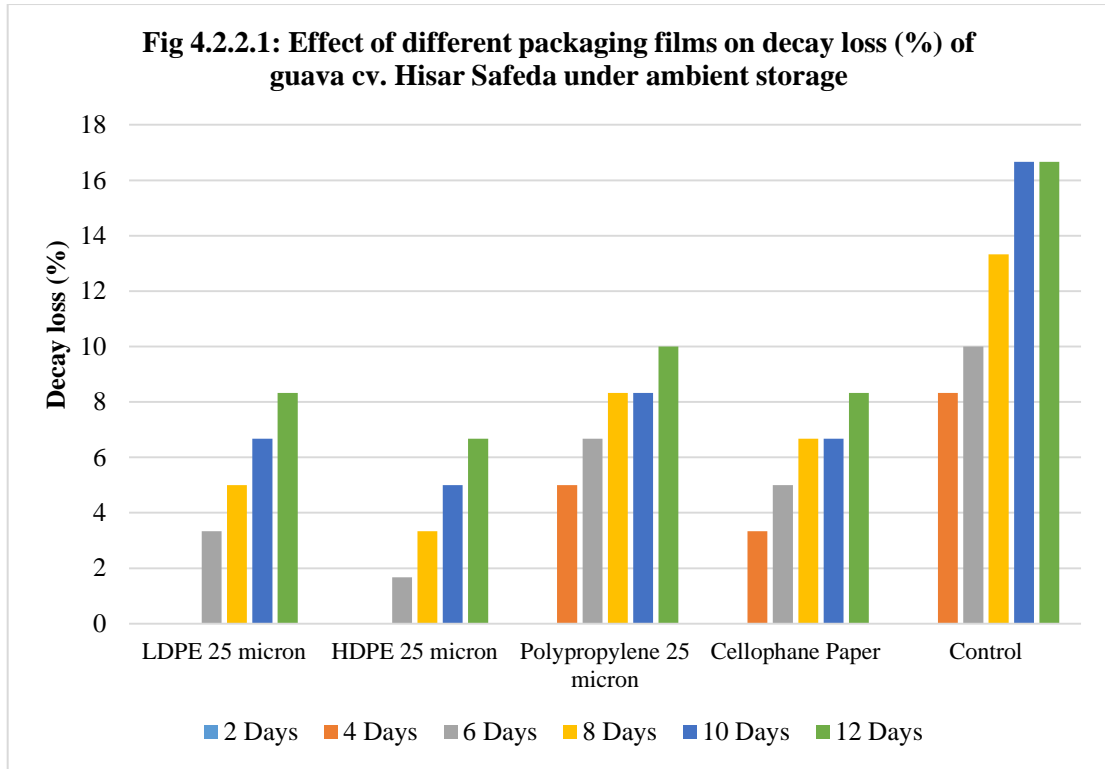
Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	3.71	3.47	3.36	3.06	1.92	1.72	2.87	2.14	1.84	1.58	1.24	1.06	0.96	1.47
HDPE 25 micron	T₂	3.42	3.31	3.20	2.86	1.45	1.38	2.60	2.04	1.76	1.42	1.17	0.94	0.80	1.36
Polypropylene 25 micron	T₃	4.08	4.01	3.80	3.69	2.80	2.34	3.45	2.24	2.06	1.98	1.82	1.56	1.52	1.86
Cellophane Paper	T₄	3.88	3.74	3.60	3.34	2.48	2.12	3.19	2.19	1.91	1.73	1.41	1.38	1.24	1.64
Control	T₅	4.90	4.60	4.28	4.20	3.82	3.30	4.18	2.65	2.53	2.47	2.32	2.25	1.70	2.32
Mean		4.00	3.83	3.65	3.43	2.49	2.17		2.25	2.02	1.84	1.59	1.44	1.25	
C.D. at 5%		Treatment (T) = 0.20 Days (D) = 0.22 T×D = NS							Treatment (T) = 0.10 Days (D) = 0.12 T×D = 0.26						



recorded in fruits packed with HDPE 25 micron (T_2) that was statistically at par with LDPE 25 micron (T_1 ; 3.33%), while maximum decay loss (7.78%) was observed in control treatment (T_9). Under ambient condition, fruits packed with HDPE 25 micron (T_2) showed minimum decay loss (2.78%) that was statistically at par with LDPE 25 micron (T_1 ; 3.89%), while maximum decay loss (10.83%) was recorded in control treatment (T_9).

Table 4.2.2: Effect of different packaging films on decay loss (%) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	0.00	0.00	3.33	5.00	6.67	8.33	3.89	0.00	0.00	3.33	5.00	5.00	6.67	3.33
HDPE 25 micron	T₂	0.00	0.00	1.67	3.33	5.00	6.67	2.78	0.00	0.00	1.67	1.67	3.33	6.67	2.22
Polypropylene 25 micron	T₃	0.00	5.00	6.67	8.33	8.33	10.00	6.39	0.00	0.00	5.00	6.67	8.33	10.00	5.00
Cellophane Paper	T₄	0.00	3.33	5.00	6.67	6.67	8.33	5.00	0.00	0.00	3.33	5.00	6.67	8.33	3.89
Control	T₅	0.00	8.33	10.00	13.33	16.67	16.67	10.83	0.00	1.67	8.33	11.67	11.67	13.33	7.78
Mean		0.00	3.33	5.33	7.33	8.67	10.00		0.00	0.33	4.33	6.00	7.00	9.00	
C.D. at 5%		Treatment (T) = 1.6 Days (D) = 1.7 T×D = NS							Treatment (T) = 1.4 Days (D) = 1.5 T×D = NS						



Storage period also had significant influenced on decay loss as it increased with prolongation of storage period. There was no decay incidence till 2nd day of storage under both conditions in all treatments including control. Fruits on 4th day of storage (S₂) showed minimum decay loss (0.33% and 3.33%) which reduced to on 6th day of storage (S₃; 4.33% and 5.33%) under refrigerator and ambient conditions, respectively. Maximum decay loss (9.00% and 10.0%)

was observed on 12th day of storage (S₆) under refrigerator and ambient conditions, respectively. However, the interaction between different packaging films and storage period was found non-significantly influence decay loss under both storage conditions.

4.2.3 Total soluble solids (%)

Data related to total soluble solids (TSS) has been presented in Table 4.2.3. Highest TSS (11.87 and 11.70%) was recorded in fruits packed with HDPE 25 micron (T₂) followed by LDPE 25 micron (T₁; 11.57 and 11.39%) under refrigerator and ambient storage, respectively. Lowest TSS (10.99 and 10.69%) was reported in fruits under control treatment (T₅) in refrigerator and ambient storage, respectively.

It was observed that TSS content initially increased and further decreased with prolongation of storage time. Maximum TSS (12.01%) was observed on 4th day of storage (S₂) that was statistically at par with 6th day of storage (S₃; 11.91%), while minimum TSS (10.13%) was recorded on 12th day of storage (S₆) under refrigerator condition. Under ambient condition, maximum TSS (12.14%) was observed on 4th day of storage (S₂) followed by 2nd day of storage (S₁; 11.89%), while minimum TSS (9.56%) was recorded on 12th day of storage (S₆).

TSS was also significantly influenced by the combined effect of various packaging films and storage time. In refrigerator storage, highest TSS (12.60%) was recorded in T₂S₅ that was statistically at par T₅S₂ (12.45%), whereas lowest TSS (9.26%) was recorded in T₅S₆. At ambient storage, highest TSS (12.50%) was observed in T₂S₄ that was statistically at par T₁S₃ (12.17%) and T₅S₂ (12.26%), while lowest TSS (8.67%) was recorded in T₅S₆.

4.2.4 Titratable acidity (%)

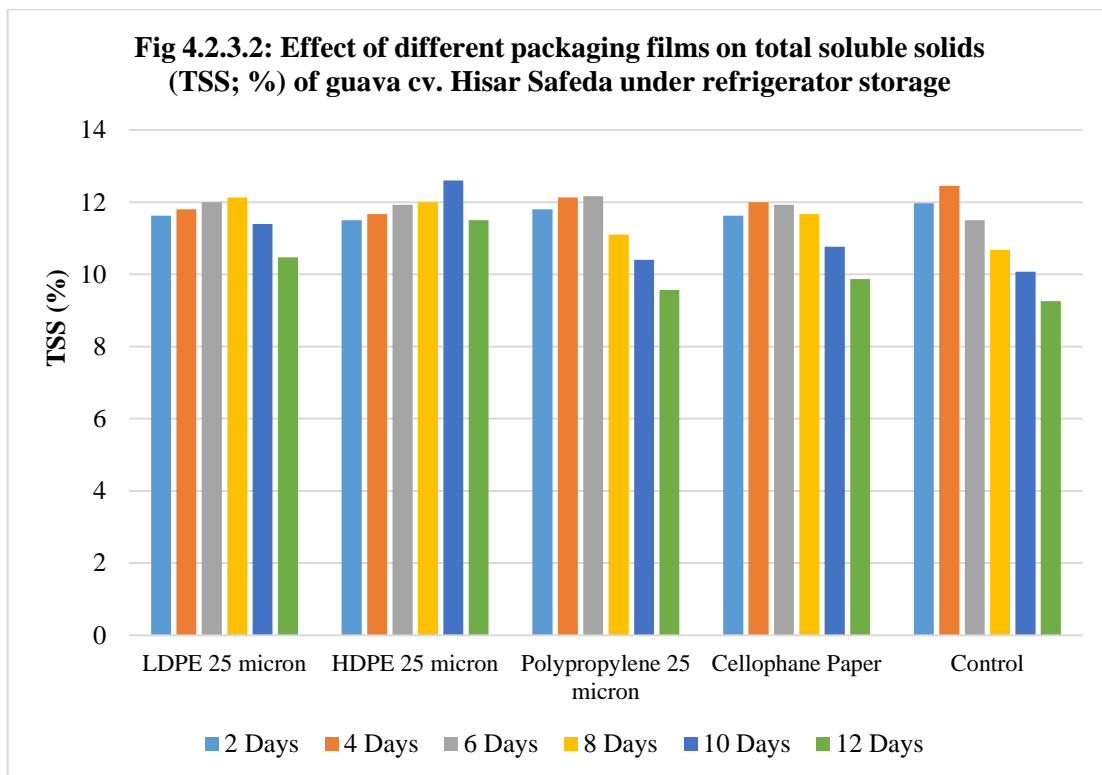
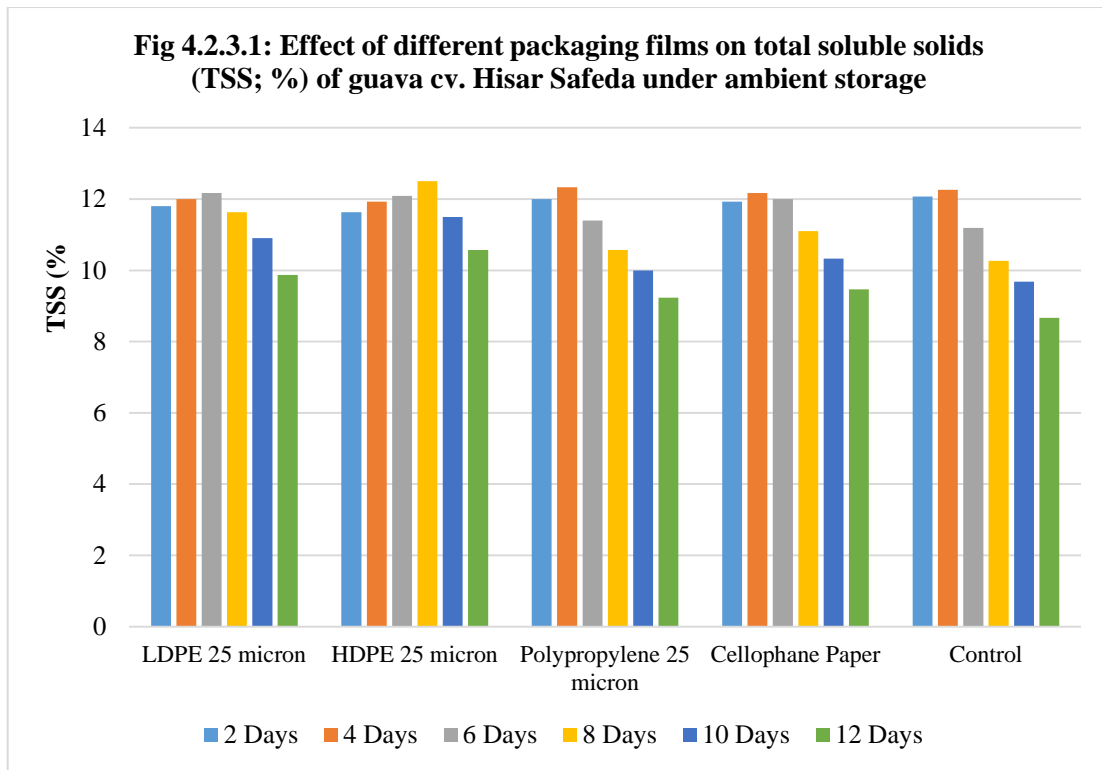
The data given in Table 4.2.4 reveal that different packaging films, storage period and interaction of packaging films and storage period non-significantly influence the titratable acidity (TA) in the guava under both storage conditions.

4.2.5 TSS: Acid ratio

The data pertaining to TSS: Acid ratio of guava fruits with different packaging films and days has been presented in Table 4.2.5. Under refrigerator storage, HDPE 25 micron (T₂) showed maximum TSS: Acid (38.77) that was statistically at par with LDPE 25 micron (T₁; 38.19), while minimum TSS: Acid ratio (37.36) was estimated in control treatment (T₅). Under ambient storage, maximum TSS: Acid ratio (38.51) was observed in T₂ that was statistically at par with T₁ (37.94), whereas minimum TSS: Acid ratio (36.74) was observed in T₅ (control).

