EFFECT OF POSTHARVEST TREATMENTS AND PACKAGING MATERIALS ON SHELF LIFE AND QUALITY OF GUAVA

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This is to certify that the thesis entitled, **"EFFECT OF POSTHARVEST TREATMENTS AND PACKAGING MATERIALS ON SHELF LIFE AND QUALITY OF GUAVA"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** in ***HORTICULTURE****, embodies the result of a piece of Bonafede research work carried out by* ***MD. NOZIBULLAH AKONDO****, Registration No****. 14-06100*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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ABSTRACT

The experiment was carried out in the Postharvest Laboratory of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of different postharvest treatments on shelf life and quality of guava. The experiment comprised two factors viz. Factor A: T_0 = No postharvest treatments, T_1 = Hot water (45^0c for 5 minutes), T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb) and Factor B: P_0 = No packaging material, P_1 = Perforated polythene bag and P_2 = Newspaper were used in this experiment. The experiment was laid out in completely randomized design (CRD) with five replications. Various physical and chemical parameters were recorded during the experiment. In case of packaging material, the highest shelf life (10.92 days) were observed in P_1 (Perforated polythene) the lowest was recorded in P_0 (no packaging) (7.25 days). Regarding postharvest treatments, T_3 (1-MCP treated fruits) gave the best results on studied parameters and showed highest shelf life (11.00 days) compared to other treatments and shortest shelf life (6.67 days) was recorded from T_0 (no postharvest treatments). In combined application of postharvest treatments and packaging materials, the highest percent dry matter content (22.99%), total soluble solid (8.90%), percent total sugar (9.06%), percent reducing sugar (6.05%), percent titratable acidity (2.12%), non-reducing sugar (3.01%) and vitamin C (195.17 mg/100g) were found from the treatment combination of T_3P_1 whereas T_0P_0 showed the lowest results. Likewise, the highest shelf life (12.67 days) was also recorded from T_3P_1 whereas the lowest (5.33 days) was found in T_0P_0. Therefore, T_3P_1 is considered to be the most effective postharvest treatment for extending shelf life and quality of guava.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ = Agroecological Zone

BARI = Bangladesh Agricultural Research Institute

DAS = Days after storage

et al. = And others

FAO = Food and Agricultural Organization of United Nations

g = gram (s)

ha^{-1} = Per hectare

HRC = Horticulture Research Centre

kg = Kilogram

LSD = Least Significant Difference

Max = Maximum

Min = Minimum

MOP = Muriate of Potash

NRS = Non-reducing sugar

NS = Not significant

RCBD = Randomized Complete Block Design

RS= Reducing sugar

SAU = Sher-e-Bangla Agricultural University

SRDI = Soil Resources and Development Institute

TS= Total sugar

TSS = Total soluble solid

wt. = Weight

% = Percent

^0C = Degree Celsius

CHAPTER I

INTRODUCTION

Guava (*Psidium guajava* L.) is an important fruit crop in Bangladesh. It belongs to the family Myrtaceae. Guava is a climacteric fruit (Brown and Wills, 1983). It is generally known as the tropic's apple, is a well-known edible tree fruit that is grown in more than sixty countries throughout the world. Guava is one of the most popular and delicious fruits in Bangladesh. It holds a unique position in terms of nutritional quality, flavor and consumer preference. Every year, due to a lack of appropriate postharvest management, 3.4151% of total guava fruits are wasted (Madan and Ullasa, 1993).

Guava is rich in antioxidants like phenolics and carotene (Joseph and Priya, 2011). Early degradation during storage is caused by a high respiration rate. Firmness, acidity, and vitamin C decrease while PLW, TSS, and sensory rating increase in storage under ambient conditions (Deepthi *et al.*, 2016). Temperature and humidity have a direct impact on the quality of guava. In Bangladesh there have insufficient refrigeration facilities. The alternative means for increasing shelf life of fruits for a short period are likely to prove more beneficial. The translucent films that cover the product surface and act as a barrier to humidity and oxygen which cause postharvest deterioration. Several types of edible coating such as 1-MCP, hot water and $CaCl_2$ has been known to protect perishable goods from deterioration by reducing transpiration, respiration and maintaining quality.

1-methylcyclopropene (1-MCP) has been added to the list of options for extending the shelf life and quality of plant products (Vicente *et al.*, 2005). 1-MCP an ethylene action inhibitor, interacts with ethylene receptors and thereby prevents ethylene-dependent responses in many horticultural commodities (Sisler and Serek, 1997; Blankenship and Dole, 2003; Watkins, 2006). Calcium compounds extend the shelf-life of fruits by maintaining firmness, minimizing rate of respiration, protein breakdown, disintegration of tissues and disease incidence (Bangerth *et al.*, 1972). Calcium ions play an essential role in the structural maintenance of membranes and cell walls (Oms-Oliu *et al*. 2010. Calcium delays the process of ripening particularly the softening and hence, increases the shelf-life by altering intercellular and extracellular processes (Shehata *et al*. 2009). Calcium salts can also reduce pathogen spore germination, sporulation and growth and

form complexes with plant cell walls, which improves structural integrity, retards tissue softening and delays ripening (Silva *et al*., 2012; Cruz *et al*., 2015). Post-harvest treatments with hot water have been well studied for controlling post-harvest decay of citrus fruits (Lurie, 2009), also in the case of long-term refrigerated storage for improving fruit resistance to chilling injury (Rodov *et al* 1995). Heat treatment exposure to the fruits to temperatures 40-42°C increases the storage life and flavor of fruits (Barber and Sharpe, 1971 and Lurie, 2009).

Due to the adoption of inappropriate packinghouse operations, packaging material and transport vehicle, 20-25% of the total produce is going waste every year before reaching the consumer (Chandra *et al.*, 2011). Pereira *et al*. (2003) found that fruits packed in polyethylene terephthalate (PET) trays and stored at 5℃ had the lowest weight loss microbial spoilage and best physio-chemical characteristics. The highest retention of green color (20%) was observed in the polythene laminated with aluminum foil packaging (Mandhyan, 1999). The polyethylene packaging further had a concomitant effect in delaying senescence and physiological processes by creating modified atmospheric condition around the produce by controlling the gaseous (CO_2 and O_2) concentration in the package (Neeraj et al., 2003).

For maintaining the quality and shelf life of guava fruits, postharvest application of coatings like 1-MCP, $CaCl_2$, hot water and different packaging materials may show best results as these are known to increase quality and shelf life of guava fruits. With all of this in mind, an experiment was done with the following aims to examine the applicability of various postharvest treatments on the shelf life and quality of guava-

1. To evaluate guava shelf life and quality under various postharvest treatments and packaging materials at varied storage times;
2. To evaluate an effective postharvest treatment for guava to improve its shelf life and quality.

CHAPTER II

REVIEW OF LITERATURE

Guava is very delicious and usually picked fresh from the tree when ripe or mature. Fruits are used to make drink, nectar, jam, and jelly in addition to being consumed fresh. It is also used in the preparation of sauce and chutney, or cooked as a vegetable when green. Moreover, guavas are also processed into a variety of products like toffee, canned fruits, wine, squash, cheese, dried fruits, as well as flavoring for other foods. Guava is becoming very popular over other fruit trees due to its high adaptability, productivity and vitamin C content. Guava has high nutritive value as well as heavy crop bearing habit every year.

Compared to other large fruits, guava requires less maintenance. Agricultural inputs cost money, yet the output is profitable. The literature related to postharvest life of guava is very limited. However, the relevant information available on other fruit crops which has been used as a base for planning and execution of the present studies is also briefly reviewed in this chapter under appropriate headings.

2.1 Origin

Guava (*Psidium guajava*), an exotic fruit belongs to the family Myrtaceae. Guava, goiaba or guayaba are some of the names given to the “apple of the tropics”. It’s popular for its penetrating aroma and flavor. It’s place of origin is uncertain, extending in an area from southern Mexico through Central and South America. Currently, its cultivation has extended to many tropical and subtropical countries of the world, where it also thrives well in the wild (Morton, 1987; Yadava, 1996; Mitra, 1997).

2.2 Morphology

Guava tree is very hard with characteristic pale, smooth spotted bark that peels off in skinny flakes easily and usually grows up to about 7-8 meters high. According to their cultivar’s fruits are different in size, flavor and shape. The sweet varieties are better while others may be astringent. Guava shape is certain, rather it ranges from round, ovoid, to pear-shaped and with an average diameter of 4-10cm and weight ranging from 100-400g (Mitra, 1997).

Exterior skin color of the fruit ranges from light green to yellow when ripe and its pulp may be white, yellow, pink, or light red. Unripe guava fruit are sometimes astringent, hard in texture, acidic in taste and starchy due to its low sugar and high polyphenol content. When the fruit ripens, it becomes very sweet, soft, its skin becomes thin and edible and non-acidic (Malo and Campbell, 1994; Mitra, 1997).

Many guava cultivars exist today, and they can be broadly classified as pink or white. Seedless cultivars are grown in many countries around the world, which have a great potential to become popular in the future (Yadava, 1996).

Guava fruit has a fleshy mesocarp of varying thickness and a softer endocarp with numerous small, hard yellowish-cream seeds (Malo and Campbell, 1994; Marcelin *et al.*, 1993).

2.3 Nutritional Profile of Guava Fruit

Carbohydrate is the principal and the main component of guava and its composition depends on the variety. Sugars contribute about 6-11% of the fresh weight of guava. About 60% of the total carbohydrates is sugar and fructose are predominant (about 59%), followed by 35% glucose and 5% sucrose (Yusof, 2003).

Fiber from guava pulp and peel was tested for antioxidant properties and found to be a potent source of radical-scavenging compounds, presumably from the high content of cell-wall bound polyphenolics (2.62-7.79% w/w basis) present in each fiber isolate. Both guava peel and pulp contained high amount of dietary fiber ranging from 48.55 to 49.42% (Jimenez-Escrig *et al.*, 2001).

According to a study by Bose *et al.*, (1999), the fruit is rich in ascorbic acid (vitamin C) 160-375mg/100g, at higher levels than other fruits. Minerals are present in the fruit in higher quantities like calcium (14-30 mg/100g), phosphorus (23-37 mg/100g), iron (0.5-1.3 mg/100g) and vitamins like B_1, B_2, B_3, B_5 and vitamin A are also present in appreciable amount.

Vinik and Jenkins (1998) reported that dietary fiber decreases total cholesterol and bad cholesterol in body and have other helpful effects in diabetic patients.

Guava fruit is also main source of pectin which range from 0.4% to 1.9% which is affected by several factors such as variety, crop season and stage of maturity. The quality of pectin is defined by its capacity to make a gel. In winter, guava fruits contain higher amounts of pectin with more jelly units than the rainy season crop (Dhingra *et al.*, 1983)

Guava contains 73–87% moisture, 0.8–1.5% protein, 0.4–0.7% fat, 0.5–1% ash, 5% dietary fiber and 12–26% dry matter (Chin and Yong, 1980).

Chang *et al.* (1971) evaluated the pectin content in guava and reported that unripe guava fruits gave pectin having less jelly units than half-ripe ones. Upon hydrolysis, guava pectin yields 72% D-galacturonic acid, 12% D-galactose, and 4% L-arabinose. A study carried out by Gorinstein *et al.* (1999) showed that guava has highest content of total and soluble dietary fibers with values of 5.60 and 2.70g/100g, respectively. Soluble and total fiber content of guava is very high in comparison to all fruits and vegetables.

2.4 Health Benefits of Guava

Farinazzi-Machado *et al.* (2012) concluded that animals fed on guava pulp juice had lesser body weight, cholesterol, triglycerides and glycemia levels and increased levels of good cholesterol. Lyophilized pulp of guava showed hypoglycemic effects in diabetic rats due to its antioxidant activity.

Rishika and Sharma (2012) showed that guava leaf extract is used for ache vulgarism, a chronic inflammatory disease, caused by Propionibacterium acne. It is effective for dental carries and dental plaque as well. They also demonstrated guava stem, leaf and bark extract was used for the antigiardiasic activity.

Huang *et al.* (2011) reported that guava lower the blood glucose level. Guava fruit extract has promising role to restore the loss of body weight and reduces the blood glucose level in the diabetic condition. Fruit extract of guava protects the pancreatic tissues, including islet β-cells, against lipid peroxidation and thus reduces the loss of insulin-positive β-cells which results in insulin secretion.