Table 4.2.3: Effect of different packaging films on total soluble solids (TSS; %) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	11.80	12.00	12.17	11.63	10.90	9.87	11.39	11.63	11.80	12.00	12.13	11.40	10.47	11.57
HDPE 25 micron	T₂	11.63	11.93	12.09	12.50	11.50	10.57	11.70	11.50	11.67	11.93	12.00	12.60	11.50	11.87
Polypropylene 25 micron	T₃	12.00	12.33	11.40	10.57	10.00	9.23	10.92	11.80	12.13	12.17	11.10	10.40	9.57	11.19
Cellophane Paper	T₄	11.93	12.17	12.00	11.10	10.33	9.47	11.17	11.63	12.00	11.93	11.67	10.77	9.87	11.31
Control	T₅	12.07	12.26	11.19	10.27	9.68	8.67	10.69	11.97	12.45	11.50	10.68	10.07	9.26	10.99
Mean		11.89	12.14	11.77	11.21	10.48	9.56		11.71	12.01	11.91	11.52	11.05	10.13	
C.D. at 5%		Treatment (T) = 0.16 Days (D) = 0.18 T×D = 0.40							Treatment (T) = 0.16 Days (D) = 0.17 T×D = 0.39						



It is evident from the data that TSS: Acid ratio initially increased, thereafter declined with the advancement of storage period. Maximum TSS: Acid ratio (39.23) manifested on 8th day of storage (S_4) that was statistically at par with 6th day (S_3 ; 39.09) and 10th day of storage (S_5 ; 38.80), whereas minimum TSS: Acid ratio (35.08) was estimated on 2nd day of storage (S_1) under refrigerator condition. In ambient condition, maximum TSS: Acid ratio (39.32)

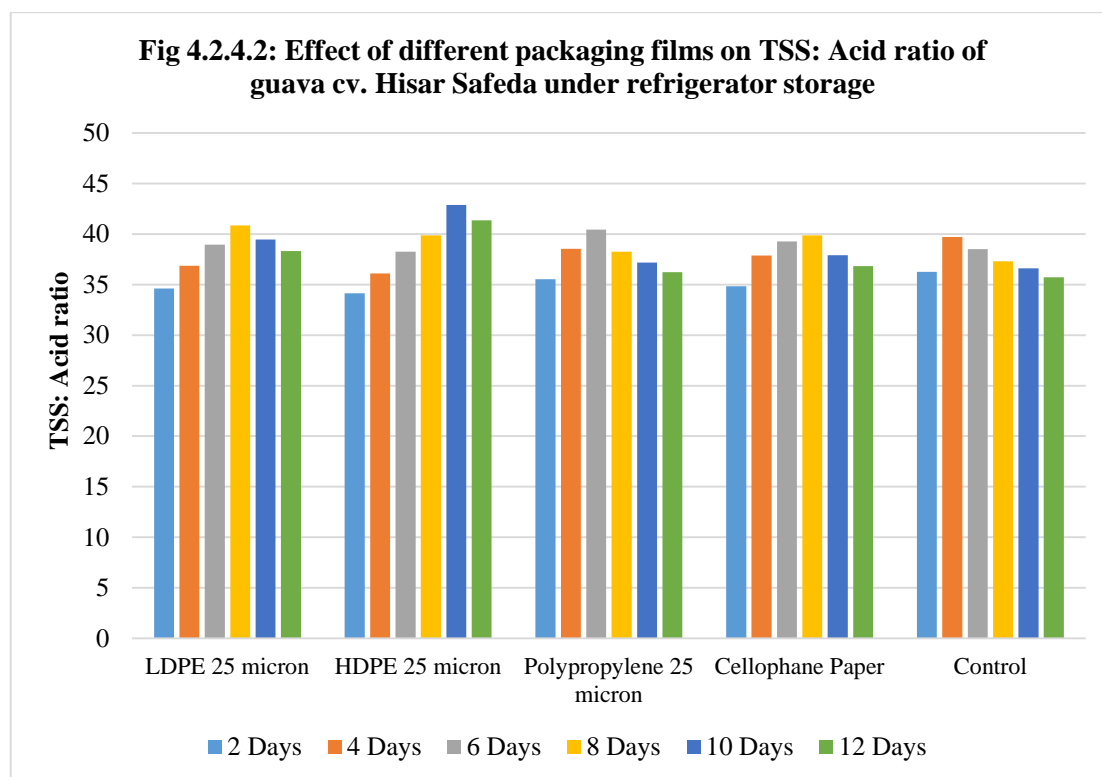
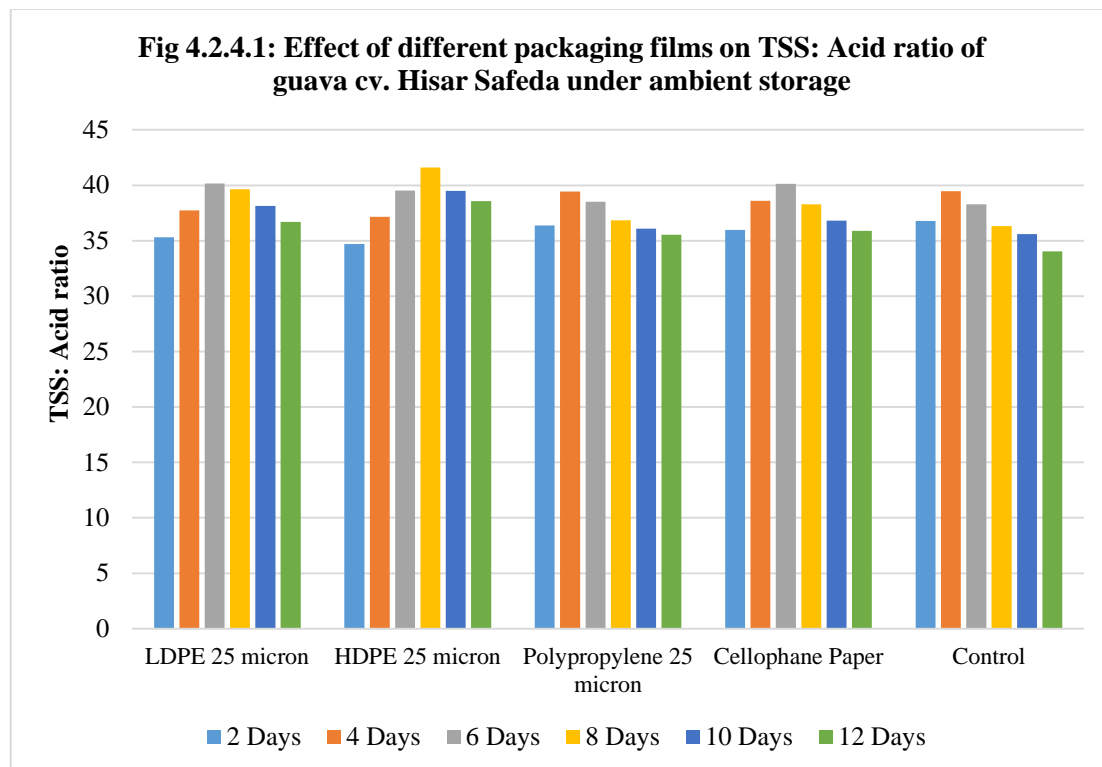
Table 4.2.4: Effect of different packaging films on titratable acidity (%) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	0.33	0.32	0.30	0.29	0.29	0.27	0.30	0.34	0.32	0.31	0.30	0.29	0.27	0.30
HDPE 25 micron	T₂	0.34	0.32	0.31	0.30	0.29	0.27	0.30	0.34	0.32	0.31	0.30	0.29	0.28	0.31
Polypropylene 25 micron	T₃	0.33	0.31	0.30	0.29	0.28	0.26	0.29	0.33	0.32	0.30	0.29	0.28	0.26	0.30
Cellophane Paper	T₄	0.33	0.32	0.30	0.29	0.28	0.26	0.30	0.33	0.32	0.30	0.29	0.28	0.27	0.30
Control	T₅	0.33	0.31	0.29	0.28	0.27	0.26	0.29	0.33	0.31	0.30	0.29	0.28	0.26	0.29
Mean		0.33	0.32	0.30	0.29	0.28	0.26		0.33	0.32	0.31	0.29	0.29	0.27	
C.D. at 5%		Treatment (T) = NS Days (D) = NS T×D = NS							Treatment (T) = NS Days (D) = NS T×D = NS						

Table 4.2.5: Effect of different packaging films on TSS: Acid ratio of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	35.30	37.73	40.17	39.63	38.13	36.70	37.94	34.63	36.87	38.97	40.87	39.47	38.33	38.19
HDPE 25 micron	T₂	34.70	37.17	39.53	41.60	39.50	38.57	38.51	34.13	36.10	38.27	39.87	42.87	41.37	38.77
Polypropylene 25 micron	T₃	36.37	39.43	38.50	36.83	36.10	35.53	37.13	35.53	38.53	40.43	38.27	37.17	36.23	37.69
Cellophane Paper	T₄	35.97	38.60	40.13	38.27	36.80	35.90	37.61	34.83	37.87	39.27	39.87	37.90	36.83	37.76
Control	T₅	36.77	39.47	38.27	36.33	35.60	34.03	36.74	36.27	39.73	38.50	37.30	36.60	35.73	37.36
Mean		35.82	38.48	39.32	38.53	37.23	36.15		35.08	37.82	39.09	39.23	38.80	37.70	
C.D. at 5%		Treatment (T) = 0.82 Days (D) = 0.88 T×D = 2.01							Treatment (T) = 0.75 Days (D) = 0.82 T×D = 1.83						

estimated on 6th day of storage (S₃) that was statistically at par with 8th day of storage (S₄; 38.53), while minimum (35.82) on 2nd day of storage (S₁).



TSS: acid was also significantly influenced by the integrated effect of both packaging films and storage period. Highest value of TSS: Acid ratio (42.87) was recorded in T₂S₅ that

was statistically at par with T₂S₆ (41.37), whereas lowest value was observed in T₂S₁ (34.13) under refrigerator storage condition. At ambient storage, highest value of TSS: Acid ratio (41.60) was recorded in T₂S₄ that was statistically at par with T₁S₄ (39.63), T₁S₃ (40.17) and T₄S₃ (40.13), whereas lowest value was observed in T₅S₆ (34.03).

4.2.6 Juice pH

The data related to juice pH has been presented in Table 4.2.6. It is obvious from the data that rate of increase in juice pH was reduced in all treatments as compared to control under both storage conditions. Lowest juice pH (5.10 and 5.18) was recorded in fruits packed with HDPE 25 micron (T₂) that was statistically at par with LDPE 25 micron (T₁; 5.14 and 5.22), while highest value (5.24 and 5.31) was recorded in control treatment (T₉) under refrigerator and ambient storage, respectively.

Among the storage intervals, a significant difference in pH of fruit juice was observed. There was gradual increase in pH of fruit juice with the prolongation of storage period. Lowest juice pH (4.93 and 4.96) was observed on 2nd day of storage (S₁) followed by 4th day of storage (S₂; 5.08 and 5.14), while highest juice pH (5.46 and 5.56) was observed on 12th day of storage (S₆) under refrigerator and ambient storage, respectively.

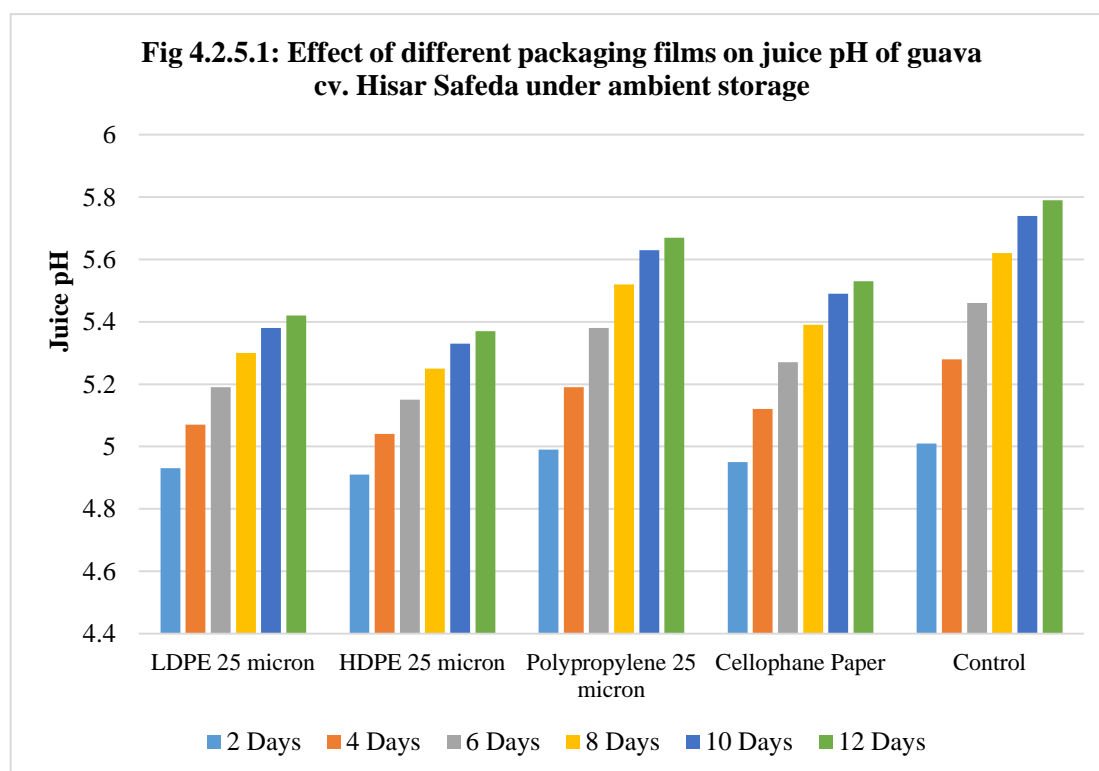
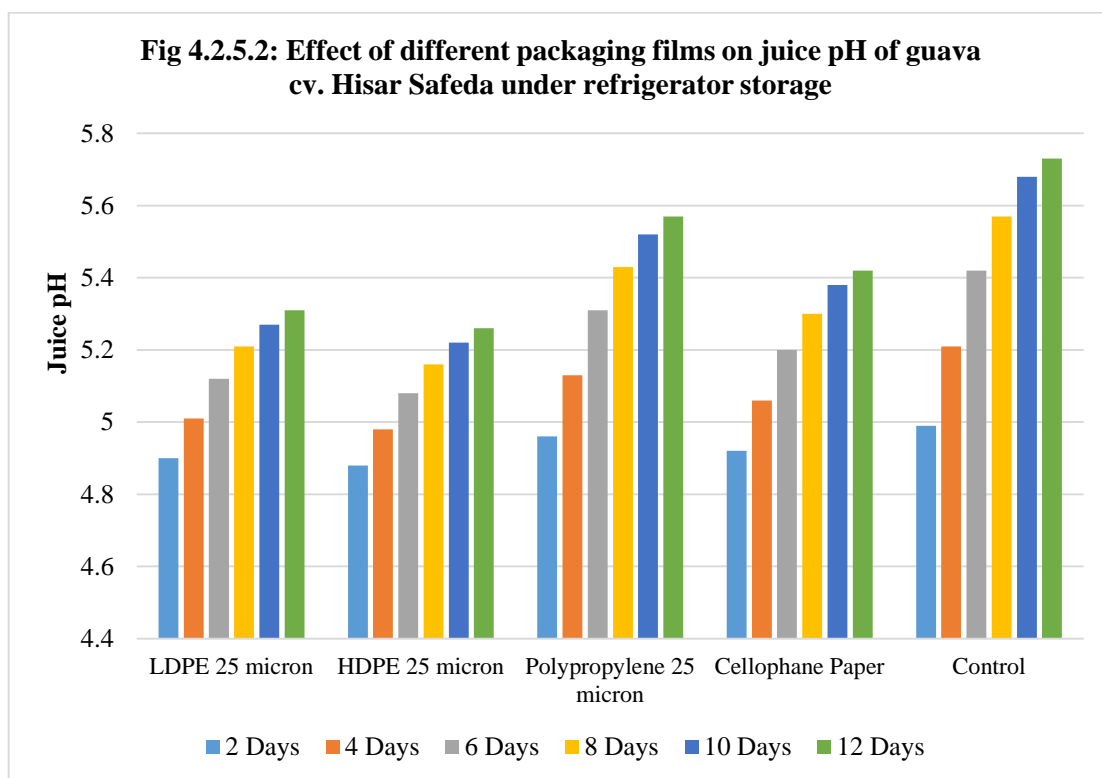