According to a study by Shu *et al.* (2009), guava contains a sufficient amount of benzophenone glycosides in ripe edible fruits and can inhibit accumulation of

triglycerides in body. Ascorbic acid, gallic acid, ethyl benzoate and ß-caryophyllene are major components identified in white and red guavas. The guava pulp has antioxidant properties that can be associated with anti-cancer effects.

White guava (*Psidium guajava* L.), as one of traditional Chinese medicines, is widely cultivated and mostly consumed raw. Hypoglycemic activity of guava leaves has been well-known (Shen *et al*., 2008; Cheng *et al*., 2009), but not for guava fruit.

Rahmat *et al*. (2006) evaluated the effect of guava consumptions on antioxidant and lipid state low density lipoprotein (LDL) and high-density lipoprotein (HDL) in young men. They reported a distinct increase in HDL and antioxidant profile during the treatment phase for four weeks. Increase in HDL was associated with reduction in possibility of heart diseases.

Nishino *et al*. (2002) opined that guava is rich source of lycopene, a major pigment found in guava flesh of pink guavas. The most important carotenoids which give oxidative defense are α-carotene, β-carotene, lutein, and β-cryptoxanthin. Main function of carotenoids is antioxidant activity. Carotenoids obstruct the free radicals that harm the lipoprotein membranes (Shami and Moreira, 2004).

Study on humans by Singh *et al.* (1992) has shown that the utilization of guava for a period of 12 weeks reduced total cholesterol levels by 9%, blood pressure by 8%, triacyl glycerides by 8%, and with increase in the levels of good cholesterol up to 8%.

Cheng and Yang (1983) reported that guava juice exhibited hypoglycemic effects in mice by examining blood glucose level.

2.5 Postharvest physiology of guava

Guavas have a rapid rate of ripening after harvest, therefore a relatively short shelf life ranging from 3 to 8 days depending on the variety, harvest time, and environmental conditions (Reyes and Paull, 1995; Basseto *et al*., 2005).

As guava ripens, total soluble solids and total sugars increase in both the peel and pulp, whereas titratable acidity declines after reaching its climacteric peak of respiration. In

general, climacteric fruits undergo rapid changes in sugar content during ripening, where starch and sucrose are broken down into glucose (Bashir and Abu- Goukh, 2002).

Studies evaluating respiratory patterns of guava showed a climacteric response as increased carbon dioxide corresponded to increased ethylene production (Akamine and Goo, 1979; Mercado-Silva *et al*., 1998; Bashir and Abu-Goukh, 2002).

Ascorbic acid content is at its maximum level at the mature-green stage and declines with ripening in both white and pink guavas (Bashir and Abu-Goukh, 2002), and may also be a function of postharvest handling.

Ripening and factors associated climacteric fruits is regulated by ethylene synthesis. Ethylene (C2H4) is a naturally-produced, gaseous growth regulator associated with numerous metabolic processes in plants (Mullins *et al.*, 2000).

Ethylene is produced from L-methionine via 1-aminocyclopropane-1-carboxylic acid (ACC) synthase in a complex signal transduction pathway, which is widely researched today (Salveit, 1999; Mullins *et al.*, 2000). All plants produce ethylene, but only climacteric fruits and wounded or stressed tissue produce enough amounts to affect other tissues.

According to Salveit (1999) in climacteric fruits, ethylene stimulates its own biosynthesis at the start of ripening, enhancing its production until reaching saturation levels. Stresses such as chill injury, heat shock (Cisneros-Zevallos, 2003) or disease (Mullins *et al.*, 2000), can induce ethylene production and thus enhance fruit ripening, and the factors

Ethylene production and respiration (CO_2 production) increases after the first day of harvest. Guava reaches its climacteric peak between day 4 and 5 after harvest (mature-green harvested fruits) and then declines (Akamine and Goo, 1979; Bashir and Abu-Goukh, 2002).

Moisture loss in guava in tropical climate can be substantial resulting in up to 35% weight loss (Mitra, 1997).

The ripeness level of guava can be characterized by its skin color ranging from a dark green when unripe to a bright yellow or yellow-green at full ripeness. However, ripeness

determination can be misleading for some varieties and may be combined with a simple test for specific gravity, by placing fruit in water to determine if it sinks (unripe) or floats (ripe) to obtain a clearer picture of the degree of fruit ripeness (Reyes and Paull, 1995).

Total fiber content decreases significantly during ripening, from 12 to 2g/100g, (El-Zoghbi, 1994).

Increase in polyphenol oxidase (PPO) activity was reported with ripening and a decrease in polyphenolics, which is responsible for the reduction of astringency (Mowlah and Itoo, 1982).

Lycopene synthesis in pink guavas increases during ripening. In the case of tomatoes, the respiration rate decreases when lycopene is accumulated (Thimann, 1980).

2.6 Guava Postharvest Handling and Storage

Depending on its further use (fresh or processed) postharvest conditions for guava may vary under different situations; however, its short shelf life is a recurring pressure for growers, packers, and processors. Due to its delicate nature, it is carefully hand-harvested while still green, and immediately stored at cool temperatures. In Florida, guavas are usually stored at temperatures between 9 to 12ºC due to their sensitivity to chilling injury. They are typically shipped from packing houses in a mature green stage (yellowish-green skin, firm), after harvesting at optimum fruit size.

Reyes and Paull (1995) reported less disease incidence in mature green guavas stored at 15°C as compared with fruit that were quarter- and half-yellow under the same conditions. Additionally, 15°C was determined to be an optimum holding temperature prior to processing, since it allowed gradual ripening of mature-green fruit while delaying deterioration of quarter-yellow and half yellow fruit. Fruit stored at 5°C did not ripen and developed skin bronzing after two weeks in storage due to chilling injury.

2.7 Effect of edible coatings on ripening behavior and shelf life

Almuhayawi (2020) reported that propolis exhibits various bioactivity such as antibacterial, anti-angiogenic, antiulcer, anti-inflammatory, antioxidant, and anti-viral activities.

Anjum *et al.* (2020) showed that antioxidant activity and antioxidant capacity were higher in gum Arabic + Aloe Vera gel treatment and total carotenoids were higher in ginger extract + gum Arabic combination while total flavonoid contents were higher in garlic extract + gum Arabic coated guava fruits.

Arroyo *et al.* (2020) showed chitosan matrices (100%Q or 90%Q) protected fruits against excessive mass loss and retarded physic-chemical changes related to maturation.

According to Nascimentoa *et al*. (2020), use of Chitosan-Citric acid combination as a coating is a promising strategy for improving postharvest quality of fresh-cut fruits.

Oliveira *et al.* (2020) opined Chi-CCEO (Cinnamon oil) coating delayed weight and firmness losses, changes in soluble solids, titratable acidity, pH, color and phenolics in guava during storage. Chi-CCEO coating decreased polyphenol oxidase and pectin-methyl esterase activity, while increased peroxidase activity after 5 days. Coated guava had lower fructose content and higher citric and succinic acid content than uncoated guava after 10 days.

Etemadipoor *et al.* (2019) showed that 10% GA + 1% CEO is a potential edible coating formulation to maintain the quality of guava fruit during cold storage.

According Nair *et al.* (2018), the influence of chitosan (1% w/v) and alginate (2% w/v) coatings in combination with pomegranate peel extract (PPE; 1% w/v) on quality of guavas (cv. Allahabad safeda) were studied. Restricted changes were recorded in respiration rate, ripening index, and instrumental color values in case of the coated samples as compared to the control for 20 days at 10 °C.

Murmu (2017) reported that combined effect of GA, CEO (cinnamon essential oil) and sodium alginate resulted in lower activity of PPO & POD, higher DPPH radical scavenging activity, higher retention of ascorbic acid, phenol & flavonoid content, exhibited slower rise of reducing and total sugar in guava pulp.

Silva *et al.* (2017) reported that treatment with 2% and 3% of chitosan in the solid soluble content and ascorbic acid were reduced; retarded the loss of titratable acidity during 96 h after treatment.

Mattiuz *et al.* (2015) showed that mangoes that were infected with a spore suspension of *Colletotrichum gloeosporioides* and solution of either propolis (1.5%) or chitosan (1.5%) were used for controlling the pathogen development. Results demonstrated the net superiority of propolis for controlling the development of the pathogen, the in vitro results showed the opposite order when classifying the performance of the products with alive fresh produce.

Shelf life of guava fruit under the normal atmospheric condition is very short. Hence, edible coatings can be used to maintain the quality and ensure longer storage of guavas during the period. The use of edible coatings with certain additives, such as Chitosan, Gum Arabic and those with essential oils incorporated, has been particularly highlighted over the years, because of its effect on extending the shelf life and facilitating the processing and consumption of food (Sung *et al.*, 2013).

Hong *et al.* (2012) showed that treatment with 2.0% chitosan significantly reduced firmness and weight loss, delayed changes in chlorophyll and malondialdehyde (MDA) contents and soluble solids content (SSC), and retarded the loss of titratable acidity (TA) and vitamin C during 12 days of storage.

2.8 Effect of the packaging materials (perforated, non-perforated transparent polythene bags and newspaper) on shelf life of guava

Pesis *et al.* (2005) carried out a study on ethylene pretreatment banana ripening utilizing modified atmosphere and vacuum packaging were used and stated that storage in polythene (PE) bags with low micro-perforation (PE8) that provided an environment with 11 percent CO_2 and 12 percent O_2 was the most efficient treatment for delaying banana ripening.

Brunini *et al.* (2003) worked with guava fruit pulp. They conditioned pulp in polythene bags (40 micro m. thickness), frozen, then stored at -20 in a refrigerated chamber. The ascorbic acid content, total soluble solids, titratable acidity, firmness and color obtained products were determined. In this process pulp up could be preserved up to 18 weeks.

Mortuza *et al* (2002) noted that the polythene bag wrapping caused maximum reduction in incidence of fungal disease anthracnose which was followed by newspaper and tissue

paper. They also reported that polythene wrapping had role in delayed ripening of the fruit.

Singh *et al.* (2001) opined that mangoes can retain their color in low density polythene (LDP) for a longer period. Fruit color development reduced in wrapped mangoes (in perforated polythene bag) stored for 32 days.

Jiang *et al*. (1999) studied Cavendish bananas at the ripe stage. They discovered that using the anti-ethylene compound 1-methylcylopropene (1-MCP) in sealed polythene bags (0.03 mm thick) delayed peel color change and fruit soften. Fruits exposed to 0.01-1.0 micro liter 1-MCP/liter for 24 hours were delayed in ripening, and rising 1-MCP concentrations were generally more effective for longer periods of time. The suppression of both C_2H_4 evolution and respiration was confirmed by measuring C_2H_4 and CO_2 concentrations in polythene bags. They concluded that using 1-MCP in conjunction with polythene bags can considerably extend banana postharvest shelf life.

Sarker *et al*. (1997) evaluated the appropriate thickness and color of polyethylene film for extending the shelf life of the banana cv. Gaint Governor. Bananas were packed in 300-gauge film of various colors (2 kg/pack) using polythene film with or without perforations and of various thicknesses (20,300, and 400gauge) (yellow, light yellow, red and pink). Fruits packed in un-perforated polythene packs showed the least physiological weight loss, with fruits being marketable for up to 28 days following harvest. Fruits maintained in colored polythene packets had the highest levels of total soluble solids, total sugar, and ascorbic acid.

Abdullah *et al.* (1993) reported that merely putting the fruit in sealed polythene bags allowed for storage for up to four weeks.

Momen *et al*. (1993) used physical measures such as perforated and non-perforated polythene with or without Dithiane M-45 on the shelf life of Banana (cvs. Sabri and Amritasagar). They discovered that a non-perforated polythene cover considerably slowed ripening and extended the shelf life of bananas. The perforated polythene cover, on the other hand, had no effect. The use of Dithiane M-45 in banana treatments increased the shelf life of the fruit.

Satyan *et al*. (1992) reported that banana fruits stored in sealed polythene bags extended average storage life by 2 to 3 times (over control) up to 28 days following harvest. Fruits maintained in colorful polythene packets had the highest levels of TSS, total sugar, and ascorbic acid.

Parabawati *et al.* (1991) investigated the effects of low-pressure storage on the physicochemical characteristics of Dwarf Cavendish bananas in polythene bags. When stored in a polythene bag and subjected to low pressure, the banana variety Dwarf Cavendish fruits remained green for 21 days (200-300mm Hg). They went on to say that after 9 days, such green fruits would mature regularly.