Table 4.2.6: Effect of different packaging films on juice pH of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	4.93	5.07	5.19	5.30	5.38	5.42	5.22	4.90	5.01	5.12	5.21	5.27	5.31	5.14
HDPE 25 micron	T₂	4.91	5.04	5.15	5.25	5.33	5.37	5.18	4.88	4.98	5.08	5.16	5.22	5.26	5.10
Polypropylene 25 micron	T₃	4.99	5.19	5.38	5.52	5.63	5.67	5.40	4.96	5.13	5.31	5.43	5.52	5.57	5.32
Cellophane Paper	T₄	4.95	5.12	5.27	5.39	5.49	5.53	5.29	4.92	5.06	5.20	5.30	5.38	5.42	5.21
Control	T₅	5.01	5.28	5.46	5.62	5.74	5.79	5.48	4.99	5.21	5.42	5.57	5.68	5.73	5.43
Mean		4.96	5.14	5.29	5.42	5.51	5.56		4.93	5.08	5.23	5.33	5.41	5.46	
C.D. at 5%		Treatment (T) = 0.04 Days (D) = 0.05 T×D = 0.11							Treatment (T) = 0.04 Days (D) = 0.05 T×D = 0.11						



Up to 4th day of storage, no significant difference had been observed in juice pH among different treatments. Minimum pH (5.08 and 5.15) was recorded in fruits packed with HDPE 25 micron on 6th of storage (T_2S_3) that was statistically at par with T_1S_3 (5.12 and 5.19) and T_2S_4 (5.16 and 5.25), whereas maximum pH (5.73 and 5.79) was observed in control treatment on 12th day of storage (T_5S_6) under refrigerator and ambient conditions, respectively.

4.2.7 Pectin content (%)

Results on pectin content of guava fruits as affected by different packaging films during different period of storage has been presented in Table 4.2.7. It is clearly illustrated that all the packaging films had significant influence in retaining the pectin content as compared to the control. Among the different packaging films, maximum pectin content (0.99 and 0.97%) was observed in fruits packed with HDPE 25 micron (T_2) that was statistically at par with LDPE 25 micron (T_1 ; 0.98 and 0.96%), while minimum (0.93 and 0.91%) was observed in control treatment (T_5) under refrigerator and ambient storage, respectively.

Among the storage time, pectin content gradually declined with the advancement of storage period. Maximum pectin content (1.06 and 1.05%) was recorded on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 1.02 and 1.01%), whereas minimum pectin content (0.86 and 0.82%) was recorded on 12th day of storage (S_6) under refrigerator and ambient

Table 4.2.7: Effect of different packaging films on pectin content (%) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	1.06	1.02	0.99	0.94	0.89	0.85	0.96	1.07	1.03	1.01	0.97	0.93	0.88	0.98
HDPE 25 micron	T₂	1.06	1.03	1.00	0.96	0.91	0.87	0.97	1.07	1.04	1.02	0.99	0.94	0.90	0.99
Polypropylene 25 micron	T₃	1.04	1.00	0.95	0.91	0.85	0.80	0.93	1.05	1.01	0.97	0.94	0.88	0.83	0.95
Cellophane Paper	T₄	1.05	1.01	0.96	0.92	0.86	0.82	0.93	1.06	1.02	0.98	0.95	0.89	0.85	0.96
Control	T₅	1.04	1.00	0.94	0.89	0.83	0.77	0.91	1.04	1.01	0.96	0.92	0.86	0.81	0.93
Mean		1.05	1.01	0.97	0.92	0.87	0.82		1.06	1.02	0.99	0.95	0.90	0.86	
C.D. at 5%		Treatment (T) = 0.01 Days (D) = 0.01 T×D = NS							Treatment (T) = 0.01 Days (D) = 0.01 T×D = NS						

storage, respectively. However, the interaction between different packaging films and storage time was found non-significantly influence pectin content.

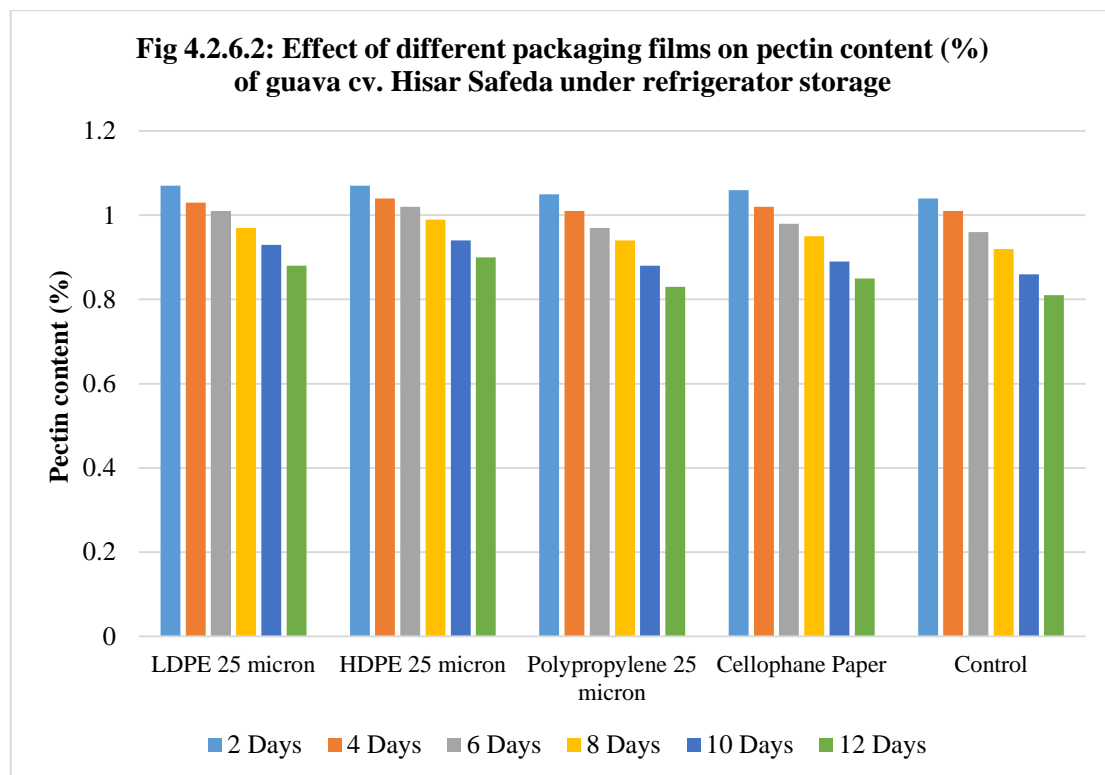
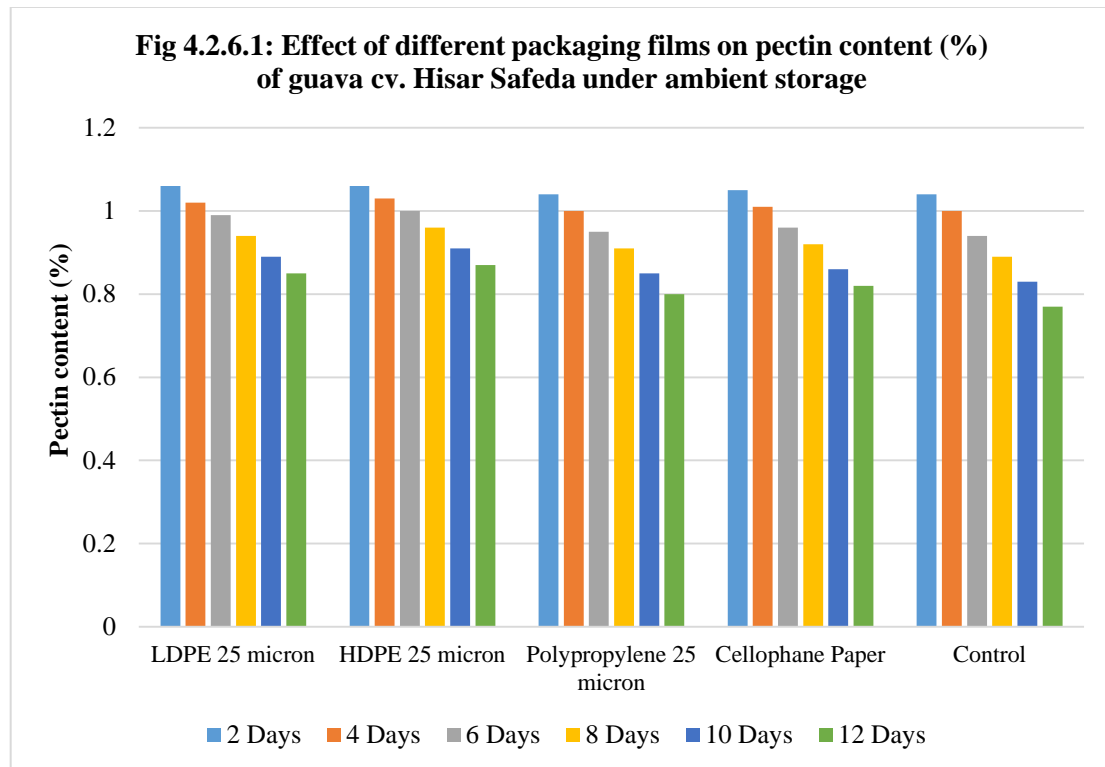


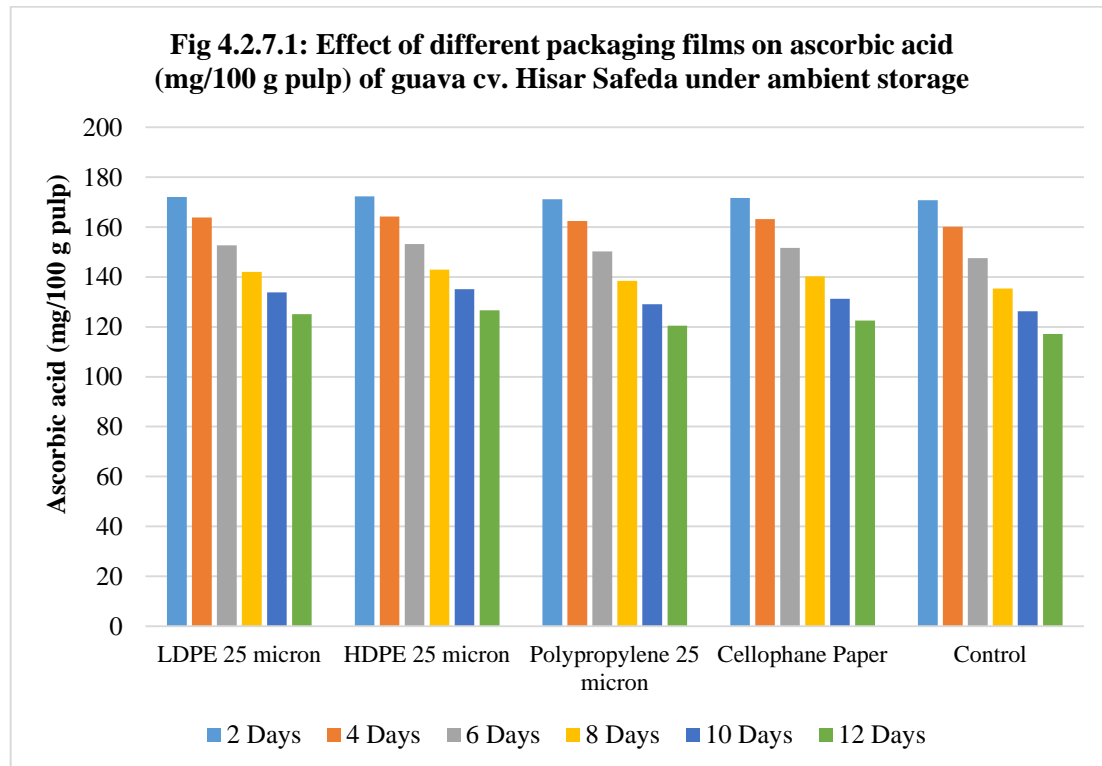
Table 4.2.8: Effect of different packaging films on ascorbic acid content (mg/100 g pulp) of guava cv. Hisar Safeda

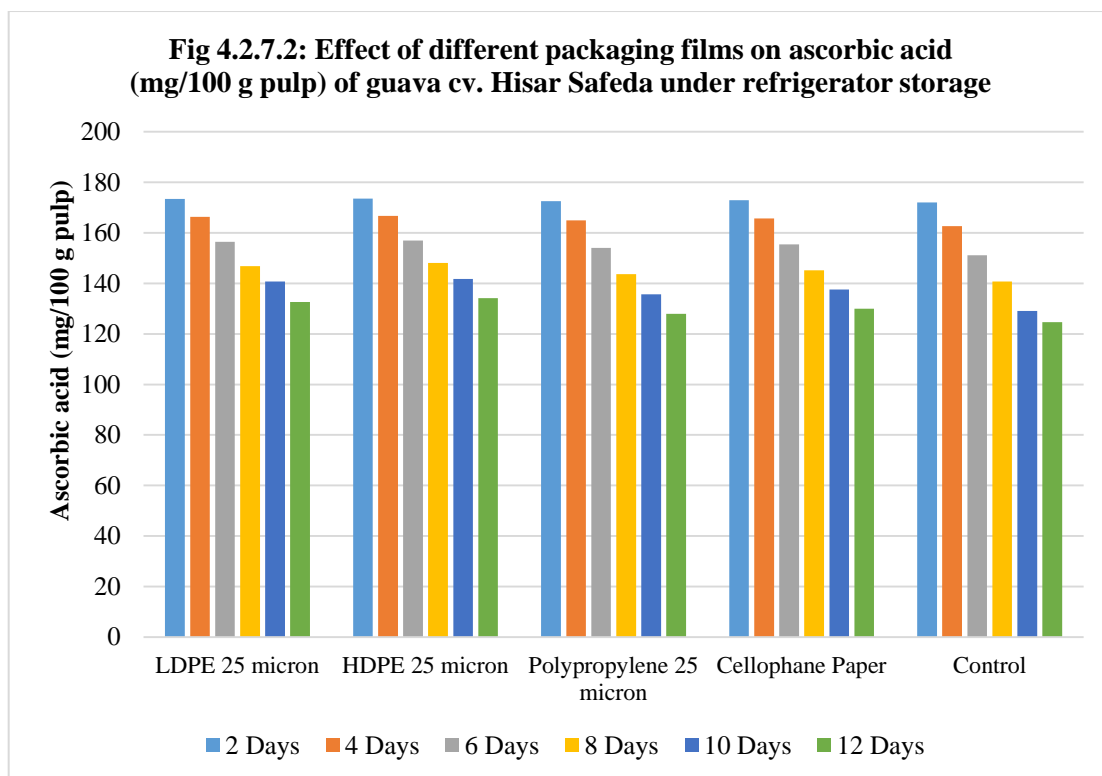
Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	172.1	163.9	152.7	142.1	133.8	125.1	148.3	173.4	166.4	156.4	146.8	140.7	132.6	152.7
HDPE 25 micron	T₂	172.3	164.2	153.2	143.0	135.1	126.6	149.1	173.6	166.7	157.0	148.1	141.7	134.1	153.5
Polypropylene 25 micron	T₃	171.2	162.5	150.3	138.5	129.1	120.5	145.4	172.5	164.9	154.0	143.6	135.7	128.0	149.8
Cellophane Paper	T₄	171.7	163.2	151.7	140.2	131.3	122.5	146.8	172.9	165.7	155.4	145.2	137.6	130.0	151.1
Control	T₅	170.8	160.2	147.5	135.4	126.2	117.1	142.9	172.1	162.7	151.2	140.8	129.1	124.6	146.8
Mean		171.6	162.8	151.1	139.9	131.1	122.4		172.9	165.3	154.8	144.9	137.0	129.9	
C.D. at 5%		Treatment (T) = 0.6 Days (D) = 0.7 T×D = 1.5							Treatment (T) = 0.9 Days (D) = 1.0 T×D = 2.2						

4.2.8 Ascorbic acid content (mg/100 g pulp)

The results related to ascorbic acid content in guava wrapped in different packaging films and storage period are shown in Table 4.2.8. It was observed that all the packaging films had significant effect in maintaining the higher level of ascorbic acid as compared to control. Among the different packaging films, fruits packed with HDPE 25 micron (T_2) retained highest ascorbic content (153.5 mg/100 g pulp) that was statistically at par with LDPE 25 micron (T_1 ; 152.7 mg/100 g pulp) followed by cellophane paper (T_4 ; 151.1 mg/100 g pulp), while control treatment (T_5) showed lowest ascorbic acid (146.8 mg/100 g pulp) under refrigerator storage. Similarly, at ambient storage, T_2 showed highest ascorbic content (149.1 mg/100 g pulp) followed by T_2 (148.3 mg/100 g pulp), while it was lowest (142.9 mg/100 g pulp) in T_5 (control).

Among the storage period, ascorbic acid content of guava fruit decreased with the advancement of storage period. Highest ascorbic acid content (172.9 mg/100 g pulp) was recorded on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 165.3 mg/100 g pulp), whereas lowest ascorbic acid content (129.9 mg/100 g pulp) was recorded on 12th day of storage (S_6) under refrigerator condition. Likewise, at ambient storage, highest ascorbic acid content (171.6 mg/100 g pulp) was recorded in S_1 followed by S_2 (162.8 mg/100 g pulp), whereas minimum ascorbic acid content (122.4 mg/100 g pulp) was recorded in S_6 .





Upto 6th day of storage, no significant variation has been observed in ascorbic acid content among different packaging films. Highest ascorbic acid content (148.1 mg/100 g pulp) was recorded in fruits packed with HDPE 25 micron on 8th of storage (T_2S_4) that was statistically at par with T_1S_4 (146.8 mg/100 g pulp), whereas lowest ascorbic acid content (124.6 mg/100 g pulp) was observed in control treatment on 12th day of storage (T_5S_6) under refrigerator condition. Likewise, under ambient condition, highest ascorbic acid content (143.0 mg/100 g pulp) was recorded in T_2S_4 that was statistically at par with T_1S_4 (142.1 mg/100 g pulp), while lowest ascorbic acid content (117.1 mg/100 g pulp) was observed in control treatment on 12th day of storage (T_5S_6).

4.2.9 Total sugars (%)

The observations regarding effect of various packaging films and storage period on total sugars of guava fruits presented in Table 4.2.9. It was observed that total sugars initially increased, afterward declined with advancement of storage period under all treatment including control but all the treatments reduced the rate of declining and maintain higher level of total sugars as compared to control at the end of storage under both conditions. Among the different packaging films, fruits packed with HDPE 25 micron (T_2) showed maximum level of total sugars (7.23 and 7.31%) followed by LDPE 25 micron (T_1 ; 7.12 and 7.15%), whereas control treatment (T_9) showed minimum level of total sugars (7.05 and 6.90%) under refrigerator and ambient storage, respectively.

Table 4.2.9: Effect of different packaging films on total sugars (%) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	6.76	7.32	7.72	7.42	7.04	6.65	7.15	6.56	6.86	7.38	7.82	7.20	6.90	7.12
HDPE 25 micron	T₂	6.70	7.22	7.88	7.68	7.38	7.00	7.31	6.50	6.78	7.30	7.92	7.58	7.28	7.23
Polypropylene 25 micron	T₃	7.30	7.76	7.34	6.94	6.58	6.20	7.02	6.88	7.38	7.56	7.20	6.88	6.60	7.08
Cellophane Paper	T₄	7.12	7.66	7.42	7.00	6.76	6.38	7.06	6.64	7.20	7.66	7.32	7.02	6.74	7.10
Control	T₅	7.84	7.56	7.12	6.68	6.28	5.90	6.90	6.94	7.78	7.42	7.06	6.74	6.35	7.05
Mean		7.15	7.50	7.50	7.15	6.81	6.43		6.70	7.20	7.46	7.46	7.08	6.77	
C.D. at 5%		Treatment (T) = 0.06 Days (D) = 0.06 T×D = 0.14							Treatment (T) = 0.06 Days (D) = 0.07 T×D = 0.16						

Among the storage time, Maximum total sugars (7.47%) was recorded on 8th day of storage (S₄) that was statistically at par with 6th day of storage (S₃; 7.46%), while minimum was recorded on 2nd day of storage (S₁; 6.70%) under refrigerator condition. At ambient condition, maximum total sugars (7.50%) were recorded on 4th (S₂) and 6th day of storage (S₃) both, while minimum was recorded on 12th day of storage (S₆; 6.43%).

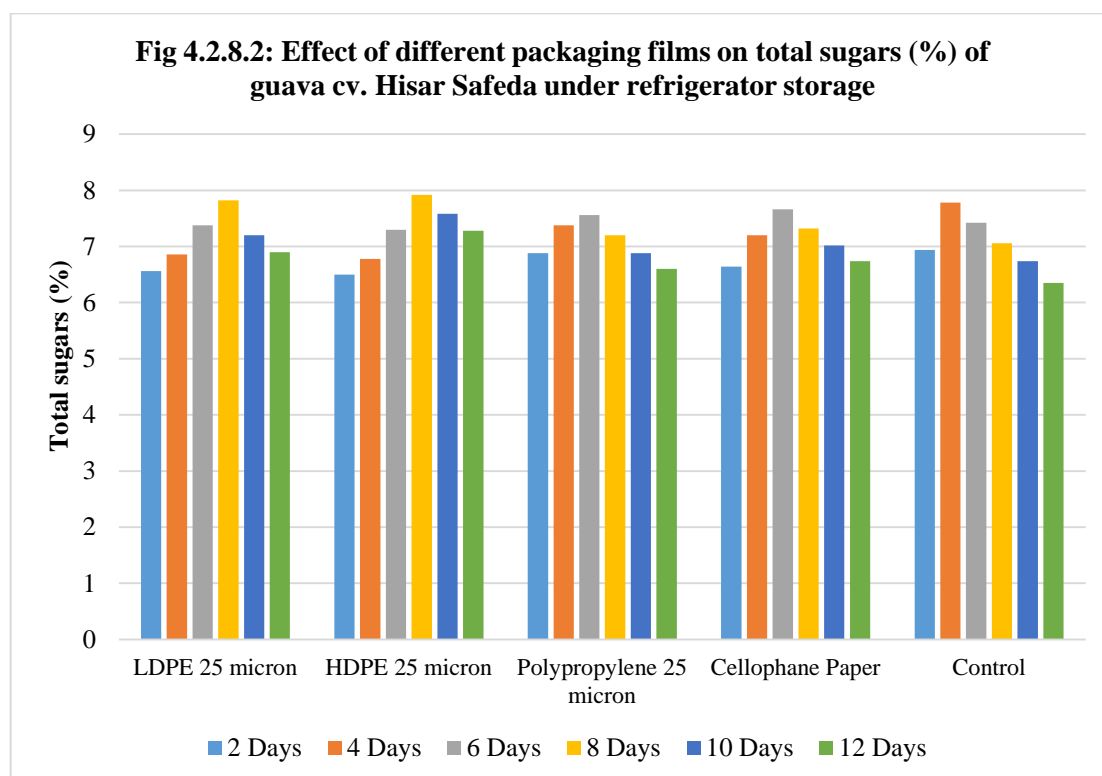
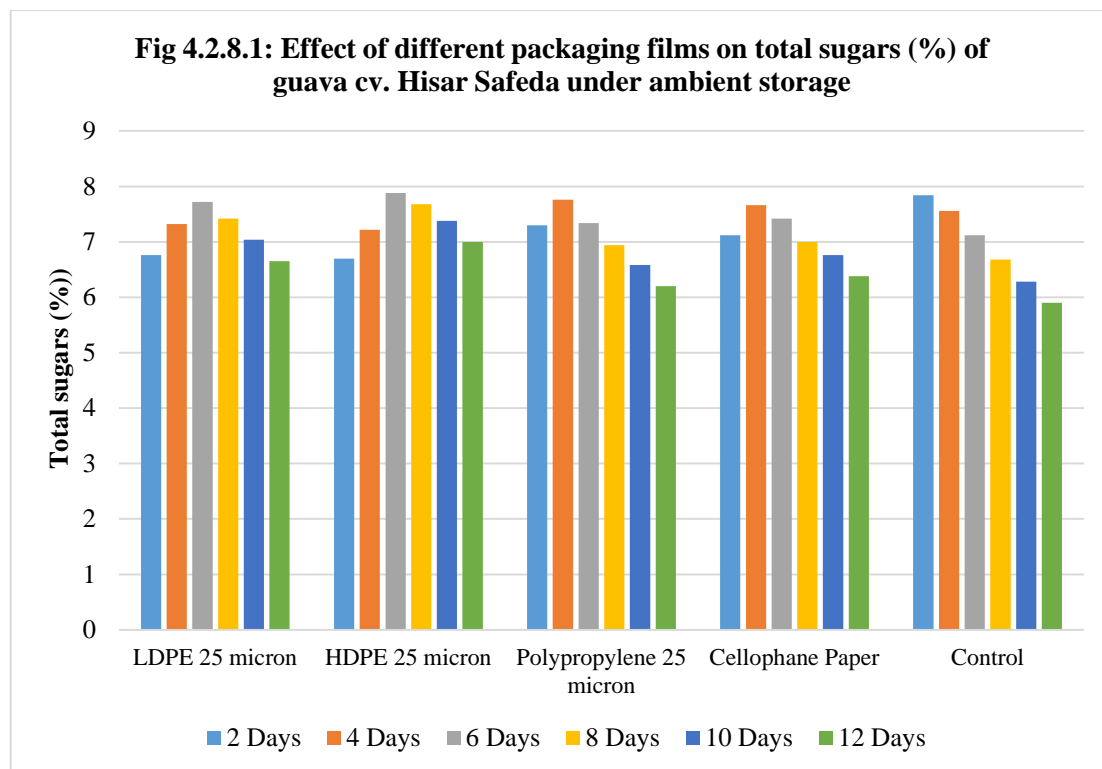


Table 4.2.10: Effect of different packaging films on reducing sugar (%) of guava cv. Hisar Safeda