Rao and Rao (1979) reported that when fruits were treated with wax emulsion and stored in polythene bags, color development and ripening were delayed. The fruits had a longer shelf life and were of higher quality.

Ahlawat *et al.* (1978) carried out an experiment and reported that guava cv. Sardar packed in 30 45 cm polythene bags into which CO2 was placed reduced the weight loss and wastage. Organoleptic rating was similar for treated and control fruits at 6 days of storage and it was acceptable, after 10 days, in the treated fruits.

Sen *et al*. (1978) discovered that matured banana fruits of cv. Kalibabu had a three-day shelf life when stored in polythene bags at room temperature (26-32°C).

Patil and Magar (1976) reported that purofil lowers ethylene levels and calcium hydroxide lowers CO_2 levels in sealed polythene bags containing pre-climacteric bananas. They recommended using purofil and calcium hydroxide in a 1:1 ratio to extend the shelf life of bananas.

Singh *et al.* (1976) showed the effect of perforated polythene on shelf life of guava and concluded that guava could be successfully stored up to 6 days in perforated polythene bags and wooden boxes without rotting.

Hardenburg (1971) investigated the use of film wrapping to reduce fruit weight loss. He further claimed that the reduced weight loss was related to a decrease in the rate of

transpiration. It was suggested that increasing the number of perforations in polythene bags might reduce the risk of rotting fruits caused by increased humidity inside the bags.

Scott *et al*. (1971) reported that fruits from bunches picked around three months after being wrapped in the polyethylene cover took longer to ripen than control fruit from unsealed covers. Fruits that had been sealed were still hard and green. After that, they were collected and allowed to ripen for another 20 to 31 days.

Scott and Robert (1966) reported that regularly regulated fruit matured in 5-6 days while bagged fruits remained green.

2.8.1 Effect of 1-methylcyclopropene (1-MCP) for prolonging shelf life

The effect of 1-MCP treatment on guava shelf life has received little attention. As a result, we'll investigate the effects of 1-MCP on climacteric and other fruits.

Manganaris *et al.* (2008) observed that when plum fruit was harvested at an advanced maturity stage and ripened immediately after harvest or after cold storage, a post-harvest application of 1-MCP formulation by immersion delayed fruit ripening, reduced firmness loss, skin color changes, respiration rate, and fruit weight loss, and extended the shelf-life period.

Jiang *et al*. (2004) stated that 1-MCP slows or stops the rate of rise in breathing. The peaks of respiration and ethylene production were greatly delayed in mature green bananas treated with 1-MCP, but the peak height was not reduced.

Moretti *et al*. (2002) found that the treatment of 1-MCP after harvest proved an effective way to delay tomato fruit ripening. Ripening was further slowed as the concentration of 1-MCP rose. Tomatoes given 250, 500, or 1000 ml/l of 1-MCP grew 8-11, 11-13, and 15-17 days later, respectively.

Beaudry (2001) explained that Apple fruit sensitivity to ethylene can be inhibited by a single exposure to 1-MCP. 1-MCP postpones the commencement of ethylene synthesis, as well as the onset of respiration, fragrance generation, and softening. It can keep fruit from ripening for up to 30 days at room temperature (25°C) and minimizes the occurrence of the storage disorder superficial scald.

Golding *et al*. (1998) stated that it has been well demonstrated that 1-MCP can postpone the ripening of mature-green, pre-climacteric bananas.

2.8.2 Effect of $CaCl_2$ for prolonging shelf life

The effect of $CaCl_2$ treatment on guava shelf life has rarely been studied. As a result, we'll investigate the effects of $CaCl_2$ on climacteric and other fruits.

Nguyen Phuoc Minh (2021) evaluated that the impact of $CaCl_2$ treatment on guava fruit physicochemical quality features, Phyto-chemical and antioxidant activities, and potential enzymes during storage.

Sanjay Sahay *et al*. (2015) found that fruits treated with $CaCl_2$ (4 %) + polyethylene bag had the highest retention of bio-chemical constituents such as total soluble solids, titratable acidity, and reducing sugars, as well as an extended shelf-life of up to 16 days.

Yan Zhao and Chen Wang (2015) explained that the effects of calcium chloride ($CaCl_2$) and salicylic acid (SA) alone and in combination against *Colletotrichum gloeosporioides* caused post-harvest anthracnose rot on apples were explored, as well as the effects on many quality and disease resistance related measures.

Senevirathna and W.A.M. Daundasekera (2010) stated that to improve shelf life and quality, mature turning tomato fruits (cv. 'Thilina') were treated with four different concentrations of $CaCl_2$ (0%, 2%, 4%, and 6% aqueous solutions) using three different modes of application: dipping, vacuum infiltration, and pressure infiltration.

R.B.H Wills *et al.* (1982) observed that dipping unripe pears (cv Williams Bon Chretien) in a calcium chloride solution at low pressure (125-375 mm Hg) and then storing them at 20°C delayed ripening by up to 40% compared to control fruit. The Ca-treated fruit ripened normally, and a tasting panel determined that it was edible. However, dipping unripe bananas (cv Cavendish) in $CaCl_2$ solution increased ripening, whether at ambient or lower pressure.

2.8.3 Effect of hot water treatment on shelf life of guava

There is a scarcity of research on the effect of hot water treatment on guava shelf life. As a result, we'll look at how hot water affects some climacteric and other fruits.

Marreo *et al*. (1998) discovered that hot water (below 50°C) treatment slowed peel color development but did not impact soluble solids accumulation in Banana cv. Santa Catarina Prata (AAB) and Dwarf Cavendish (AAA).

Kodikara *et al*. (1996) employed a hot water treatment in papaya. The ability of a double dip treatment (42°C for 30 minutes, followed by 48°C for 20 minutes) to control papaya storage disease was tested. They claimed that the shelf life was extended by three days and that ripening was expedited slightly, but that there was no appreciable weight loss.

Jacoby *et al*. (1995) investigated the impact of postharvest hot water treatment on mango cv. Kensington fruit quality up to 8 days after harvest, and discovered that hot water treatment (46°C for 30 minutes at a fruit core temperature of 45°C) enhanced fruit softness and reduced disease incidence.

Kumar and Dhawan (1995) conducted an experiment to determine the impact of postharvest therapy on mango ripening (cv. Dashehari). Fruits were picked when they were still green and treated with hot water (50°C for 10 minutes). After that, the fruits were placed into cardboard boxes and kept at room temperature. Fruits treated with hot water had good texture and color, according to the findings.

Harmanto and Yuniarti (1994) found that treating mangos with hot water for 10 minutes at 49°C or 5 minutes at 51°C or higher inhibited anthracnose illness. They also discovered that a 10-minute hot water treatment at 51°C or 53°C was most effective, with no loss of fruit quality.

Feng *et al*. (1991) reported that hot water treatment of mature mango fruits at 52°C temperature for 8-10 minutes suppressed mango anthracnose during storage and extended shelf life.

Gupta and Oathak (1990) shown that hot water treatment (50±2°C for 10 minutes) was to be particularly successful in controlling *Fusarium equiseti*, *Alternaria altrnata*, and *Colletotrichum gloeosporiodess.*

Nishijima *et al*. (1987) reported that hot water treated fruits exhibited a reduced disease incidence than untreated fruits.

2.9.1 Physical changes of guava during storage

Tiwary (2011) showed that a gradual decrease in fruit length, breadth and volume in all the treatments along with control happened in mango fruits with the advancement of storage period.

Adrees *et. al* (2010) did an experiment on 8 guava varieties viz. Sufaida, Surahi, Surekha, Waikea, Beamount, Ruby×Supreme and Hong Kong and local variety Gola. Dry matter content of all the guava varieties varied from 7.27 to 14.93%. Maximum dry matter (14.93%) was present in Sufaida followed by Ruby×Supreme (14.68%) and minimum dry matter (7.27%) was found in Surekha.

Zhu *et al.* (2008) reported that loss of weight in fresh fruit and vegetable is mainly due to the loss of water caused by transpiration and respiration processes.

Biswas (1999) worked on 6 guava varieties of Bangladesh viz. Swarupkathi, Deshi, Seedless, Kashi, Kazi and Rachi and recorded maximum moisture content of 83.90% in Kazi.

Gasper *et al.* (1997) suggested that mature green guava (cv. Kumagi) stored at 8 °C had the best quality characteristics during 2-3 weeks of fruits wrapped in polyvinyl chloride plastic film or in low density polythene (LDP) bags. Fruit wrapped in polythene showed 3.3 to 5.3% weight loss after 2 to 3 weeks of storage respectively.

El-Buluk *et al.* (1995) studied the biochemical and physical changes of 4 guava cultivars viz. Ganib, Pakistani, Shambati and Shendi during growth and development and found that moisture content increased significantly with fruit growth and development in all 4 cultivars reaching maximum of 76% in Ganib.

Padmanabhan *et al.* (1995) observed that moisture loss was higher in untreated fruits during the period of storage whereas only minimum water loss was observed in fruits treated with fused Ca salts.

Ramchandra and Chandra (1995) concluded in their finding that fruit moisture content increased during maturation and declined during storage.

Ramchandra and Chandra (1995) found that weight loss of guava reached a maximum at day 12 during 16 days storage. They stored fruits in paper boxes under ambient conditions of 12 ℃ and 97% RH.

Yusof (1992) stated that moisture loss and color changes were delayed when papaya fruits cv. Eksotica were coated with polythene wax emulsion (1:2, 1:4 or 1:6 wax: total volume of water) and stored at a temperature of 10℃.

Dutta *et al.* (1991) carried out an experiment on the shelf life of guava (cv. L- 49) and reported physiological loss in weight (%) was 5.20 after 12 days storage under controlled condition.

Mootoo (1991) observed that the rate of fresh weight loss was highest in untreated fruits.

Ahlawat *et al.* (1978) found that guava cv. Sardar harvestd at light green stage and packed in 30×45cm polythene bags into 5g CO2 was placed. The weight loss was greatly reduced during storage period.

Imungi and Wabule (1990) conducted their experiment on 14 Kenyan varieties of papaya and found that there were significant differences in dry matter content among them.

Yusof (1990) worked on some guava varieties of Malaysia and stated that moisture content ranged from 79.2 to 85.9%.

Dhillon *et al.* (1987) used guava cv. L-49 and Allahabad Safeda in their experiment and found that moisture content was above 80% in both cultivars at ripening.

Brown and Wills (1983) evaluated the postharvest changes of guava fruits in Australia. They were able to store fruits for 8-12 days and reported that emulsion applied to the fruits reduced weight loss.

Selvaraj *et al.* (1982) mentioned in their findings that the dry matter content of guava remained as much as the same level from the earliest stage of development until development (15-160 days after anthesis).

According to Chin and Yong (1980), the guava fruit contains 12–26% dry matter.

Rathore (1976) showed that moisture content in fruits was higher in rainy season.

2.9.2 Chemical changes of guava during storage

Deshmukh *et al.* (2013) stated that highest total sugar was recorded in RCGH 1 (8.07%) followed by RCGH 7 (8.05%) while minimum in RCGH 4 (6.42 %) followed by Lalit (6.58 %).

Tamta *et al.*, (2012) found that maximum TSS (9.83°Brix) was recorded in upper canopy fruits with peduncle at harvesting.

Patel *et al.* (2011) opined that total sugar (%) in Allahabad Safeda was 6.95%, while it was 7%, 6.92% and 6.96% in case of Lucknow-49, Lalit and Sangam, respectively.

Kaur *et al.* (2010) reported that TSS (11.0%) contents were higher in Allahabad Safeda followed by Lucknow-49 (10.8%).

Gomez and Lajolo (2008) found 55% increase in vitamin C concentration in guava at maturity stage, but in mango fruit 35% concentration of ascorbic acid reduced during ripening.

According to Singh (2007), the TSS values ranged from 10.5 to 13.50 °Brix in Pant Prabhat at the time of harvesting.

Soares *et al.* (2007) conducted a study on increasing style in amount of ascorbic acid during maturation. They noticed that concentration of ascorbic acid in green stage fruit was75mg per 100 g of sample. Later, the quantity of ascorbic acid increased from 126 to 170 mg/100g at maturation and fully ripe stage of sample. This increase in ascorbic acid quantity in fruit may be due to degradation of starch or carbohydrate to glucose that eventually enhances the synthesis of vitamin C.

Lim *et al.* (2006) found that seeded guava has more ascorbic acid contents as compared to that of seedless guava.

Lim *et al.* (2006) reported increased quantity of ascorbic acid from 30mg to 145mg/100g in mature fruit.

According to Bashir and Abu-Goukh (2003), firmness decreases gradually as well as TSS will increase rapidly with the ripening fruit

Jitender-Kumar *et al.* (2003) stated that acidity content and ascorbic acid of fruits decreased with increased storage duration.

Jitender-Kumar *et al.* (2003) reported that TSS of fruits increased with the increasing storage period.

Agarwal *et al.* (2002) also reported that the TSS value increased during ripening and the highest of 12.7 brix was observed when the fruits were 100% yellow and the lowest of 10.5 brix was observed when the fruits were 100% green. After the climacteric peak of ripening, a significant increase in the total sugar was observed, may be due to the increase in the activity of enzymes responsible for starch hydrolysis and for reduction in the rate of sugar breakdown by respiration.

Vitamin C concentration varies in different fruit with different manners during maturation and ripening stages. During ripening, AA concentration may increase, decrease or can remain constant (Cordenunsi *et al.*, 2002).

Guavas are considered an excellent source of ascorbic acid (AA), 3 to 6 times higher than the content of an orange and after acerola cherries it has the second highest concentration among all fruits. Guava fruits ripened during winter season (November-December) was found to contain more ascorbic acid (325mg/100g) than those ripened during rainy season (July-August) (140mg/100g). Enhancement of ascorbic acid in guava was determined by

Mercado-Silva *et al.* (1998). They observed that ascorbic acid increased with the maturation of guava and fruits that were obtained during the winter-season had more amount of ascorbic acid than those that were obtained during the summer season.

Mitra (1997) reported that the ascorbic acid content is higher in the skin and declines towards the middle portion. He also mentioned that AA content is more influenced by the fruit's variety than by its ripening stage and storage conditions.

According to Malo and Campbell (1994), AA is concentrated in the skin, followed by the mesocarp and the endocarp. At the mature green stage, the ascorbic acid content in guava is at maximum level and starts to decline rapidly as the fruit ripens. At the final stage when is flesh firmness 0.3kg/cm2, the quantity of ascorbic acid was 85.6% in the peel and 86.3% in the pulp of the white-fleshed guava fruits compared to 78.1% and 76.6% of the peel and pulp of the pink fleshed guavas, respectively. It was observed that peel of guava fruit has more ascorbic acid then pulp (Bashir and Abu-Goukh, 2003).

Maximum level of vitamin C is present in guava at green unripe stage and when fruit ripens, level of vitamin C starts to decline. Different research reports are present about the concentration of vitamin C in white and pink guavas.

El- Faki and Saeed (1975) found greater level in white pulp guava, while other researcher reports indicate reverse conditions.

Maximum vitamin C is present in peel of guava fruit as compared to pulp of fruit (Wilson, 1980).

Maximum level of vitamin C is present in the skin of guava due to intervening of phenolic components with the dye 2,6 dichlorophenol indophenols used to analyze it.

Abu-Goukh and Abu-Sarra (1993) determined minimum level of vitamin C in skin of mango than flesh of fruit in three varieties of mango cultivar. The white guava fruits had 19.2% and 22.3% more ascorbic acid than the pink ones, in pulp and peel, respectively.

Rodriguez *et al.* (1971) reported that the increase of ascorbic acid was accelerated during ripening period of fruit.

Mitra (1997) determined the ascorbic acid contents in guava and mentioned that AAs are more influenced by the fruit's variety than by its ripening stage and store room conditions.

Within the fruit, ascorbic acid is present more in the skin than mesocarp and the endocarp (Malo and Campbell, 1994).

As a water-soluble vitamin, ascorbic acid is more likely to oxidation due to its unstable nature and is considered as a standard for stability of other nutrients during processing.

O'Hare (1995) claimed that titratable acidity started to decline slowly when mango fruits were stored at 13 ℃.

According to Kumar and Sing (1993), acid concentration of fruits reduced in storage.

Lazan *et al.* 1990 found that sealed packaging reduced the titratable acidity of mature papaya fruits (cv. Backcross solo) during ripening stage. There were no noticeable differences in TA when fruits stored in cold condition.

Phandis (1970) showed that guava cv. Sardar contained acidity 2.45%.

Yusof (1990) carried out an experiment on guava and concluded that TA ranged from 0.26 to 0.52% in guava.

Rathore (1976) analyzed guava to study its chemical composition and showed that the acidity of guava flesh ranged from 0.33 to 0.99%.

Tripathi and Gangwar (1971) carried out an experiment on biochemical changes of guava and reported that acidity ranged between 0.342 to 0.408%

Yamdagni *et al.* (1987) showed that acidity decreased in ripening stage in cultivars of Safeda, Allahabad Safeda and Banarsi Surkha.

Nag (1998) also found similar results when worked with 4 varieties of Guava namely Kazi, Mukundapara, Swarupkathi and local one Bangladesh.

Wilson (1980) analyzed guava chemically to see their changes during storage and found that acidity of guava flesh was 0.80% as citric acid.

In all varieties of guava, it was seen that concentration of sugar gradually increased in the green phase of fruit. More sugar level was increased at maturity stage of fruit formation.

Mowlah and Itoo (1982) determined that fructose was main sweetening element in white and red guava. Fructose enhances in all stages of guava maturation process. During ripening process, reducing sugars increased and afterward started to decrease in guava.

El-Buluk *et al*. (1995) mentioned that the final sugars contents vary in different varieties of guava, glucose, fructose and sucrose were in the range of 1.9% to 18.1%, 5.6% to 7.7% and 6.2% to 7.8%, respectively.

Augustin *et al.* (1988) reported that guava fruits showed significant increase in total sugar at all temperatures when they were stored at 26, 20 and 5℃. The fructose: glucose ratio significantly increased during storage period at all temperature conditions.

Calabrese and Panno (1986) worked on the fruit quality of some guava cultivars and observed that sugar content ranged from 4.96 to 8.70%.

Kahlon *et al.* (1997) reported that guava contained 4.81 to 8.77% total sugar in rainy season and 5.24 to 9.29% in winter season.

Arenas-de-Moreno *et al.* (1995) in his experiment determined the sugars in guava fruit and found that sugar content ranged from minimum 4.11g/100g fruit weight in green ripe fruits to a maximum of 10.01g/100g in fully ripe fruits.

Kumar (1998) studied the performance of guava under Bihar conditions and observed that reducing sugar content was maximum in Selection-8 (5.6%) followed by Allahabad Safeda (5.3%).

Rathore (1976) reported that reducing sugar was highest in Allahabad Safeda (4.6%) in winter and lowest was in Red Fleshed (3.92%) while total sugar was highest in Lucknow-49 (9.2%).

El-Buluk *et al.* (1996) worked on 4 cultivars namely Shambati, Pakistani, Shendi and Ganib in their experiment and reported that total sugar content increased slowly during the initial growing period followed by rapid increase during maturation and ripening stage to maximum of 24.2, 12.4, 26.9 and 7.5% respectively.

Singh *et al.* (1993) noticed that most of the wrapping papers or bags significantly reduced the percentage of physiological weight loss in the fruits. Total soluble solid content of

ripe fruits was improved when the fruits were stored and packed in bags and papers in storage.

Ghanta (1994) reported that the TSS content was low until 120 day after anthesis but thereafter increased sharply up to ripening.

Ramchandra and Chandra (1988) observed that total sugars, sucrose, pectin and ascorbic acid in fruits were gradually increasing with maturation and reached maximum at 8 days of storage and declined thereafter.

Augustin *et al.* (1988) concluded that the TSS content was increasing at all storage temperatures.

Roberto *et al.* (1990) found that TSS content was best when the guava fruits were stored at 7°C along with 80% RH for 3 weeks.

Palaniswami and Shanmugavelu (1974) worked with 11 varieties of guava in India and found that TSS varied from minimum of 4.0% in Lucknow-49 and to maximum of 12.5% in smooth green and red fleshed fruits.

Wilson (1980) analyzed the chemical properties of guava and found that fruit contained a TSS of 12%.

Dhillon *et al.* (1987) observed that TSS increased with the maturity of fruit and ripening.

Ullah *et al.* (1992) opined that TSS in juice of mesocarp varied from 7.1% in Kazi piara to 10.2% in Gu-008 and TSS of endocarp from 10.7% in Kazi piara to 13.9% in Gu-008.

Bhardra and Sen (1999) conducted an experiment and found that as the storage period advanced, the total reducing sugar content of banana pulps rose.

Joshi and Roy (1988) stated that non-reducing sugar remains more or less constant after reaching a peak.

Rao and Chundawat (1986) conducted an experiment and discovered that ripening changes include quick conversion of starch into sugars, increased activity of respiratory enzyme peroxides, and ethylene generation.

Rao and Chundawat (1988) conducted an experiment and discovered that key ripening changes include increased activity of respiratory enzyme peroxides and ethylene generation, as well as quick conversion of starch into sugars.

The breakdown of starches to glucose and fructose by the activities of amylase and maltose caused the increase in reducing sugar with the progression of ripening as well as storage duration (Wills *et al*., 1981).

2.10 Shelf life

Basseto *et al.* (2005) demonstrated the effectiveness of application of 1-MCP to Pedro Sato variety of guavas as well as a direct relation between concentration and exposure time. Fruit were subjected to different concentrations (100, 300, 900 mL/L) of 1-MCP and exposure times (3, 6, 12h) at 25º C, to improve the shelf life of guavas marketed at room temperature. In general, treated fruit had a storage life twice as long as non-treated fruit (5 vs. 9 days respectively).

Reyes and Paull (1995) reported that guava stored at 15℃ delayed the deterioration of quarter yellow and half yellow fruits and allowed gradual ripening of green fruits to full color in 11 days. Ripening was delayed most in green fruits stored at 10 ℃.

Suhaila *et. al.* (1992) conducted an experiment on various surface treatments (Palm oil, liquid paraffin, Semperfresh or Starch surface coating and LDP wrappings) on the shelf life of guava cv. Vietnamese at 10℃. Coating with palm oil (20%) resulted in the best treatment during storage (2 months) for maintaining quality followed by LDP (Low Density Polythene) shink wrap and LDP cling wrap. Parafin film was unsuitable as it caused lesions in some parts of the skin and produced an off flavor.

Dutta *et al.* (1991) conducted an experiment on the shelf life of guava cultivar L-49 and stated that the physiological loss in weight was 5.2 % while ripening was 65% and marketable fruits was 40% after 12 days of storage in color condition.

Singh *et al.* (1990) harvested fruits at color break stage and packed in 5kg ventilated wooden boxes using newspaper as the packing material. Fruits were stored for up to 12 days under ambient conditions. The cultivar Chittidar and Sardar did have good shelf life

(9 days) compared with a maximum of 6 days in Allahabad Safeda. The cultivar Chittidar, Sardar, Karela and Apple color was noted for high calcium content and relatively good pulp firmness for up to 9 days.

Azad *et al.* (1987) mentioned in experiment that the fruits of Kazi piara remained in acceptable condition for 10 days when stored at room temperature while fruits of Allahabad, Kanchan Nagar, Mukundapuri and Swarupkathi stored well for 4, 2, 3 and 2 days, respectively at room temperature.

Another experiment on postharvest studies of guava was carried out by Brown and Wills (1983) that reported that cold storage of guava at 0-10℃ extended postharvest life by about 2 weeks.

Ahlawat *et al*. (1978) observed that when guava cv. Sardar (harvested when light green) was packed in 30×45 cm polythene bags into which 5g CO2 was placed, the weight loss and wastage greatly reduced. At 6 DAS (maximum for control fruit) organoleptic rating was similar for treated and control fruits and it was acceptable, after 10 days in the treated fruit.

Singh *et al.* (1976) stored guava successfully up to 6 days in perforated polythene bags and wooden boxes without rotting and much weight loss.

Shaha (1971) reported that mature green fruits were treated with different concentrations of 2,4-D, 2,4,5-T or GA3 at 100 and 200ppm or MH at 500 and 100ppm. Both ripening and weight loss were enhanced with 2,4-D and 2,45-T and treated by MH and GA3 treatment.

Teaotia *et al.* (1968) also reported 2.5 days shelf life at room temperature of red fleshed varieties of Guava.