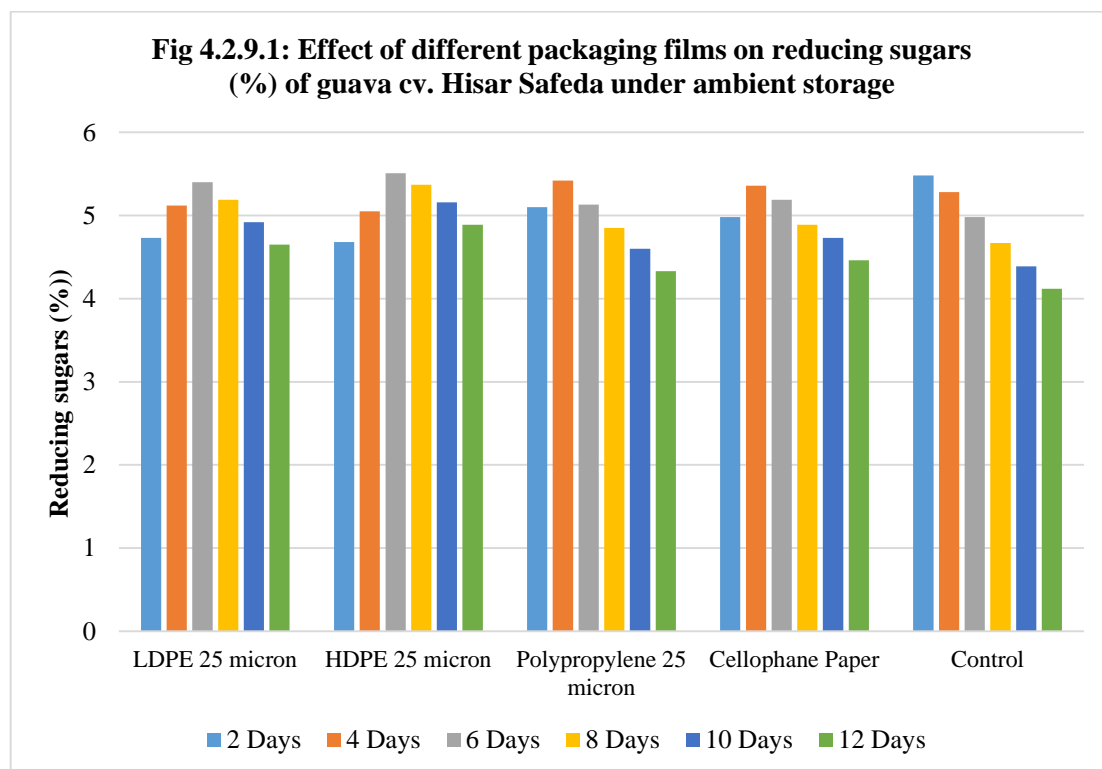
Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	4.73	5.12	5.40	5.19	4.92	4.65	5.00	4.58	4.80	5.16	5.47	5.03	4.83	4.98
HDPE 25 micron	T₂	4.68	5.05	5.51	5.37	5.16	4.89	5.11	4.55	4.74	5.10	5.54	5.30	5.09	5.05
Polypropylene 25 micron	T₃	5.10	5.42	5.13	4.85	4.60	4.33	4.91	4.81	5.16	5.28	5.03	4.81	4.61	4.95
Cellophane Paper	T₄	4.98	5.36	5.19	4.89	4.73	4.46	4.93	4.64	5.03	5.35	5.12	4.91	4.71	4.96
Control	T₅	5.48	5.28	4.98	4.67	4.39	4.12	4.82	4.84	5.41	5.19	4.92	4.64	4.36	4.89
Mean		4.99	5.25	5.24	4.99	4.76	4.49		4.69	5.03	5.22	5.21	4.94	4.72	
C.D. at 5%		Treatment (T) = 0.04 Days (D) = 0.04 T×D = 0.10							Treatment (T) = 0.04 Days (D) = 0.05 T×D = 0.11						

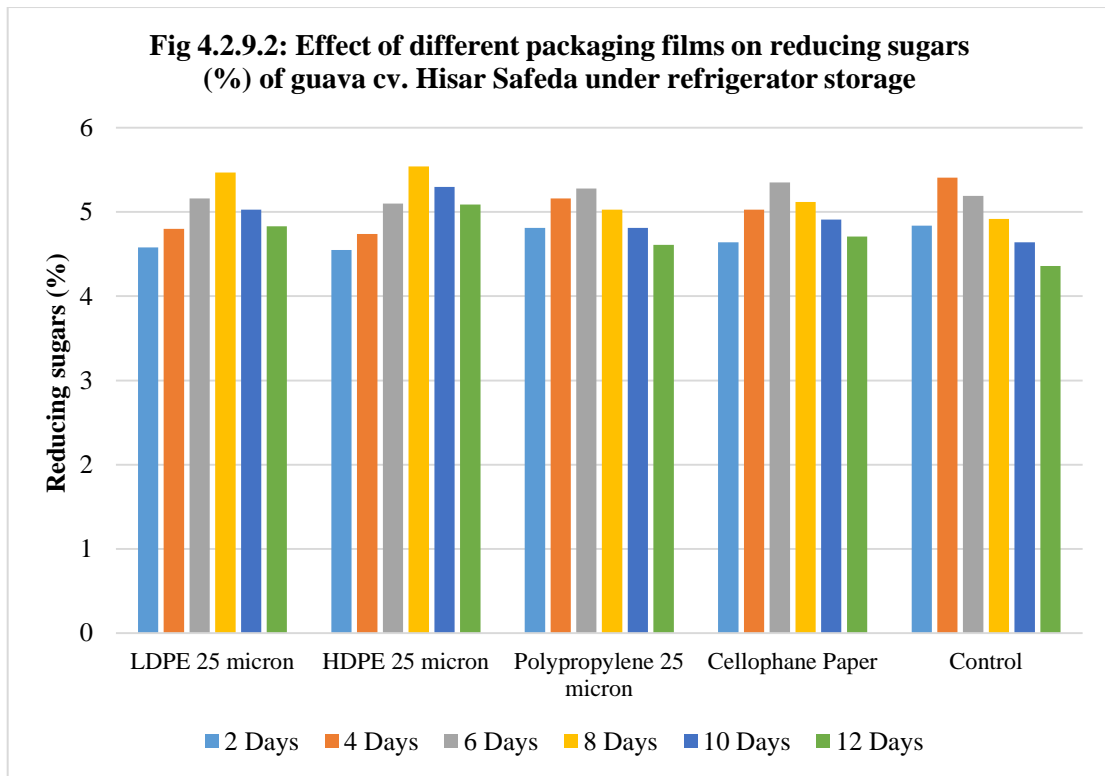
Total sugars content was also significantly influenced by the integrated effect of both packaging films and storage period. Highest level of total sugars (7.92%) was recorded in T₂S₄ which was statistically at par with T₁S₄ (7.82%) and T₅S₂ (7.78%), whereas lowest level was observed in T₅S₆ (6.35%) under refrigerator storage condition. At ambient storage, highest level of Total sugars (7.88%) was recorded in T₂S₃ that was statistically at par with T₃S₂ (7.76%) and T₅S₁ (7.84%), while lowest level was observed in T₅S₆ (5.90%).

4.2.10 Reducing sugar (%)

The data pertaining to reducing sugars in guava as affected by different packaging films revealed an increasing-decreasing trend during the storage period presented in Table 4.2.10. All treatments influenced the reducing sugar level. Under refrigerator storage, maximum reducing sugar content (5.05%) was observed in fruits packed with HDPE 25 micron (T₂) followed by LDPE 25 micron (T₁; 4.98%), whereas minimum (4.89%) was observed in control treatment (T₅). Likewise, at ambient storage, maximum reducing sugar content (5.11%) was observed in T₂ followed by T₁ (5.00%), whereas minimum (4.82%) was observed in T₅ (control).

All storage intervals significantly affected the level of reducing sugar irrespective of the packaging films. Maximum reducing sugar content (5.22%) was recorded on 6th day of storage (S₃) that was statistically at par with 8th day of storage (S₄; 5.21%), while minimum was recorded 2nd day of storage (S₁; 4.69%) under refrigerator condition. At ambient condition, maximum reducing sugar content (5.25%) was recorded on 4th day of





storage (S_2) that was statistically at par with 6th day of storage (S_3 ; 5.24%), while minimum was recorded on 12th day of storage (S_6 ; 4.49%).

Combined effect of different packaging films and storage period also significantly influenced the reducing sugar level. Maximum reducing sugars (5.54%) was recorded in T_2S_4 which was statistically at par with T_1S_4 (5.47%), whereas minimum was observed in T_5S_6 (4.36%) under refrigerator storage condition. At ambient storage, maximum reducing sugar (5.51%) was recorded in T_2S_3 that was statistically at par with T_3S_2 (5.42%) and T_5S_1 (5.48%), while minimum was observed in T_5S_6 (4.12%).

4.2.11 Non-reducing sugars (%)

The data regarding non-reducing sugars have been presented in Table 4.2.11. Non-reducing sugars varied significantly in fruits wrapped in different packaging films. Under refrigerator storage, fruits packed with HDPE 25 micron (T_2) showed maximum non-reducing sugar content (2.18%) followed by LDPE 25 micron (T_1 ; 2.14%), whereas control treatment (T_5) showed minimum non-reducing sugar content (2.11%). At ambient storage, T_2 showed maximum non-reducing sugar content (2.20%) followed by T_1 (2.15%), while T_5 (control) showed minimum non-reducing sugar content (2.07%)

Storage period also significantly affected the non-reducing sugar content. An increasing-decreasing pattern of non-reducing sugar was observed during the storage. Maximum non-reducing sugar content (2.25%) was recorded on 6th (S_3) and 8th day of storage (S_4) both followed by 4th day of storage (S_2 ; 2.17%), while minimum was recorded on

Table 4.2.11: Effect of different packaging films on non-reducing sugar (%) of guava cv. Hisar Safeda

Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	2.04	2.20	2.33	2.23	2.12	2.00	2.15	1.98	2.07	2.22	2.35	2.17	2.08	2.14
HDPE 25 micron	T₂	2.02	2.17	2.38	2.31	2.22	2.11	2.20	1.96	2.04	2.20	2.39	2.28	2.19	2.18
Polypropylene 25 micron	T₃	2.20	2.34	2.21	2.09	1.98	1.87	2.11	2.07	2.22	2.28	2.17	2.07	1.99	2.13
Cellophane Paper	T₄	2.14	2.31	2.24	2.11	2.03	1.92	2.12	2.00	2.17	2.31	2.20	2.11	2.03	2.14
Control	T₅	2.36	2.27	2.14	2.01	1.89	1.77	2.07	2.08	2.33	2.24	2.12	2.00	1.88	2.11
Mean		2.15	2.26	2.26	2.15	2.05	1.93		2.02	2.17	2.25	2.25	2.13	2.03	
C.D. at 5%		Treatment (T) = 0.02 Days (D) = 0.02 T×D = 0.04							Treatment (T) = 0.02 Days (D) = 0.02 T×D = 0.05						

2nd day of storage (S₁; 2.02%) under refrigerator condition. At ambient condition also maximum non reducing sugar content (2.26%) was recorded on 4th (S₂) and 6th day of storage (S₃) both, while minimum was recorded on 12th day of storage (S₆; 1.93%).

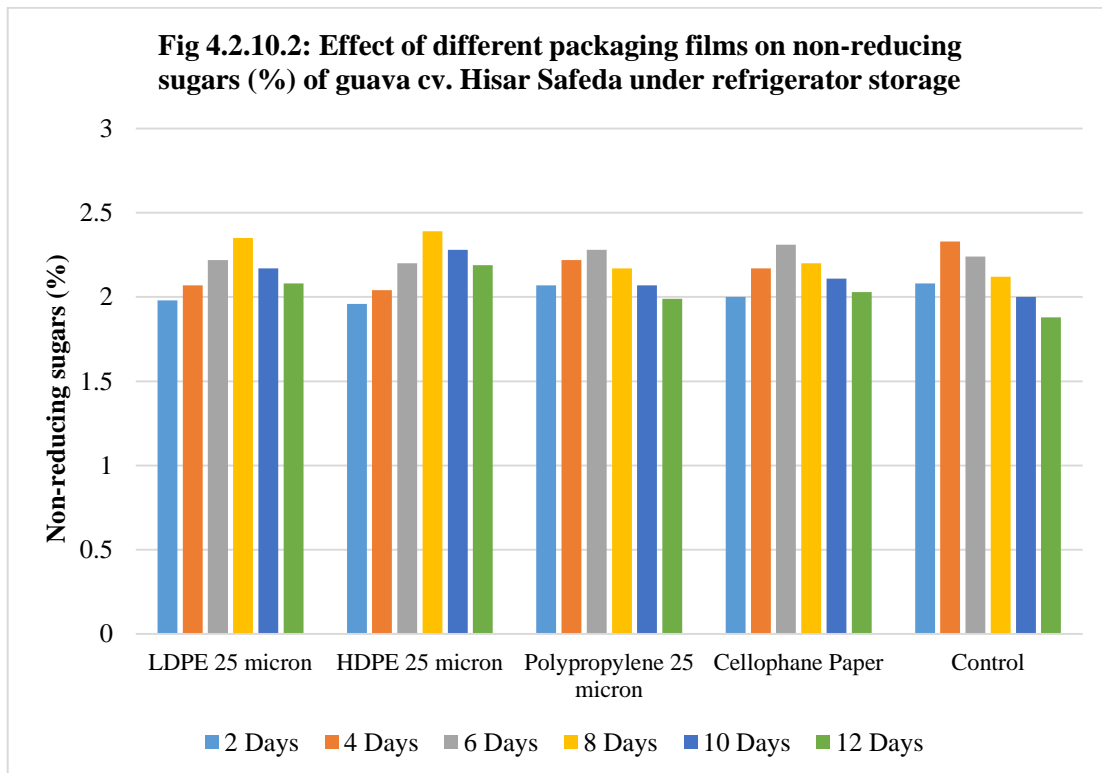
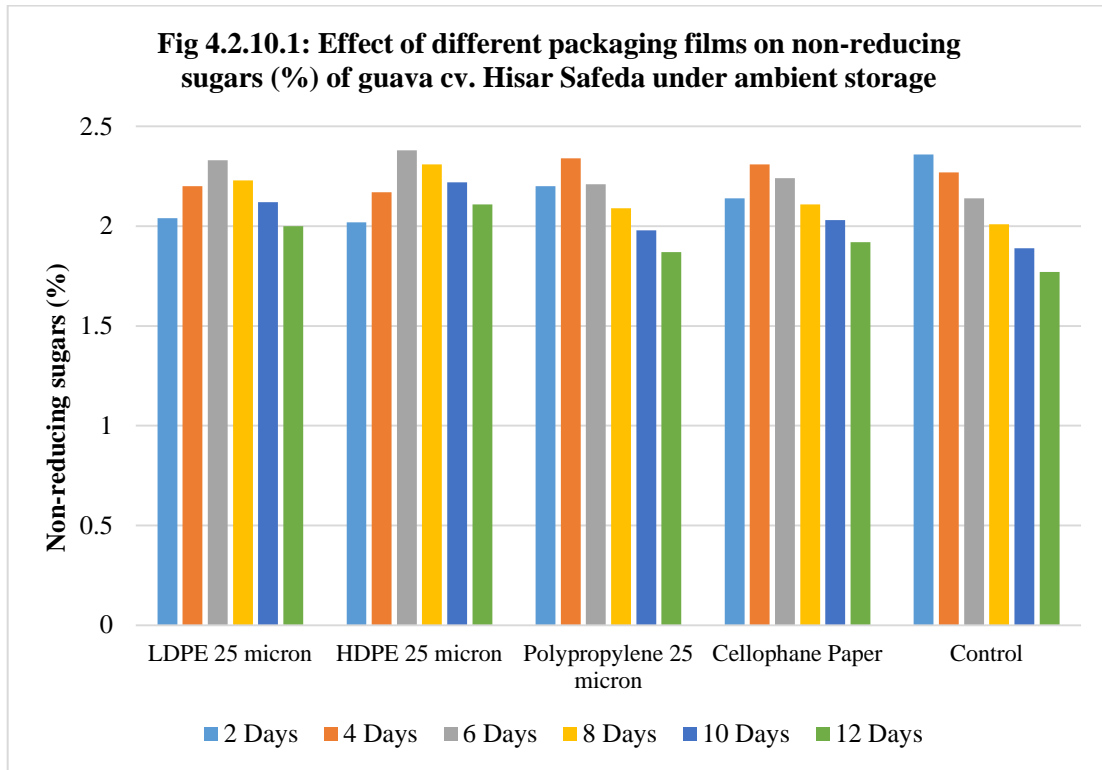