Singh and Mathur (1954) reported that all the cultivars except Allahabad Safeda could be stored for two days at room temperature. The Safeda can be stored for 4 weeks in cold storage at 8.5 to 14℃.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at the Postharvest Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, during January 2022 to April 2022. At the postharvest laboratory, the fruits were treated as well as some physio-chemical analyses. This chapter goes into the specifics of the materials used and the procedures used in the current investigation.

3.2 Climate

The temperature of the postharvest lab was measured every day at 10 am and 5 pm with the help of digital thermometer and it was 20-25^{0}C during the experiment. Relative humidity (RH) was 80-90%.

3.3 Experimental Materials

Guava was used as experimental material in the research work. Thai guava used was collected from farmers field from Sirajganj. Commercially mature fruits of guava were harvested from farmers field on February, 2022. Maturity was identified by external feature *i.e*. when the color of the fruit was pale green and had bumpy smooth surface that indicated declared maturity of guava.

3.4 Treatments

The experiment consisted of two factors:

1. Factor A: Postharvest treatments
   a. T_0 = No postharvest treatments
   b. T_1 = Hot water (45°C for 5 minutes)
   c. T_2 = $CaCl_2$ (4%)
   d. T_3 = 1-MCP (250 ppb)
2. Factor B: Packaging materials
   a. P_0 = No packaging
   b. P_1 = Perforated polythene bag
   c. P_2 = Newspaper

3.5 Experimental Design

The experiment was laid out in completely randomized design (CRD) with four replications. The treatments were assigned randomly in each replication where randomly selected fruits were set in each treatment combination.

3.6 Methods

Fresh guava fruits which uniform in size, shape and color were collected from farmers from Sirajganj and transported to the central laboratory by proper management to avoid harm and then placed in the postharvest laboratory. Then the fruits were cleaned with water in the laboratory.

3.7 Application of postharvest treatments

The postharvest treatments used in the experiment were used sequentially in the collected fruits. After applying the treatments, fruits were kept on white hard paper in postharvest shelf. To ensure the application of different treatments to the fruits, the following procedure was followed-

No Postharvest treatments (T_0)

Fruits were selected randomly and kept on the hard-white papers at ambient room conditions without any kind of treatments.

Hot water treatment (45°C for 5 minutes) (T_1)

For hot water treatment, the guava fingers were immersed into hot water (45°C) for 5 minutes before placing them on the white paper placed on the table in the laboratory at ambient condition.

Washing guava fruits

Hot water treatment

$CaCl_2$ treatment

Weight measuring of guava

Plate 1: Application of postharvest treatment

$CaCl_2$ (4%) (T_2)

4% $CaCl_2$ solution was prepared by dissolving 40g of $CaCl_2$ salt in 1000 mL water (Plate 1). The solution was stirred with manually, and subsequently the fruits were soaked for 10 minutes and later dried before it was moved to storage.

1-MCP (250 ppb) (T_3)

Fruits were treated with 250 ppb 1-MCP for 24 hours at 20±1˚C in hermetically sealed 20 liters plastic chambers. The required concentrations of 1-MCP were obtained by adding 1000 ml of warm distilled water at 50˚C to the appropriate amounts of 1-MCP powder, calculated according to the free space volume, in 100 ml flasks. After complete dissolution of 1-MCP powder, the flasks were placed and opened in the treatment chambers which were immediately sealed to avoid gas loss. Following the 24 hours treatment time, fruits were placed in different packaging materials.

No packaging (P_0)

In P_0, no packaging material was used and fruits were left on the shelf, open to the room atmosphere where room temperature and relative humidity might affect the physiochemical properties of the fruits.

Perforated polythene Bag (P_1)

Fruits were stored in perforated zipper polythene bag (8 holes per bag) after being treated with different treatments. The fruits were treated first and then left for the coatings being absorbed and/or dried out and then put into the perforated polythene bags. After that, the fruits were stored on the shelf on hard white paper.

Newspaper (P_2)

Fruits were stored in newspaper after being treated with chemicals. The fruits were treated first and then left for the coatings being absorbed and/or dried out and then put into the newspaper. After that, the fruits were stored on the shelf on hard white paper.

3.8 Stage of physio-chemical analyses during storage

The period of storage was divided into 4 stages viz. 3, 6, 9 and 12 days. Physical and chemical analyses and supervision was done every 3 days being defined by different fruit characteristics.

3.9 Parameters studied

In this experiment, the following parameters of the fruit at different storage days were studied.

a) Weight loss (%)
b) Moisture content (%)
c) Dry matter (%)
d) Vitamin C (mg/100g)
e) Titratable acidity (%)
f) Total sugar (%)
g) Total soluble solids (%)
h) Reducing sugar (%)
i) Non reducing sugar (%)
j) Storage duration (days)

3.10 Methods of studying physio-chemical properties

Physio-chemical parameters were studied at certain storage duration to see the changes occurred as a result of treatments.

3.10.1 Physical properties

Total weight loss (%)

The weight of the fruits of each treatment was taken with the help of electric balance at 3 days interval and then percent weight loss was calculated by the following formula by Ranganna (1979) –

$$\text{Total weight loss (\%)} = \frac{IW - FW}{IW} \times 100$$

Here,

IW= Initial/Fresh weight

FW= Final weight

Moisture content

10g of fruit pulp was weighed from each treatment and replications and placed in electric oven at 80℃ for 72 hours until the weight didn't change anymore. Then it was cooled down and again the weight was taken. Moisture content was measure by the following formula by Ranganna (1979)-

$$\text{Moisture content (\%)} = \frac{Fresh\ weight - Dry\ weight}{Dry\ weight} \times 100$$

Dry matter content (%)

Percent dry matter content was determined using the data obtained moisture content using following formula-

$$\text{Dry matter content (\%)} = \frac{Fresh\ weight - Dry\ weight}{Fresh\ weight} \times 100$$

Vitamin C (mg/100g)

Ascorbic acid content of persimmon was estimated by titration method (Ranganna, 1986) using 2,6-dichlorophenol indophenol dye solution. The method of estimation involves the reduction of 2,6-dichlorophenol indophenol dye to a colorless form by ascorbic acid in an

alkaline solution. The reaction is quantitative and particularly specific for ascorbic acid in solution in the pH range of 1-3.5.

Preparation of Standard dye (Indophenol) Solution

0.05g of 2, 6 dichlorophenol indophenol was dissolved in 50 ml water, to which 42 mg sodium carbonate was added and made up to 200 ml with water. Sodium carbonate was added for stability purpose.

Standard Ascorbic acid solution

0.05 gm pure ascorbic acid was dissolved in 60 ml of 3% metaphosphoric acid (HPO3) and diluted with DW to exactly 250 ml in a volumetric flask.

Standardization of dye

The dye solution was first standardized against standard ascorbic acid in order to determine the dye factor. The sample was diluted with 3% metaphosphoric acid and then the phosphoric acid extract of the sample was titrated against the dye solution until a pink color was obtained that persisted for 15 seconds.

Dye factor was determined by the following equation-

$$\text{Dye factor} = \frac{0.5}{\text{Titrate volume}}$$

Metaphosphoric acid (3%)

3g of metaphosphoric acid was added to a 100 ml volumetric flask, dissolved with water, stirred and brought up to the mark. Ascorbic acid was estimated as mg of ascorbic acid/ml, and was determined by the following way-

Preparation of the sample

10g fresh pulp was taken in a 100ml beaker with 50ml 3% metaphosphoric acid and transferred to a blender. After blending well, it was filtered and transferred to a 100ml volumetric flask and finally the volume was made up to 100ml with 3% metaphosphoric acid.

Titration

5ml of aliquot was taken in a conical flask and titrated against 2, 6- dichlorophenol indophenol solution. Phenolphthalein was used as indicator to a pink color end point that persisted at least for 15 seconds. Then the ascorbic acid content of the sample calculated by the following formula-

Vitamin C (mg/100g fruit) $= \frac{T \times D \times V1}{V2 \times W} \times 100$

Here, T= Titer

D= Dye factor

V2= Volume made up

V1= Volume taken for titration

W= Weight of the sample taken for estimation

Titratable acidity (%)

TA of the fruit was determined by using Ranganna (1979) method. Two reagents were prepared for this purpose-

a. Standard NaOH solution (0.1N)

b. 1% phenolphthalein solution

10g fresh pulp was taken in a 100ml beaker and then it was homogenized with DW in the blender. The blended material was then filtered and the final volume was made up to the mark with DW.

Procedure

10ml of aliquot was taken in a conical flask and 2-3 drops of phenolphthalein indicator was added to the aliquot. It was then titrated against standard 0.1N NaOH solution until pink color appeared. The volume required for NaOH was taken noted from burette reading. The TA was then calculated from the following formula-

Titratable acidity (%) $= \frac{T \times N \times V1 \times E}{V2 \times W \times 1000} \times 1000$

T = Titer

N = Normality of the NaOH solution

V_1 = Volume made up

E = Equivalent weight of acid

V_2 = Volume of extract taken for titration

W = Weight of pulp taken for sample preparation

Total sugar (%)

Total Sugar (TS) content of guava pulp was determined calorimetrically by the Anthrone method developed by Jayaraman (1981).

Anthrone reagent: The reagent was prepared by dissolving 2g of anthrone in 100mL of concentrated H_2SO_4.

Standard glucose solution: A standard solution of glucose was prepared by dissolving 10 mg of glucose in 100 mL of DW.

Extraction of sugar from pulp

4g of guava pulp was cut into small pieces and immediately plunged into boiling ethyl alcohol and was allowed to boil for 5 to 10 minutes (5 to 10 mL of alcohol was used per gram of pulp). The extract was cooled and crushed thoroughly in a mortar with pestle. Then the extract was filtered through two layers of muslin cloths and the ground tissue was re-extracted for three minutes in hot 80% alcohol, using 2 to 3 mL of alcohol per gram of tissue. The second extraction process ensured complete removal of alcohol soluble substances. The extract was then cooled and passed through two layers of muslin cloth. Both of the extracts were filtered through Whatman no. 41 filter paper. The volume of the extract was evaporated to about 25% (1/4) of the volume over a steam bath and cooled. This reduced volume of the extract was transferred to a 100 mL volumetric flask and it was made up to the mark with distilled water.

Procedure

Aliquot of 1 mL of pulp extract was pipetted into test tubes and 4 mL of the anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each test tube to prevent loss of water through evaporation. Then the tubes were placed in a boiling water bath for 10 minutes and then cooled down. A reagent blank was prepared by taking 1 mL of water and 4 mL of anthrone reagent in a tube and treated similarly. The absorbance of blue green solution was measured at 680 nm in a colorimeter. A standard curve of glucose was prepared by taking 0, 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 mL of standard glucose solution in different test tubes containing 0, 10, 20, 40, 60, 80, and 100 μg of glucose, respectively, and the volume was made up to 1 mL with distilled water. Then 4 mL of anthrone reagent was added to each test tube and mixed

well. All these solutions were treated similarly as described above. The absorbance was measured at 680 nm using the blank containing 1 mL of water and 4 mL of another reagent.

The amount of total sugar present in the extract was calculated from the standard curve of glucose. Finally, the percentage of total sugar was determined by using the following formula-

% Total sugar (g/100gm fruit pulp) = $\frac{Amount\ of\ sugar\ obtained}{Weight\ of\ the\ pulp} \times 100$

Plate 2: Chemical analysis of guava pulp

Total Soluble Solid (%)

The total soluble solids of the thoroughly mixed guava fruit pulp were directly recorded by using hand refractometer (Model BS Eclipse 3-45) at room temperature (AOAC, 2003). A drop of fruit pulp was placed on the prism of refractometer and reading was observed. The results were expressed as percent soluble solids (%Brix).

Determination of reducing sugar

The dinitro salicylic acid technique was used to reduce the sugar content of guava pulp (Miller, 1972).

Reagents:

I. **Dinitro salicylic acid (DNS) reagent:** Simultaneously 1g of DNS, 200ml of crystalline Phenol and 50 mg of sodium sulphite were placed in a beaker and mixed with 100 ml of 1% NaOH by stirring. When it was needed to store, then sodium sulphite was added just before use.
II. **40% solution of Rochelle salt:** It was prepared by dissolving 40 g of sodium potassium tartarate with 100 ml of distilled water in 100 volumetric flasks.