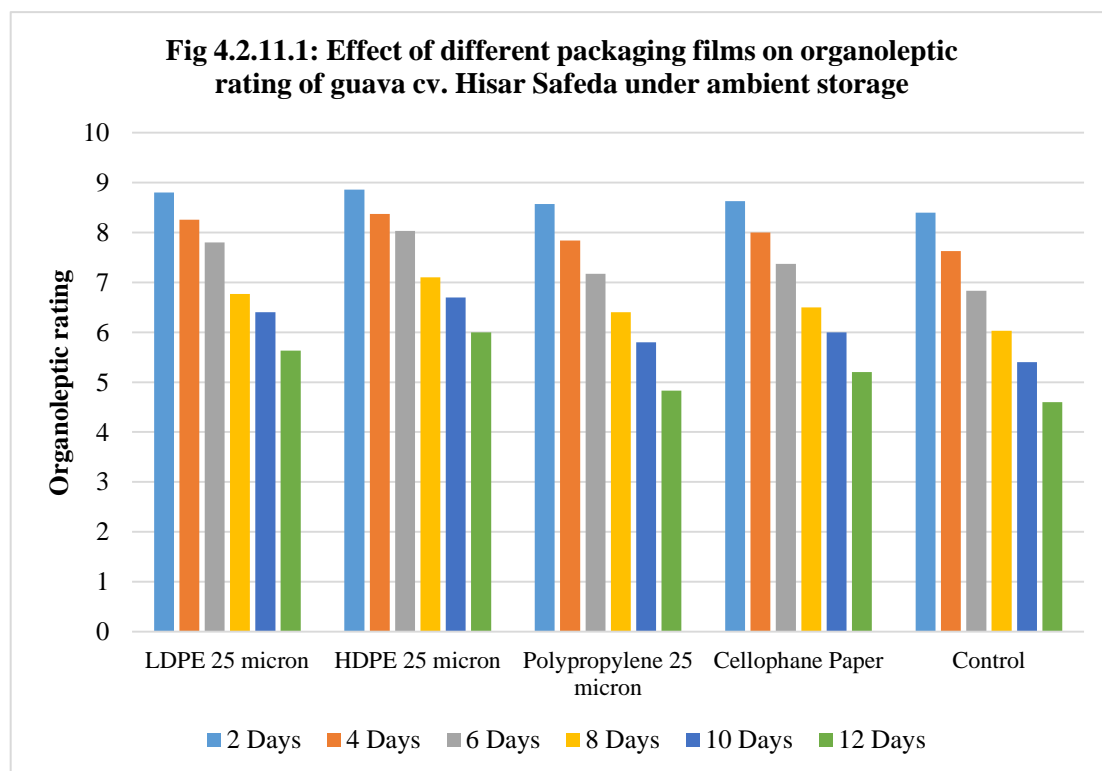
Table 4.2.12: Effect of different packaging films on organoleptic rating of guava cv. Hisar Safeda

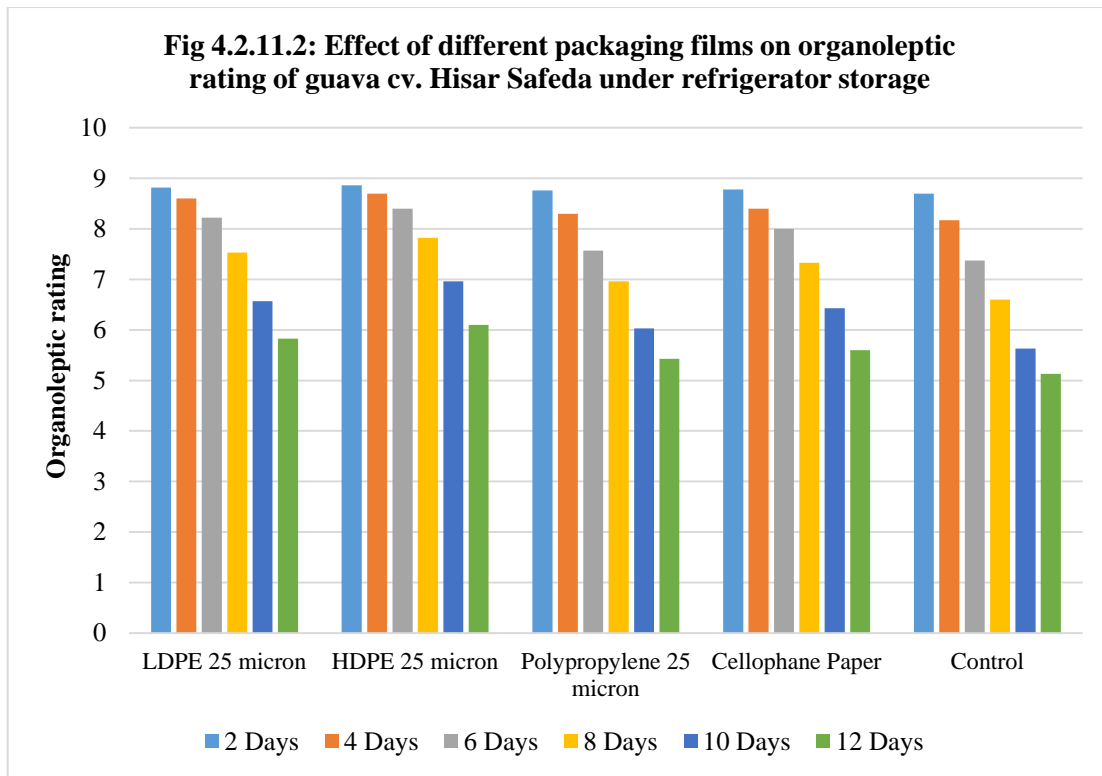
Treatments		Ambient Storage							Refrigerator Storage						
		Storage Period							Storage Period						
		2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean	2 Days	4 Days	6 Days	8 Days	10 Days	12 Days	Mean
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	
LDPE 25 micron	T₁	8.80	8.26	7.80	6.77	6.40	5.63	7.28	8.82	8.60	8.22	7.53	6.57	5.83	7.60
HDPE 25 micron	T₂	8.86	8.37	8.03	7.10	6.70	6.00	7.51	8.86	8.70	8.40	7.82	6.96	6.10	7.81
Polypropylene 25 micron	T₃	8.57	7.84	7.17	6.40	5.80	4.83	6.77	8.76	8.30	7.57	6.96	6.03	5.43	7.18
Cellophane Paper	T₄	8.63	8.00	7.37	6.50	6.00	5.20	6.95	8.78	8.40	8.00	7.33	6.43	5.60	7.42
Control	T₅	8.40	7.63	6.83	6.03	5.40	4.60	6.48	8.70	8.17	7.37	6.60	5.63	5.13	6.93
Mean		8.65	8.02	7.44	6.56	6.06	5.25		8.78	8.43	7.91	7.25	6.33	5.62	
C.D. at 5%		Treatment (T) = 0.09 Days (D) = 0.10 T×D = 0.22							Treatment (T) = 0.08 Days (D) = 0.08 T×D = 0.19						

Various packaging films and storage period influenced non-reducing content significantly. Maximum non-reducing sugar content (2.39%) was recorded in T₂S₄ which was statistically at par with T₁S₄ (2.35%) followed by T₅S₂ (2.33%) while minimum non-reducing sugar content (1.88%) was recorded in T₅S₆ under refrigerator storage. Likewise, under ambient storage, Maximum non-reducing sugar content (2.38%) was recorded in T₂S₃ which was statistically at par with T₃S₂ (2.34%) and T₅S₁ (2.36%), whereas minimum non-reducing sugar content (1.77%) was recorded in T₅S₆.

4.2.12 Organoleptic rating

The observations recorded on organoleptic rating in guava as affected by different packaging films during different period of storage are presented in Table 4.2.12. It is evident from the data that all the packaging films had significant effect in maintaining the higher organoleptic rating as compared to control. Among the different packaging, fruits wrapped with HDPE 25 micron (T₂) exhibited maximum organoleptic rating (7.81) followed by LDPE 25 micron (T₁; 7.60), while control treatment (T₅) exhibited minimum organoleptic rating (6.93) under refrigerator storage. Likewise, under ambient storage T₂ exhibited maximum organoleptic rating (7.51) followed by T₁ (7.28), while it was minimum (6.48) in T₅ (control).





Storage period also had significant influence on palatability of fruits as organoleptic rating decreased with prolongation of storage time. Maximum organoleptic rating (8.78 and 8.65) was observed on 2nd day of storage (S_1) followed by 4th day of storage (S_2 ; 8.43 and 8.02), whereas minimum (5.62 and 5.25) was observed on 12th day of storage (S_6) under refrigerator and ambient conditions, respectively.

Under refrigerator storage, no significant variation had been observed in organoleptic rating among different treatments up to 2nd day of storage. Maximum organoleptic rating (8.70) was recorded in fruits packed with HDPE 25 micron on 4th of storage (T_2S_2) that were statistically at par with T_1S_2 (8.60), while minimum organoleptic rating (5.13) was observed in control treatment on 12th day of storage (T_5S_6). Under ambient condition, maximum organoleptic rating (8.86) was recorded in T_2S_1 that was statistically at par with T_1S_1 (8.80), while minimum organoleptic rating (4.60) was observed in control treatment on 12th day of storage (T_5S_6).

Growth, development and ripening of fruits are processes that involve numerous biochemical and physiological changes as a result of which fruits become more appealing to consumers. Ripening includes softening, sweetening, decreased bitterness, improved texture, increased pigmentation and flavour in fruits. Generally, such apparent changes take place in a coordinated manner. An understanding of these changes during development and ripening is crucial in reducing post-harvest losses and extending shelf-life of fruits.

Post-harvest chemical treatments and modified atmosphere has been evidenced to be a valuable and reliable method for reducing post-harvest losses and maintaining quality of perishable fruits. Present experiment entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda.**” was conducted in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2020-21 with an objective to study the effect of different chemical, different packaging films and storage conditions on shelf-life of guava fruits. In this chapter, results of the experiments have been discussed along with the finding of earlier research workers.

5.1 Experiment I: Effect of salicylic acid and putrescine on the shelf-life of guava.

5.1.1 Physiological loss in weight (%)

The physiological loss in weight (PLW) decreased significantly with the prolongation of storage period. This may be due to less availability of moisture content for respiration and transpiration on later days compare to initial days which leads to less PLW. Minimum PLW was recorded in fruits treated with salicylic acid @ 4 mM followed by fruits treated with salicylic acid @ 3 mM, while maximum PLW was recorded under control treatment in both storage conditions (ambient and refrigerator storage). Salicylic acid treatment has a beneficial impact on maintaining membrane integrity and suppressing metabolic activity like respiration and ethylene evolution might be reason for lower PLW in treated fruits (Manthe *et al*, 1992 and Zheng and Zhang, 2002). Han *et al.* (2002) also observed that salicylic acid effectively reduced the rate of respiration in peach fruits. Ennab *et al.* (2020) reported that post-harvest application of salicylic acid and putrescine had significantly reduced the weight loss in ‘Murcott’ mandarin fruit. Present findings also got support from the results of Abd El-Aziz (2020), Arafat (2019) and Madhav *et al.* (2016) in guava, Brar *et al.* (2014) in peach.

It was observed that PLW was less in refrigerator storage as compared to ambient storage might be due maintenance of high moisture around the surface of fruit along with high humidity storage conditions. Similar results were found by Haider *et al.* (2020) in Kinnow, Gupta *et al.* (2011) in peach and Jawandha *et al.* (2008) in ber.

5.1.2 Decay loss (%)

Decay loss percentage increased with the passage of storage period but all post-harvest treatments significantly reduced the decay loss over the control under both storage conditions. Minimum decay loss observed in fruits treated with salicylic acid @ 4 mM which was statistically at par with salicylic acid @ 3 mM and putrescine @ 5 mM under both storage conditions. Continuous biochemical changes in fruits leads to fruit softening and decay which eventually degrades the quality of fruits. Under cold storage conditions, these changes can be slowed down to some extent (Kaur and Bal, 2014). Salicylic acid has impact in maintaining membrane integrity and suppresses the respiration and ripening process (Zheng and Zhang, 2002). It also strengthens defence system by enhancing activities of antioxidant enzymes that develop the resistance in treated fruits against the fungal attack (Xu and Tian, 2008). Putrescine had a significant influence on the reduction in decay loss due to anti-pathogenic properties (Khosroshahi *et al.*, 2007). Ours results are in agreement with those of Ennab *et al.* (2020) in 'Murcott' mandarin, Kaur *et al.* (2019) in guava cv. Allahabad Safeda and Brar *et al.* (2014) in peach.

5.1.3 Total soluble solid (%)

Total soluble solid (TSS) of guava was significantly influenced by treatments and storage period. Highest TSS was recorded in fruits treated with salicylic acid @ 4 mM that was followed by salicylic acid @ 3 mM, whereas lowest TSS was reported in fruits under control treatment in both storage conditions. It was observed that TSS increased initially and declined afterwards. Increase in TSS and sugars may be due to hydrolysis of starch into sugars, as after complete hydrolysis of starch, no further increase occurs and afterwards decline in TSS is anticipated as they along with other organic acids are primary substrate for respiration (Jain *et al.*, 2017; Han and Li, 1997; Kays, 1991 and Wills *et al.*, 1980). Since, salicylic acid might have suppressed the catabolic processes such as respiration rate and ethylene production, so the treated fruits initially showed a slow increase in TSS and further maintain higher TSS for longer duration. Alike pattern of TSS was also observed by Bhooriya *et al.* (2018), Deepthi (2017) and Amanullah *et al.* (2017) in guava, Brar *et al.* (2014) and Tareen *et al.* (2012) in peach and Han and Li (1997) in apples.