Extraction of sugar from guava pulp

The same procedure of extraction of sugar from guava pulp was followed as described in 3.10.2.3

Procedure

3ml aliquot of the extract was pipette into a test tube then 3ml of DNS reagent was added to each solution and thoroughly mixed. In a boiling water bath, the test tube was heated for 5 minutes. When the color had developed, 1ml of Rochelle salt (40%) was added to the tubes while they were still heated. After that, the test tubes were cooled by running water. Three milliliters of distilled water and three milliliters of DNS reagent were combined in a tube and handled similarly. In a colorimeter, the solution's absorbance was measured at 575 nm.

The amount of reducing sugar was determined using the glucose standard curve. Using the following formula, the percentage of reducing sugar in the guava pulp was calculated:

$$\text{Percent reducing sugar} = \frac{\text{Amount of reducing sugar obtained}}{\text{Weight of sample}} \times 100$$

Estimation of non-reducing sugar content of pulp

The following formula was used to calculate the non-reducing sugar content of guava pulp:

% non-reducing sugar = % total sugar - % reducing sugar

Shelf life

Shelf life of guava fruits influenced by different postharvest treatments was recorded by counting the days needed till fruits were fully ripe with marketing and eating quality.

3.11 Statistical analysis

The collected data were analyzed statistically by Analysis of variance method by using STATISTIX-10 software program. The significance of difference between treatments was tested by Least Significant Difference (LSD) at 1% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, experimental results pertaining the effect of packaging materials and preservatives and their combinations on postharvest management of guava to increase shelf- life and quality have been presented along with discussion.

4.1. Weight loss (%)

The results on percent weight loss showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 1 and Appendix II). Higher rate of increasing trend in percent weight loss was recorded only on control treatment while slow increased rate on percent weight loss was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent weight loss (4.4 %) was found in control treatment T_0 (no preservatives) and the lowest percent weight loss (3.68%) was recorded in the fruits in T_3 (1-MCP 250 ppb) treatment (Fig. 1). At 6, 9 and 12 DAS, the maximum weight loss (5.58, 6.79 and 7.42%, respectively) was recorded in control treatment T_0 (no preservatives) and the minimum weight loss (4.98, 5.51 and 6.04%, respectively) was shown in T_3 (1-MCP 250 ppb) treatment (Fig. 1). The reduction in physiological weight loss due to treatment might be associated with reduced transpiration and respiration rate in guava tissues and is in conformity with the studies conducted by Blankenship and Dole (2003); Singh *et al*. (2004); Martinez *et al*. (2009); Jatinder *et al.,* (2017).

In respect of percent weight loss, significant variation was recorded among packaging treatments (Fig. 2 and Appendix II). However, increasing trend in percent weight loss was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent weight loss was 6.22% which increased to 9.78% at 12 days after storage (DAS) in control treatment P_0 (no packaging) while in P_1 (perforated polythene) treatment, at 3 DAS and 12 DAS , the percent weight loss was 5.25 and 8.31%, respectively which was lowest compared to control treatment P_0 (Fig. 1). At 6 and 9 DAS, the highest percent weight loss (7.85 and

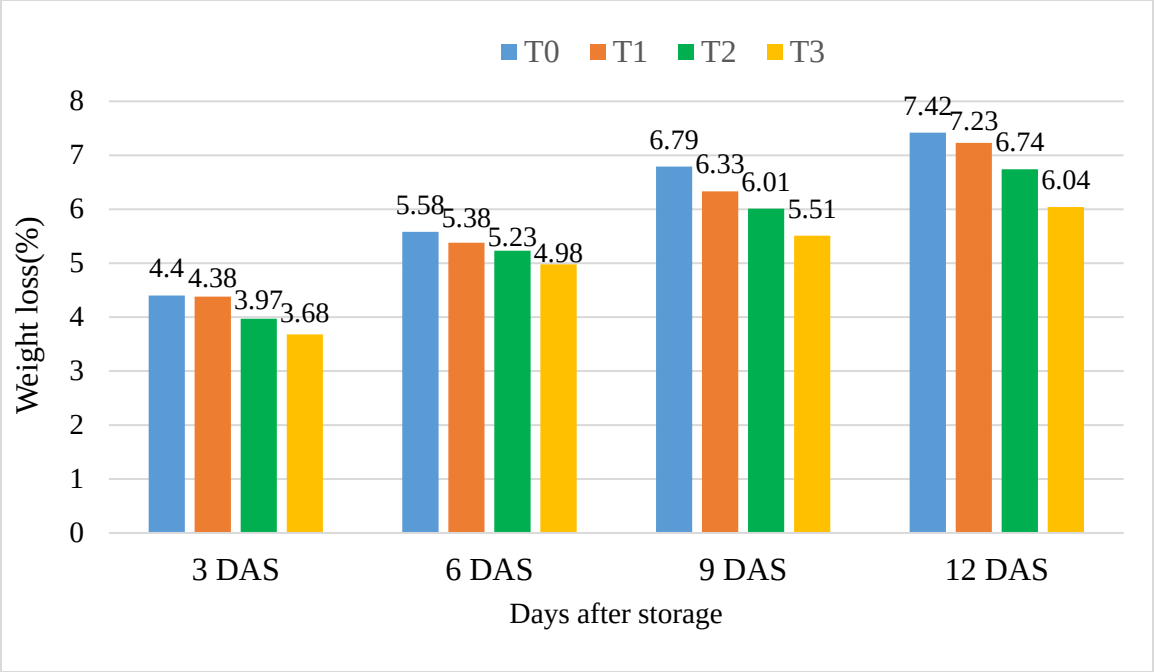

Figure 1. Effect of postharvest treatments on Percent of weight loss of guava. Note: T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

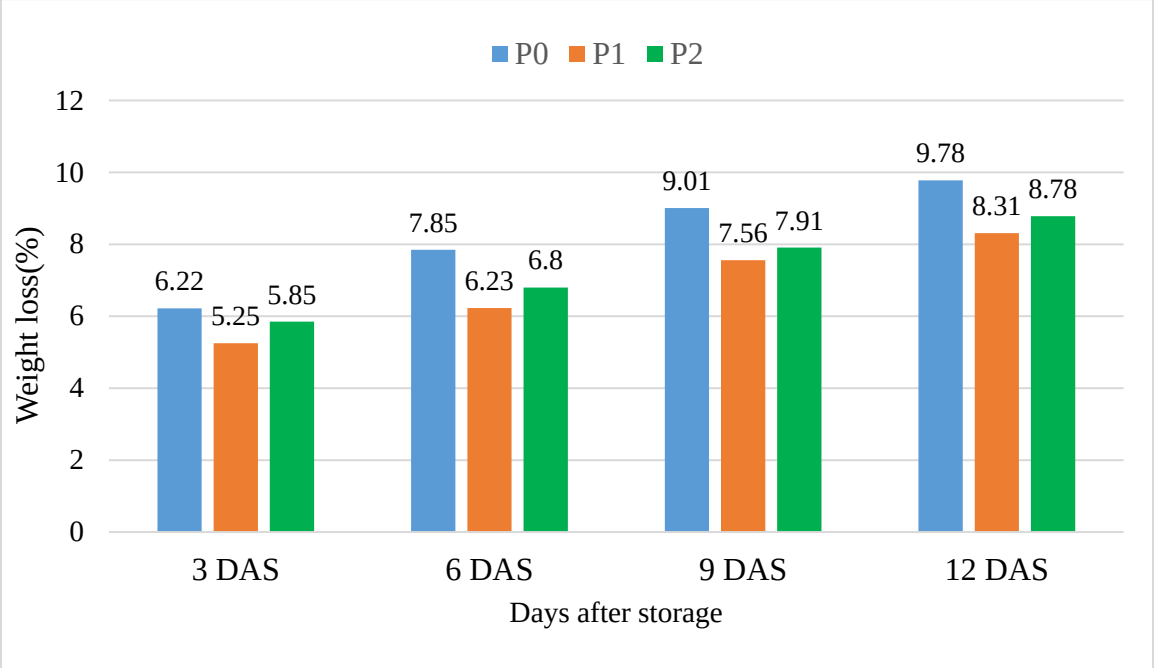

Figure 2. Effect of packaging materials on Percent of weight loss of guava. Note: P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 1. Percent weight loss of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Weight loss (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	7.02 a	8.14 a	9.73 a	10.60 a
T_0P_1	6.91 a	8.11 a	9.63 a	10.21 b
T_0P_2	5.41 bc	5.96 f	6.58 g	7.13 g
T_1P_0	4.87 fg	8.07 a	8.76 c	9.62 c
T_1P_1	4.10 f	5.43 g	6.73 h	7.18 i
T_1P_2	5.02 e	6.66 d	7.55 f	8.43 f
T_2P_0	5.65 b	7.35 c	8.94 b	9.73 c
T_2P_1	4.75 g	6.28 h	7.80 h	8.31 h
T_2P_2	5.50 bc	5.11 i	6.14 i	7.81 ij
T_3P_0	5.30 cd	7.85 b	8.62 d	9.17 e
T_3P_1	3.68 g	4.08 i	5.96 i	6.72 j
T_3P_2	5.06 de	6.47e	7.90 e	9.35 d
LSD (0.05)	0.0776	0.0776	0.0386	0.0420
CV%	2.31	0.65	0.77	8.21

Note: T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

9.01%, respectively) was found in P_0 whereas the lowest percent weight loss (6.23 and 7.66%, respectively) was recorded in P_1.

The interaction effect of packaging and preservative treatments on percent weight loss was significant at 3, 6, 9 and 12 days after storage (DAS) (Table 1 and Appendix II). At 3 DAS, the highest percent weight loss (7.02%) was in T_0P_0 which was statistically identical with T_0P_1 whereas the lowest percent weight loss (3.68 %) was recorded in T_3P_1 which was statistically identical with T_2P_1. Increasing trend of percent weight loss was recorded for increased storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent weight loss (8.14, 9.73 and10.60% respectively) was recorded in T_0P_0 whereas the minimum percent weight loss (4.08, 5.96 and 6.72%,

respectively) was found in T_3P_1 (Table 1). The weight loss in guava during storage may be attributed to substrate loss by respiration and loss of water through various mechanisms. The present result was similar to the findings Ramchandra and Chandra (1995). In an experiment, Ramchandra and Chandra (1995) found that the weight loss of guava reached a maximum at day 12 during storage period. They stored the fruits in paper boxes under ambient conditions (12°C and 97% RH). Similar result was also observed by Gasper *et al.* (1997).

4.2 Moisture content (%)

The results on percent moisture content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 3 and Appendix III). Higher rate of increasing trend in percent moisture content was recorded only on control treatment while slow increased rate on percent moisture content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent moisture content (84.88%) was found in control treatment T_0 (no preservatives) and the lowest percent moisture content (80.10%) was in the fruits under T_3 (1-MCP 250 ppb) treatment (Fig. 3). At 6, 9 and 12 DAS, the maximum percent moisture content (84.13, 83.90 and 82.34%, respectively) was recorded in T_0 and the minimum percent moisture content (79.70, 79.34 and 78.04%, respectively) was recorded in T_3 (1-MCP 250 ppb) treatment (Fig. 4). Higher moisture percentage reduce fruit quality of guava. This result is similar to Jatinder *et al.*, (2017); Martinez *et al.*, (2009); In respect of percent moisture content, significant variation was recorded among three packaging treatments (Fig. 4 and Appendix III). However, increasing trend in percent moisture content was found from 3 DAS to 12 DAS. At 3 DAS, the lowest percent moisture content was 80.51% which decreased to 78.20% at 12 DAS in control treatment P_1 (perforated polythene) while in P_0 (no packaging) treatment, at 3 DAS and 12 DAS, the percent moisture content were 84.27 and 81.84%, respectively which was the highest compared to control treatment P_0 (no packaging) (Fig. 3). At 6, 9 and 12 DAS, the lowest percent moisture content (79.01, 78.8 and 78.20%, respectively) was found in P_1 (perforated polythene) treatment whereas the highest percent moisture content (82.86, 82.3 and 81.84%, respectively) was found in P_0 (no packaging) treatment.

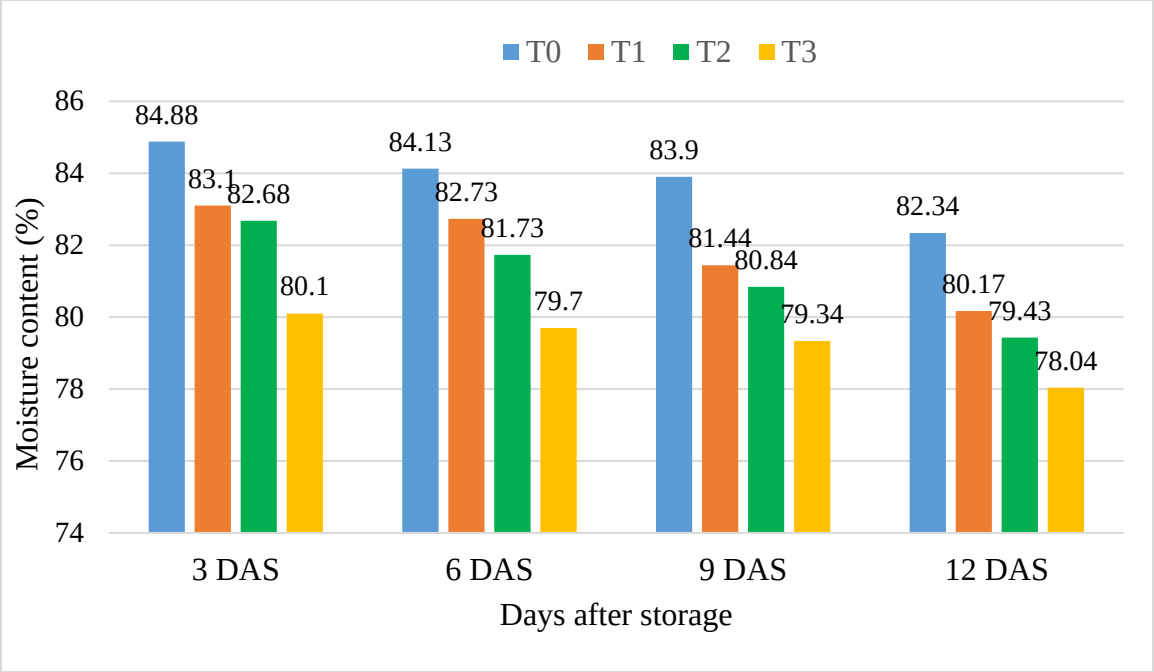

Figure 3. Effect of postharvest treatments on Percent of moisture content of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

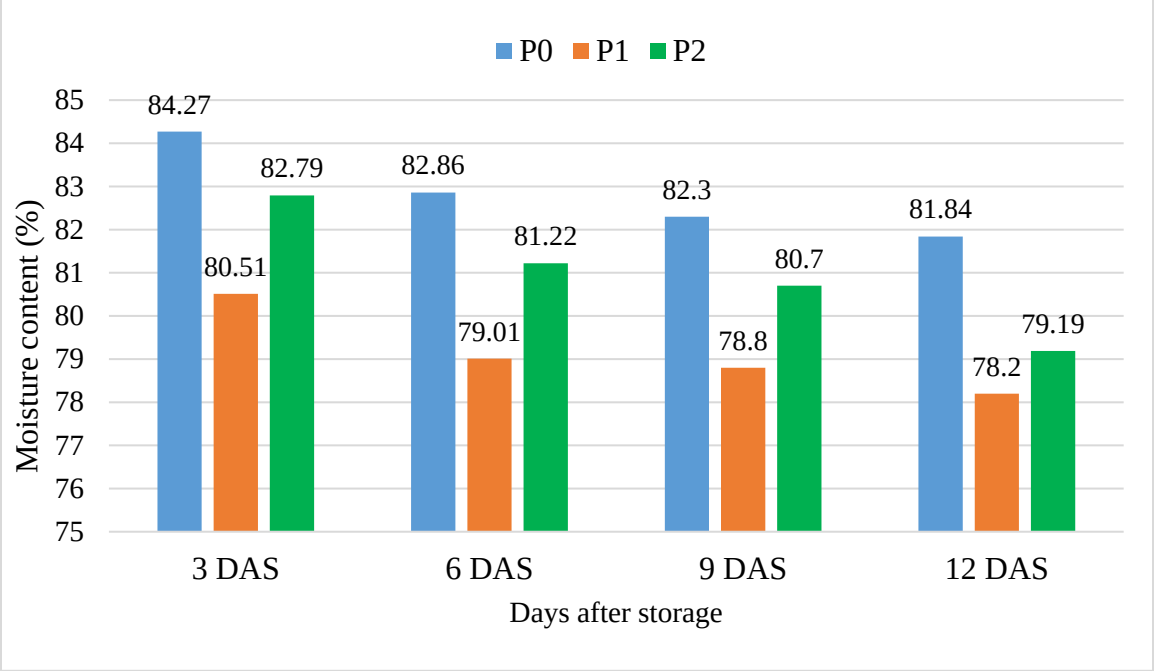

Figure 4: Effect of packaging materials on Percent of moisture content of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 2. Percent moisture content of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Moisture content (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	84.63 a	84.13 a	83.59 a	83.43 a
T_0P_1	83.45 b	83.15 ab	82.66 ab	82.38 ab
T_0P_2	83.00 bc	82.47 bc	81.58 bc	80.47 cd
T_1P_0	79.96 fg	79.90 ef	79.44 ef	78.49 fg
T_1P_1	80.60 ef	79.42 fg	79.11 ef	78.74 fg
T_1P_2	81.24 de	80.60 de	80.43 de	80.12 cde
T_2P_0	78.86 gh	78.43 gh	78.56 f	77.95 g
T_2P_1	82.00 cd	81.70 cd	81.28 cd	81.09 bc
T_2P_2	81.18 de	80.69 de	80.24 de	79.64 def
T_3P_0	80.41 ef	79.84 ef	79.70 e	78.84 efg
T_3P_1	78.60 h	78.28 h	78.01 g	77.11 h
T_3P_2	80.33 ef	79.73 ef	78.51 fg	78.17 g
LSD (0.05)	0.3545	0.3456	0.3344	0.4154
CV%	0.53	0.52	0.51	0.64

T_0 = Control, T_1 = Hot water, T_2 = T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

The interaction effect of packaging and preservative treatments on percent moisture content was significant at 3, 6, 9 and 12 DAS (Table 2 and Appendix III). At 3 DAS, the lowest percent moisture content (78.60%) was in T_3P_1 which was statistically whereas the highest percent moisture content (84.63%) was recorded in T_0P_0. Increasing trend of percent moisture content was recorded for the increase of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the minimum percent moisture content (78.28, 78.01 and 77.11% respectively) was recorded in P_3T_1 whereas the maximum percent moisture content (84.13, 83.59 and 83.43%, respectively) was found in T_0P_0 (Table 2). The decrease in moisture content during storage was also reported by Pathmanaban *et al.* (1995). The decrease of moisture content was probably due to

transpiration and evaporation loss and also starch hydrolysis. Ramchandra and Chandra (1995) also found that fruit moisture content increased during maturation and declined during storage.

4.3 Dry matter content (%)

The results on percent dry matter content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 5 and Appendix IV). Higher rate of increasing trend in percent dry matter content was recorded only on control treatment while slow increased rate on percent dry matter content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent dry matter content (19.45%) was found in control treatment T_3 (1-MCP 250 ppb) and the lowest percent dry matter content (17.12%) was in the fruits in T_0 (no preservatives) treatment (Fig. 5). At 6, 9 and 12 DAS, the maximum percent dry matter content (19.92, 21.1 and 22.96%, respectively) was recorded in T_3 (1-MCP 250 ppb) and the minimum percent dry matter content (18.87, 19.1 and 19.66%, respectively) was shown in T_0 (no preservatives) treatment (Fig. 5). The results are similar to the findings of Rawat *et al*. (2010), Jatinder *et al.,* (2017).

In terms of percent dry matter content, significant variation was recorded between two packaging treatments (Fig. 6 and Appendix IV). However, increasing trend in percent dry matter content was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent dry matter content was 19.16% which increased to 22.80% at 12 DAS in P_1 (perforated polythene) treatment while in P_0 (no packaging) treatment, at 3 DAS and 12 DAS, the percent dry matter content were 16.73 and 18.67%, respectively which was the lowest compared to control treatment P_0 (no packaging) (Fig. 6). At 6, 9 and 12 DAS, the highest percent dry matter content (20.99, 21.23 and 22.80%, respectively) was recorded in P_1 (perforated polythene) whereas the lowest percent dry matter content was recorded (17.31, 18.67 and 19.16%, respectively) in P_0.

The interaction effect of packaging and preservative treatments on percent dry matter content was significant at 3, 6, 9 and 12 DAS (Table 3 and Appendix IV). At 3 DAS, the highest percent dry matter content (21.40%) was in T_3P_1 which was statistically similar with T_0P_0 whereas the lowest percent dry matter content (15.37%) was recorded in T_3P_1.

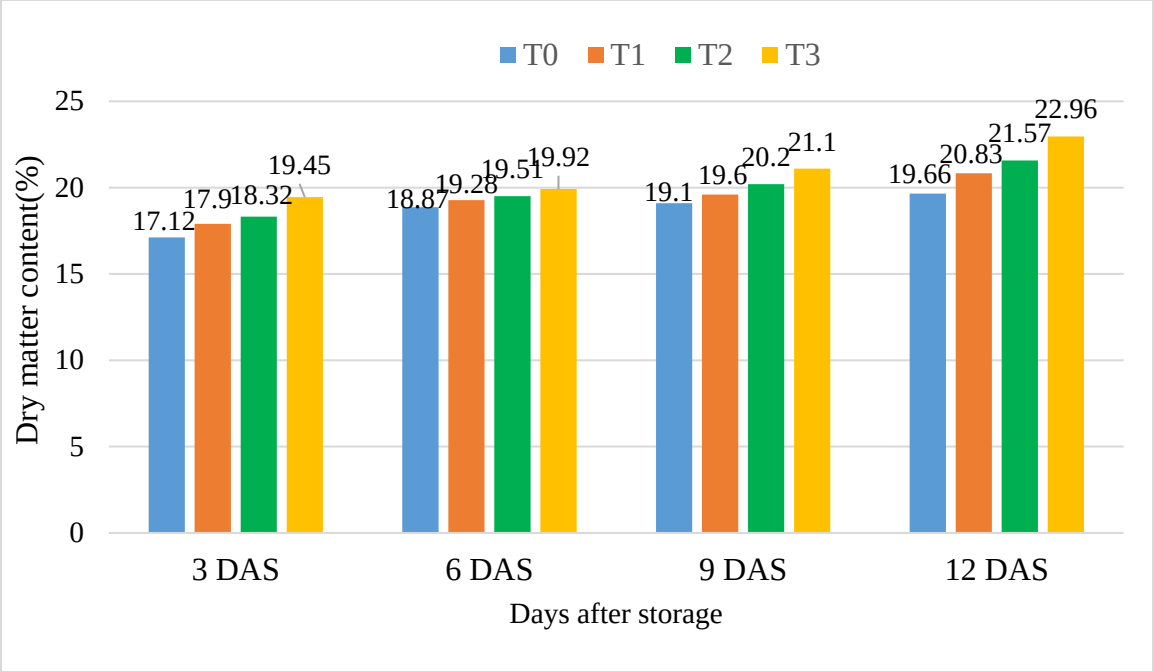

Figure 5. Effect of postharvest treatments on Percent of dry matter of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