5.1.4 Titratable acidity (%)

Non-significant variation in titratable acidity (TA) was found among post-harvest treatments, storage period and interaction of treatment and storage period under both storage conditions.

5.1.5 TSS: Acid ratio

It was very clear from the present experiment that TSS: Acid ratio varied significantly among treatments. Salicylic acid @ 4 mM showed maximum TSS: Acid ratio that was statistically at par with salicylic acid @ 3 mM and putrescine @ 5 mM, while minimum TSS: Acid ratio was estimated in control treatment under both storage conditions. TSS: Acid ratio is combined parameter of TSS and titratable acidity that is directly proportional to TSS and inversely proportion to acidity. Ennab *et al.* (2020) reported that post-harvest application of salicylic acid and putrescine both materials were effective in maintaining TSS: Acid ratio during storage of 'Murcott' mandarin fruit. In similar finding, Yeganeh *et al.* (2013) found maximum TSS: Acid ratio in 'Bidaneh Sefid' grapes when treated with 2 and 4 mM of salicylic acid solution.

It was observed that TSS: Acid ratio initially increased, thereafter declined with the passage of storage period under both storage conditions. These findings are in harmony with findings of Eman *et al.* (2015) in guava, Karuna *et al.* (2015) in mango, Navjot (2005) in peach and Hussein *et al.* (2003) in apple.

5.1.6 Juice pH

An increasing trend in juice pH occurred may be due breakdown of organic acids with respiration during storage (Pool *et al.*, 1972) but rate of increase in juice pH was slowed down in all treatments as compared to control under both storage conditions. Lowest value of juice pH was recorded in fruits treated with salicylic acid @ 4 mM that was statistically at par with fruits treated with salicylic acid @ 3 mM and putrescine @ 5 mM might be due to reduction in respiration rate and the catabolism of organic acids (Lolaei *et al.*, 2012 and Ishaq *et al.*, 2009), while highest value was recorded in control treatment resulted from a high rate of metabolic activities. Similar trend of juice pH was also observed by Azam *et al.* (2020) in guava cv. Golla and Abbasi *et al.* (2010) in peach cv. Maria Delicia.

5.1.7 Pectin content (%)

Continuous reduction in pectin content of guava fruit was observed with prolongation of storage period irrespective of treatments under both storage conditions. Similar declining trend of pectin content of guava fruit from ripe to over ripe stage was observed by Jain *et al.*

(2003) and Rashida *et al.* (1997). Declining trend of pectin content during storage might be due to breakdown of insoluble fraction of pectin to water soluble pectin by the action of pectin methyl esterase enzyme (Chandra *et al.*, 2011).

Among the treatments, maximum pectin content was observed in fruits treated with salicylic acid @ 4 mM that was statistically at par with fruits treated with salicylic acid @ 3 mM under both storage conditions. This increase in pectin content with salicylic acid application may be due to the ability of salicylic acid to reduce the activity of pectin methyl esterase enzyme that resulted in less conversion of insoluble pectin into soluble pectin (Lo'ay and Dawood, 2017). Similar results were also observed by Abd El-Aziz (2020) in guava.

5.1.8 Ascorbic acid content (mg/100 g pulp)

Ascorbic acid content of guava followed declining trend with the advancement of storage period under both storage conditions. The enzymatic oxidation of L-ascorbic acid into dehydroascorbic acid by ascorbic acid oxidase might be responsible for the gradual decrease in ascorbic acid during storage (Tiwari *et al.*, 2017). Similar gradually declining trend was also observed by Killadi *et al.* (2007) in guava, Singh *et al.* (2005) in aonla and Kaur and Bal (2014) in ber. However, this declining trend was slowed down with all treatments and maintained higher level of ascorbic acid as compared to the control throughout storage. Maximum ascorbic acid content was recorded in fruits treated with salicylic acid @ 4 mM that was statistically at par with salicylic acid @ 3 mM followed by putrescine @ 5 mM, while control treatment showed lowest ascorbic acid under both storage conditions. The results shows that salicylic acid and putrescine had a significant impact on maintaining the level of ascorbic acid during storage. This might due to reduction or delay in the activity of ascorbic acid oxidase by salicylic acid (Kazemi *et al.*, 2011) and putrescine (Muramatsu *et al.*, 1999). These results are lined with Amanullah *et al.* (2017) who observed that salicylic acid 600 µmol treated guava fruits maintained higher ascorbic acid content as compared to control. Similar results were also reported by Abd El-Aziz (2020) and Lo'ay and El Khateeb (2011) in guava, Ennab *et al.* (2020) in mandarin and Tareen *et al.* (2012) in peach.

5.1.9 Total sugars (%)

During storage, total sugars initially increased but later on, it decreased irrespective of treatment under both conditions. Initial increase in total sugars may be due to Hydrolysis of starch into sugar (Mahajan *et al.*, 2009) and later decreasing can be explained by utilization of sugars in respiration process (Hoda *et al.*, 2001). Similar trend was also observed by Singh *et al.* (2019) in guava, Kumar (2006) in ber and Kishor *et al.* (2018) in apple. Among the treatments, all were effective in slowing down initial increase and later maintained higher level of total sugars as compared to control at the end of storage. Salicylic acid @ 4 mM showed maximum level of total sugars followed by salicylic acid @ 3 mM, whereas control

treatment showed minimum level of total sugars under refrigerator as well as ambient storage. Since salicylic acid suppressed catabolic processes like respiration rate and ethylene production, the treated fruits showed a slow increase in total sugars at first and then maintained higher level of total sugars for longer period of storage. The results of this study are in agreement with Amanullah *et al.* (2017), who reported that guava fruits treated with salicylic acid exhibit higher level of total sugars at the end of storage. Similar results were also observed by Mohamed *et al.* (2012) in navel orange.

5.1.10 Reducing sugar (%)

Like total sugars, the reducing sugar also followed increasing-decreasing trend during the storage period. The initial escalation in reducing sugar level of guava fruits may be attributable to starch to sugar conversion, while the subsequent decrease in reducing sugar level may be due to sugar degradation for respiration during storage (Jayachandran *et al.*, 2007). These results are in line with the findings of Singh *et al.* (2019) in guava, Jaishankar (2015) in sapota and Kishor *et al.* (2018) in apple. It was observed that salicylic acid was effective in retaining the higher level of reducing sugar content during storage. The maximum reducing sugar was retained in salicylic acid @ 4 mM followed by salicylic acid @ 3 mM and the minimum reducing sugar was recorded in control treatment. The explanation was the same as in the case of total sugar. Similar retention of higher level of reducing sugars with salicylic acid treatments had been reported by Srivastav and Upendra (2000) in banana, Amanullah *et al.* (2017) in guava and Mohamed *et al.* (2012) in navel orange.

5.1.11 Non-reducing sugar (%)

Non-reducing sugars varied significantly in fruits among the different post-harvest treatments. Under both storage conditions, fruits treated with salicylic acid @ 4 mM showed maximum non-reducing sugar content followed by salicylic acid @ 3 mM, whereas control treatment showed minimum non-reducing sugar content. Similar to our results, Amanullah *et al.* (2017) in guava and Srivastava and Dwivedi, (2000) in banana also reported the higher level of non-reducing sugar in fruits treated with salicylic acid over the control treatment. With the prolongation of storage period, non-reducing sugar initially increased, afterwards it declined irrespective of treatment under both conditions. The present results are in accordance with the findings of Bhooriya *et al.* (2018) in guava, Jain *et al.* (2017) in ber and Jaishankar (2015) in sapota.

5.1.12 Organoleptic rating

The findings show that all post-harvest treatments had a substantial impact on maintaining a higher organoleptic rating as compared to the control. Fruits treated with salicylic acid @ 4 mM had the highest organoleptic rating followed by salicylic acid @ 3 mM

that was statistically at par with putrescine @ 5 mM, whereas control had the lowest organoleptic rating when stored in the refrigerator. Likewise, under ambient storage, salicylic acid @ 4 mM had the highest organoleptic rating followed by salicylic acid @ 3 mM, while control had the lowest. Our results are in conformity with the findings of Kaur *et al.* (2019) in guava cv. Allahabad Safeda, Kaur and Kaur (2019) and Abbasi *et al.* (2010) in peach and Jain *et al.* (2017) in ber.

With increase in storage time, the taste, flavour, and appearance of the fruits deteriorated. The decrease in organoleptic rating may be attributed to the various degradation processes that occur in fruits during storage. Decrease in the organoleptic ratings also noted by Kishor *et al.* (2018) in apple and Jaishankar (2015) in sapota.

5.2 Experiment II: Effect of different packaging films on the shelf-life of guava fruit.

5.2.1 Physiological loss in weight (%)

Physiological loss in weight (PLW) of fruits increased during storage and different packaging materials significantly reduced it. The decrease in PLW with increasing storage time in all packaging materials as seen in both storage conditions, is attributed to respiration and transpiration, both used various reserved food materials inside the fruit and on later days available moisture content was less as compare to initial days for respiration and transpiration which leads to less PLW. Haard and Salunkhe (1975) suggested that PLW is primarily caused by evaporation of water from the fruits, respiration and various degradation processes that occur during storage. In the present investigation, minimum PLW was recorded in HDPE 25 micron packed fruits followed by LDPE 25 micron and maximum PLW was observed in control treatment. This may be because polyethene reduces the rate of transpiration and respiration by limiting gas diffusion. Present findings are in accordance with Panda *et al.* (2016), Miano *et al.* (2010), Kumar *et al.* (2003) and Venkatesha and Reddy (1994) in guava, Azene *et al.* (2014) in papaya and Sandhu and Singh (2000) in pear.

5.2.2 Decay loss (%)

The decay loss of guava fruits increased with the passage of storage duration irrespective of packaging materials used under both storage conditions. This increasing trend may be linked to fruit spoilage caused by various fungal diseases such as stem end rot, side rots, and other fungi during the storage (Jeffries *et al.*, 1990 and Eckert *et al.*, 1996). Similar increasing trend of decay loss was also observed by Kishor *et al.* (2018) in apple, Kumar (2006) in ber and Hoda *et al.* (2001) in mango. All the packaging materials were effective in reducing the decay loss under both storage conditions. Under refrigerator storage, minimum decay loss was recorded in fruits packed with HDPE 25 micron followed by LDPE 25 micron. Under ambient storage, fruits packed with HDPE 25 micron showed minimum decay loss that

was statistically at par with LDPE 25 micron. Maximum decay loss was recorded in control treatment under both storage conditions. The significant check in fruits spoilage in polyethylene might be due to low concentration of oxygen and high concentration of carbon dioxide, which suppressed the multiplication of spoilage causing microorganisms. Similar results were also recorded by Avesh *et al.* (2019) and Kumar *et al.* (2003) in guava and Panda *et al.* (2016) in strawberry.

5.2.3 Total soluble solid (%)

The total soluble solids (TSS) of fruits increased initially and then decreased after attaining a certain value under both storage conditions irrespective of packaging materials. Initially, TSS may have increased due to the hydrolysis of starch into sugars, since no further increase occurs after complete hydrolysis of starch and TSS was anticipated to decline after that, as they, along with other organic acids, were the primary substrate for respiration (Jain *et al.*, 2017; Han and Li, 1997; Kays, 1991 and Wills *et al.* 1980). Similar pattern of TSS was also observed by Tiwari *et al.* (2017) and Killadi *et al.* (2007) in guava and Jaishankar (2015) in sapota. All the packaging material retained higher TSS than that of control but maximum value of TSS was observed in HDPE 25 micron packed fruits. This may be attributed to the hydrolysis of polysaccharides and the slow rate of sugar utilisation in the respiration as a result of the modified environment in polyethylene packed fruits. These findings are in agreement with Nagaraju and Banik (2019), who reported maximum TSS in HDPE packed guava cv. Khaja. Similar results were also reported by Taduri *et al.* (2017) in mango, Sandhu and Singh (2000) in pear and Singh *et al.* (1993) and Sharma *et al.* (1994) in guava.

5.2.4 Titratable acidity (%)

Non-significant variation in titratable acidity (TA) was found among post-harvest treatments, storage period and interaction of treatment and storage period under both storage conditions.

5.2.5 TSS: Acid ratio

TSS: Acid ratio is combined parameter of TSS and titratable acidity that is directly proportional to TSS and inversely proportion to acidity. Initially TSS: Acid ratio of fruits increased and then decreased after attaining a certain value under both storage conditions irrespective of packaging materials. Among the packaging materials, HDPE 25 micron showed maximum TSS: Acid ratio that was statistically at par with LDPE 25 micron, while minimum TSS: Acid ratio was estimated in control treatment under both storage conditions. The present results are in close agreement with the findings of (Taduri *et al.*, 2017), who observed highest TSS: Acid ratio in LDPE film packed fruits of mango cv. Amarpali after 12 days of storage.

5.2.6 Juice pH

With the passage of storage time, pH of guava juice increased. The increasing trend of juice pH may be due breakdown of organic acids with respiration during storage (Pool *et al.*, 1972) but rate of increase in juice pH was slowed down in fruits packed with various packaging films as compared to control under both storage conditions. Lowest value of juice pH was recorded in fruits packed with HDPE 25 micron that was statistically at par with LDPE 25 micron, while highest value was recorded in control treatment under both storage conditions. This might be due to reduction in respiration rate in polyethylene packed fruits. Present results are in harmony with Nagaraju and Banik (2019).

5.2.7 Pectin content (%)

A significant reduction in pectin content was recorded with the advancement of storage period under both storage conditions. Among the different packaging films, maximum pectin content was observed in fruits packed with HDPE 25 micron that was statistically at par with LDPE 25 micron under both storage conditions. Reducing trend of pectin content during storage might be due to breakdown of insoluble fraction of pectin to water soluble pectin by the action of pectin methyl esterase enzyme. These findings are in conformity with the previous findings of Chandra *et al.* (2011), who observed maximum pectin retention in guava fruits when packed with cling film. Kaur *et al.* (2013) also observed acceptable firmness of pear fruits packed in CFB boxes with HDPE liners at the end of storage due to retention of higher pectin content as compare to control.

5.2.8 Ascorbic acid content (mg/100 g pulp)

Ascorbic acid content of fruit gradually declined with prolongation of storage period in all the packaging materials under both storage conditions. The enzymatic oxidation and irreversible conversion of L-ascorbic acid to dehydroascorbic acid by the action enzyme ascorbic acid oxidase might be the reason of reduction in ascorbic acid (Tiwari *et al.*, 2017). Different types of packaging films helped to maintain the higher concentration of ascorbic acid in both storage conditions. This may be because these packaging films might be helpful to reduce the oxidation of ascorbic acid. Higher retention of ascorbic acid in fruits packed in HDPE 25 micron and LDPE 25 micron as compared to control was noticed due to low respiration rate. Present findings are in line with Nagaraju and Banik (2019), Chandra *et al.* (2011), Venkatesha and Reddy (1994) and Sharma *et al.* (1994) in guava and Asati *et al.* (2017) in ber.

5.2.9 Total sugars (%)

Total sugars in fruits increased with storage period advancement at first and then declined after reaching a certain value under both storage conditions. The maximum retention of total sugars was recorded in fruits packed in HDPE 25 micron followed by LDPE 25 micron, whereas minimum total sugars was recorded in control treatment under both storage conditions. The higher retention of total sugars could be attributed to the slower conversion of starch and polysaccharides in sugars as well as the slower rate of respiration (Chandra *et al.*, 2011). The results of present investigation are in close accordance with Nagaraju and Banik (2019), who reported that total sugars were maximum in fruits of guava packed in 2% perforated HDPE after 12 days of storage. Similar results were also obtained by Shalini *et al.* (2018) in kiwi, Mahajan *et al.* (2015) plum and Azene *et al.* (2014) in papaya.

5.2.10 Reducing sugar (%)

Similar to total sugars, reducing sugar also increased initially and then after attaining a certain value, it started declining with the passage of storage period under both storage conditions. The maximum reducing sugar was retained in fruits packed with HDPE 25 micron followed by LDPE 25 micron and the minimum reducing sugar was recorded in control treatment. The explanation of the higher retention of reducing sugar was the same as in the case of total sugars. The experimental results of the present investigation are in close accordance with the reports of Nagaraju and Banik (2019), who reported maximum reducing sugar in fruits of guava packed in 2% perforated HDPE after 12 days of storage and Shalini *et al.* (2018) who also reported that after seven months of refrigerated storage ($2 \pm 1^\circ\text{C}$) kiwi fruits packed in LDPE + 5g KMnO_4 retained maximum reducing sugar.

5.2.11 Non-reducing sugar (%)

Non-reducing sugar increased initially and then decreasing trend with the advancement of storage period under both storage conditions, being significantly higher in fruits packed with HDPE 25 micron followed by LDPE 25 micron, which may be attributed to starch and other polysaccharides being hydrolysed into soluble sugars (Wills *et al.*, 1980). These results are in line with the previous findings of Hiwale and Singh (2003), who reported maximum non-reducing sugar in guava fruits packed in 5% perforated LDPE and Azene *et al.* (2014), who reported that HDPE and LDPE bags retained higher level of non-reducing sugar in papaya fruits as compared to other packaging materials.

5.2.12 Organoleptic rating

The organoleptic rating of the fruits decreased with prolongation of storage period in both storage conditions irrespective of packaging materials. This drop in organoleptic rating may be attributed to decrease in taste, flavour and visual quality because various degradation

processes that occur in fruits during storage. The maximum organoleptic rating was noticed in guava fruits packed in HDPE 25 micron followed by LDPE 25 micron. These results are in accordance with the findings of Kaur *et al.* (2014), who reported that guava fruits packed in 5% perforated LDPE film and kept in corrugated fibreboard boxes at 6-8°C temperature and 90-95% relative humidity maintain good organoleptic quality for 14 days, Parihar and Kumar (2007), who reported better quality guava fruits when packed with HDPE bags as compared to other packaging materials and Taduri *et al.* (2017), who reported that fruits of mango when packed in 5% perforated LDPE film exhibited better quality after 12 days of storage as compare to other packaging materials.

Present experiment entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda.**” was conducted in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2020-21 with an objective to study physiological and biochemical changes during storage and also effect of different chemical, different packaging films and storage conditions on shelf-life of guava fruits. The salient findings of the experiment are summarized as below:

Experiment I: Effect of salicylic acid and putrescine on the shelf-life of guava.

- With the passage of storage period there was progressive loss in weight of fruits. Minimum physiological loss in weight was recorded in fruits treated with salicylic acid @ 4 mM followed by fruits treated with salicylic acid @ 3 mM under both ambient and refrigerator storage.
- Decay loss increased with the prolongation of storage period. Minimum decay loss observed in salicylic acid @ 4 mM treated fruits that was statistically at par with salicylic acid @ 3 mM and putrescine @ 5 mM under both storage conditions. Higher concentrations of salicylic acid and putrescine were found to be more efficient at preventing fruit decay.
- The total soluble solids (TSS) of fruits increased initially and then decreased after attaining a certain value. Highest TSS was retained in fruits treated with salicylic acid @ 4 mM followed by salicylic acid @ 3 mM under refrigerator as well as ambient storage.
- TSS: Acid ratio initially increased, thereafter declined with the passage of storage period. Highest TSS: Acid ratio was found in salicylic acid @ 4 mM that was statistically at par with salicylic acid @ 3 mM and putrescine @ 5 mM, while lowest in control under both storage conditions.
- Juice pH followed increasing trend during storage and lowest value of juice pH was recorded in salicylic acid @ 4 mM which was statistically at par with salicylic acid @ 3 mM and putrescine @ 5 mM, while highest in control.
- Continuous reduction in pectin content of guava fruit was observed with prolongation of storage and maximum retention of pectin was observed in salicylic acid @ 4 mM that was statistically at par salicylic acid @ 3 mM under both storage conditions.

- Ascorbic acid followed declining trend with the advancement of storage. Higher level of ascorbic acid content was maintained in the fruits treated with higher concentration of salicylic acid and putrescine as compared to control that showed lowest ascorbic acid under both storage conditions.
- During storage, total sugar initially increased but later on, it decreased. In both storage conditions, salicylic acid @ 4 mM showed maximum level of total sugars, while control showed minimum.
- Reducing sugar initially increased, afterwards it declined with the passage of storage period. The maximum reducing sugar was obtained in salicylic acid @ 4 mM treated fruits followed by salicylic acid @ 3mM.
- Non-reducing sugars also followed the same trend as total and reducing sugar. Fruits treated with salicylic acid @ 4 mM showed maximum non-reducing sugar followed by salicylic acid @ 3 mM, whereas control showed minimum under both storage conditions.
- The organoleptic rating of the fruits decreased with prolongation of storage. Maximum fruit quality was retained by salicylic acid @ 4 mM followed by salicylic acid @ 3 mM that was statistically at par with putrescine @ 5 mM throughout the storage.

Experiment II: Effect of different packaging films on the shelf-life of guava fruit.

- Physiological loss in weight (PLW) of fruits increased during storage, and different packaging materials significantly reduced it. Minimum PLW was recorded in HDPE 25 micron packed fruits followed by LDPE 25 micron, while maximum in control.
- Decay loss increased with the extension of storage time. Minimum decay loss was observed in fruits packed with HDPE 25 micron followed by LDPE 25 micron under refrigerator storage. Under ambient storage, HDPE 25 micron showed minimum decay loss that was statistically at par with LDPE 25 micron. Control showed maximum decay loss under both storage conditions.
- TSS increased initially and declined afterwards. Maximum retention of TSS was observed in HDPE 25 micron packed fruits followed by LDPE 25 micron under refrigerator as well as ambient storage.
- Initially TSS: Acid ratio of fruits increased and then decreased after attaining a certain value. Fruits packed in HDPE 25 micron showed maximum TSS: Acid ratio that was statistically at par with LDPE 25 micron, while minimum was estimated in control under both storage conditions.

- Juice pH followed an increasing trend with prolongation of storage time. Lowest pH was recorded in fruits packed with HDPE 25 micron that was statistically at par with LDPE 25 micron, while highest recorded in control under both storage conditions.
- A significant reduction in pectin content was observed with the advancement of storage period. Maximum retention of pectin was observed in HDPE 25 micron packed fruits that was statistically at par with LDPE 25 micron under refrigerator as well as ambient storage.
- Ascorbic acid gradually declined with passage of storage period. Higher level of ascorbic acid content was maintained in the fruits packed with HDPE 25 micron and LDPE 25 micron as compared to control.
- Total sugars firstly increased, afterwards it declined after attaining a certain value. The maximum retention of total sugars was recorded in fruits packed in HDPE 25 micron followed by LDPE 25 micron under both storage conditions.
- During storage, reducing sugar firstly increased but later on, it decreased. In both storage condition, fruits packed with HDPE 25 micron retained maximum reducing sugar followed by LDPE 25 micron.
- Likewise, non-reducing sugar follow the similar trend as total and reducing sugar, highest in fruits packed with HDPE 25 micron followed by LDPE 25 micron under both storage conditions.
- Fruit quality deteriorated with the prolongation of storage period. Highest organoleptic rating was recorded in HDPE 25 packed fruits followed by LDPE 25 micron under refrigerator as well as ambient storage.

CONCLUSION

Based on the results of the studies, it can be concluded that

- Higher concentrations of salicylic acid and putrescine are effective in reducing physiological loss in weight, decay loss and retaining a higher level of total soluble solids (TSS), TSS: Acid ratio, sugars, ascorbic acid and pectin content, which helps in maintaining acceptable quality and improving the shelf-life of guava cv. Hisar Safeda in the refrigerator as well as under ambient storage.
- The best overall results were found in fruits treated with salicylic acid @ 4 mM followed by salicylic acid @ 3 mM under refrigerator storage.
- Also, modified atmospheric packaging (MAP) with HDPE 25 micron was found to extend the shelf-life and maintain the better quality of guava during storage and proved to be the best MAP treatment.

Hence, salicylic acid, putrescine and HDPE seem to have the potential to enhance the post-harvest life of guava in refrigerator as well as ambient storage conditions.

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APPENDIX-1
SENSORY EVALUATION
(HEDONIC RATING SCALE)

Name.....

Date.....

Product.....

Time.....

INSTRUCTION: Taste the given samples and check how much like or dislike each one. Use appropriate scale to show your attitude by assigning points that best describe your feelings about the sample. An honest expression of yours will help us evaluate on the basis of the following scale.

Acceptability	Marks
Extremely desirable	9
Very much desirable	8
Moderately desirable	7
Slightly desirable	6
Neither desirable nor undesirable	5
Slightly undesirable	4
Moderately undesirable	3
Very much undesirable	2
Extremely undesirable	1

Sample code	Colour and appearance	Flavour	Taste	Overall acceptability	Remarks

ABSTRACT

Title of Thesis	: Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (<i>Psidium guajava</i> L.) cultivar Hisar Safeda
Name of degree holder	: Mr. Gurpreet Singh
Admission number	: 2017A49M
Title of degree	: Master of Science
Name of Discipline	: Horticulture- Fruit Science
Name and address of major advisor	: Dr. Arvind Malik Assistant Professor, Department of Horticulture CCS HAU, Hisar-125004 (Haryana), India
Degree awarding University	: CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
Year of award of degree	: 2021
Major subject	: Horticulture- Fruit Science
Total no. of pages in thesis	: 92 + ix
No. of words in abstract	: 282

Keywords: Guava, salicylic acid, putrescine, packaging, storage.

Guava fruits are highly perishable in nature, necessitating strategies to enhance post-harvest life in order to extend fresh fruit market period. Therefore, the present investigations were conducted to explore the possibilities of storage of guava cv. Hisar Safeda in refrigerated and ambient conditions with treatments of salicylic acid, putrescine and different modified atmospheric packaging. The fruits harvested at physiological maturity stage were subjected to the treatments of salicylic acid (1 mM, 2 mM, 3 mM and 4 mM), putrescine (2 mM, 3 mM, 4 mM and 5 mM) and different modified atmospheric packaging (LDPE, HDPE, Polypropylene and cellophane paper), packed in CFB boxes and stored in refrigerator and ambient conditions. The fruits were analyzed for various parameters on alternate days. Under both the storage conditions, all the treatments exhibited potential to maintain the post-harvest life of guava fruits as compared to control. However, higher concentrations of salicylic acid and putrescine are effective in reducing physiological loss in weight, decay loss and retaining a higher level of total soluble solids (TSS), TSS: Acid ratio, sugars, ascorbic acid and pectin content, which helps in maintaining acceptable quality and improving the shelf-life of guava cv. Hisar Safeda in refrigerator as well as ambient storage. The best overall results were found in fruits treated with salicylic acid @ 4 mM followed by salicylic acid @ 3 mM under refrigerator storage. Also, modified atmospheric packaging (MAP) with HDPE 25 micron was found to extend the shelf-life and maintain the better quality of guava during storage and proved to be the best MAP treatment. Hence, salicylic acid, putrescine and HDPE seems have the potential to enhance the post-harvest life of guava in refrigerator as well as ambient storage.

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SIGNATURE OF STUDENT

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Academic Qualification

Degree	Institution	Year of Passing	Percentage of marks	Subjects
M.Sc. (Horticulture)	COA, CCS HAU, Hisar, Haryana	2021	8.0/10	Major: Horticulture–Fruit Science Minor: Plant Physiology
B.Sc. Agriculture (Hons.)	COA, PAU, Ludhiana, Punjab	2017	7.82/10	All Agricultural subjects with Horticulture as elective
12th	Govt. Sen. Sec. School, Abohar, Punjab	2013	91.1%	Punjabi, English, Physics, Chemistry, Mathematics, and Computer Science.
10 th	Swami Vivekanand Public School, Abohar, Punjab	2011	86.9%	Punjabi, English, Hindi, Agriculture, Mathematics, Science and Social Science

Co-Curricular activities

- Participated in North Zone Inter Varsity Lawn Tennis Tournament (2016-17) held at Guru Jambheshwar University, Hisar.

Training/Experience

- Attended training on 'Post-Harvest Handling of Horticultural Produce' organized by CCSHAU, Hisar during 14-22 November, 2017.
- Worked in Punjab National Bank (E-OBC) as an agriculture officer for 2 years (2018-20).

Prize/ Award

- Won Gold Medal in PAU Intercollege Lawn Tennis Tournament during 2016-17.
- ICAR PG scholarship during post-graduation programme.

I, hereby, declare that all the information provided in the resume is true to best of my knowledge.

Signature of student
(GURPREET SINGH)

UNDERTAKING OF COPYRIGHT

I, **Gurpreet Singh**, Admission No. **2017A49M**, hereby undertake that I give the full copyrights of my thesis entitled “**Studies on effect of salicylic acid, putrescine and modified atmospheric packaging of guava (*Psidium guajava* L.) cultivar Hisar Safeda**” to the Chaudhary Charan Singh Haryana Agricultural University, Hisar.

I also undertake that the patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission with the competent authority of Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Signature of Student
(GURPREET SINGH)