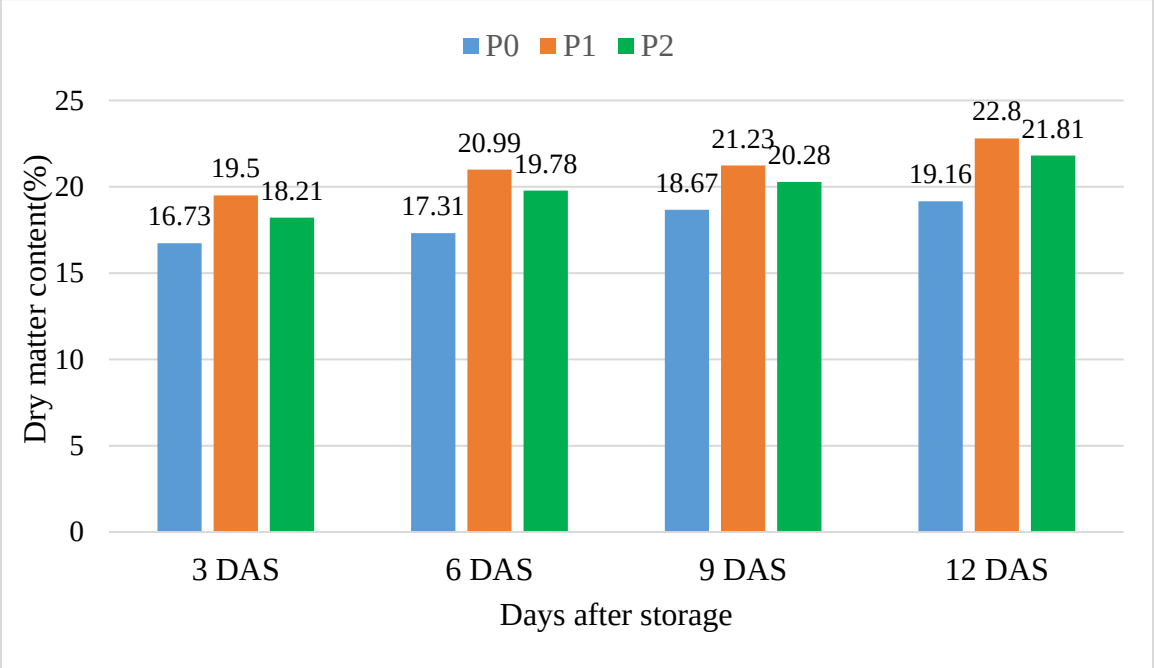

Figure 6. Effect of packaging materials on Percent of dry matter of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 3. Percent dry matter content of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Dry matter content (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	15.37 h	16.37 e	16.81 g	17.57 g
T_0P_1	16.55 g	16.85 e	17.34 fg	17.62 fg
T_0P_2	17.00 fg	18.20 d	18.89 ef	19.53 de
T_1P_0	21.14 ab	21.72 a	21.99 a	22.45 a
T_1P_1	19.40 cd	20.58 ab	20.69 bc	21.26 ab
T_1P_2	19.59 cd	20.16 bc	20.30 c	21.16 abc
T_2P_0	18.76 de	19.4 bcd	19.57 cd	19.88 cde
T_2P_1	18.00 ef	18.30 d	18.72de	18.90 ef
T_2P_2	18.81 de	19.30 cd	19.76 cd	20.36 bcd
T_3P_0	20.04 bc	20.10 bc	20.56 bc	21.51 ab
T_3P_1	21.40 a	21.58 a	22.38 a	22.99 a
T_3P_2	19.67 cd	20.27 bc	21.49 ab	21.83 ab
LSD (0.05)	0.0776	0.0776	0.0386	0.0420
CV%	2.31	2.31	2.09	2.51

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Increasing trend of percent dry matter content was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent dry matter content (21.58, 22.38 and 22.99%, respectively) was recorded in T_3P_1 whereas the minimum percent dry matter content (16.37, 16.81 and 17.57%, respectively) was found in T_0P_0 (Table 3). The scientific information regarding dry matter content of guava is not available during storage. However, the increase in dry matter percent with increasing storage period may be due to osmotic withdrawal of water from the pulp to peel.

4.4 Titratable acidity (%)

The results on percent titratable acidity showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 7 and Appendix VI). Higher rate of decreasing trend in percent titratable acidity was recorded only on control treatment while slow decreased rate on percent titratable acidity was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent titratable acidity (2.11%) was found in T_3 (1-MCP 250 ppb) treatment and the lowest percent titratable acidity (1.58%) in the fruits. under control treatment T_0 (no preservative) (Fig. 7). At 6, 9 and 12 DAS, the maximum percent titratable acidity (2.01, 1.96 and 1.86%, respectively) was recorded in T_3 treatment and the minimum percent titratable acidity (1.42, 1.27 and 1.11%, respectively) was found in T_0 (Fig. 7). Acidity percentage of guava fruit might have been augmented due to higher synthesis of nucleic acids, on account of maximum availability of plant metabolism. El-Sherif *et al.* (2000) have also reported similar results.

In respect of percent titratable acidity, significant variation was recorded among packaging treatments (Fig. 8 and Appendix VI). However, decreasing trend in percent titratable acidity was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent titratable acidity was 2.09% which decreased to 1.80% at 12 days after storage (DAS) in P_1 (perforated polythene) while in control treatment P_0 (no packaging), at 3 DAS and 12 DAS, the percent titratable acidity was 1.55 and 1.12%, respectively which was lowest compared to P_1 (Fig. 8). At 6 and 9 DAS, the highest percent titratable acidity (2.00 and 1.92%, respectively) was found in P_1 (perforated polythene) whereas the lowest percent titratable acidity (1.40 and 1.26%, respectively) was found in P_0. The results are similar to the findings of Rawat *et al*. (2010), Jatinder *et al.*, (2017). The interaction effect of packaging and preservative treatments on percent titratable acidity was significant at 3, 6, 9 and 12 DAS (Table 4 and Appendix VI). At 3 DAS, the highest percent (2.30%) was in T_3P_1 treatment whereas the lowest percent titratable acidity (1.37%) was recorded in P_0T_0 treatment.

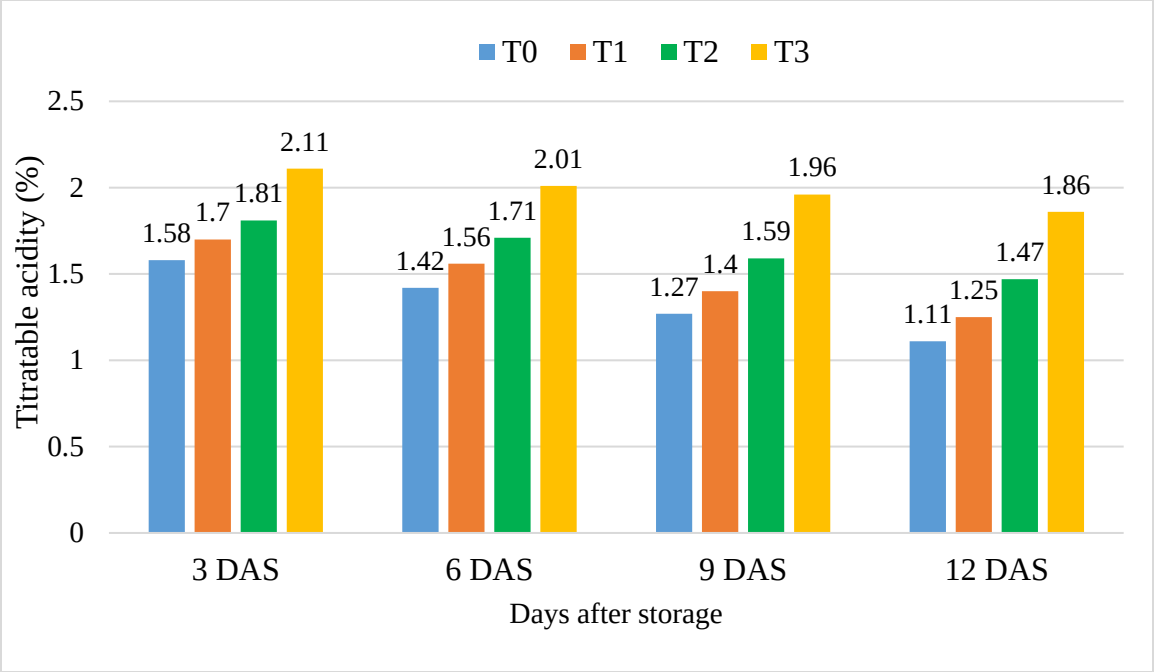

Figure 7. Effect of postharvest treatments on titratable acidity content of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

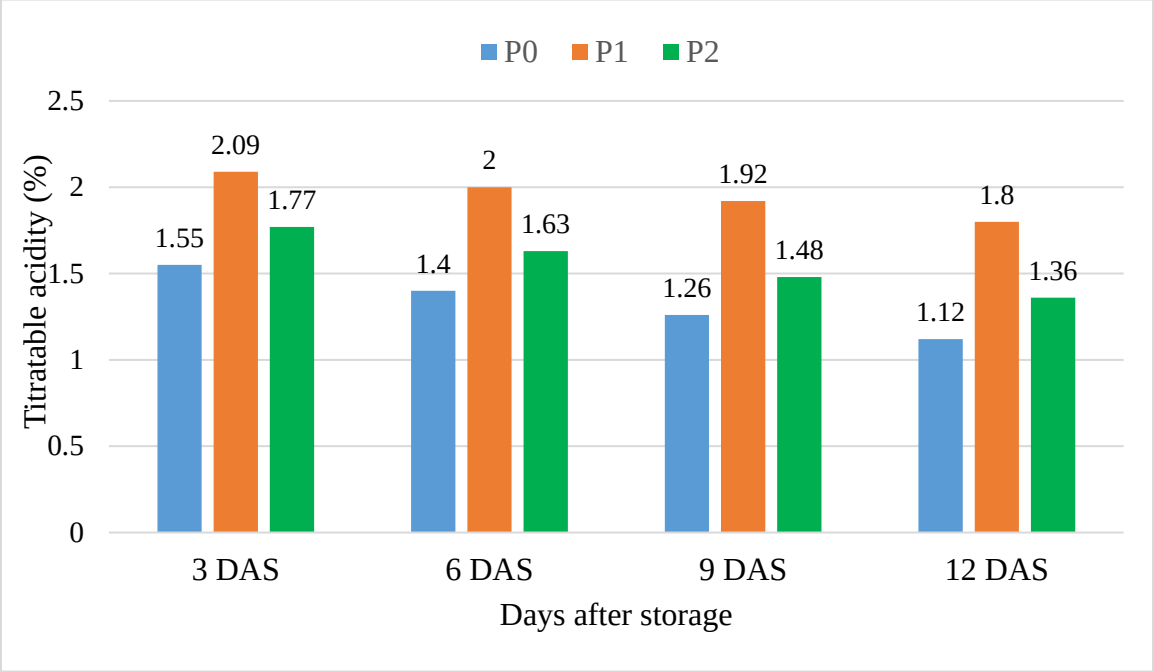

Fig. 8. Effect of packaging materials on titratable acidity content of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 4. Titratable acidity content of guava as influenced by postharvest treatments and packaging material

Treatment Combinations	Titratable acidity content (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	1.37 g	1.11 h	0.93 f	0.77 f
T_0P_1	1.84 d	1.74 e	1.65 d	1.51 d
T_0P_2	1.54 fg	1.41 f	1.23 e	1.07 e
T_1P_0	1.41 g	1.27 g	1.13 e	0.98 e
T_1P_1	2.06 bc	1.97 bc	1.89 bc	1.75 bc
T_1P_2	1.63 ef	1.44 f	1.17 e	1.03 e
T_2P_0	1.48 fg	1.37 f	1.20 e	1.09 e
T_2P_1	2.15 ab	2.05 b	1.94 b	1.81 b
T_2P_2	1.81 de	1.72 e	1.62 d	1.51 d
T_3P_0	1.95 cd	1.83 d	1.77 cd	1.63 cd
T_3P_1	2.30 a	2.24 a	2.21 a	2.12 a
T_3P_2	2.09 bc	1.96 c	1.90 bc	1.83 b
LSD (0.05)	0.3545	0.3456	0.3344	0.4154
CV%	2.31	2.31	2.09	2.51

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Decreasing trend of percent titratable acidity was recorded for increased storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent titratable acidity (2.24, 2.21 and 2.12%, respectively) was recorded in T_3P_1 whereas the minimum percent titratable acidity (1.11, 0.93 and 0.77%, respectively) was found in P_0T_0 (Table 4). In the present investigation, decreased in percent titratable acidity was recorded during storage which was similar to the result of Jitender-Kumar *et al.* (2003). The decreased in titratable acidity may be attributed to increase rate of metabolic activities and break down of different organic compounds during storage period. Similar result was also observed by Lazan *et al.* (1990) and Yusof (1990).

4.5 Vitamin C (mg/100g)

The effect of preservatives on vitamin C content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 9 and Appendix VII). Higher rate of decreasing trend in vitamin C content was recorded only on T_0 (control) treatment while slow decrease rate on vitamin C content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest vitamin C content (191.43 mg/100 g) was found in T_3 (1-MCP 250 ppb) treatment and the lowest vitamin C content (180.84 mg/100 g) in the fruits under control treatment T_0 (no preservative) (Fig. 9). At 6, 9 and 12 DAS, the maximum vitamin C content (186.04, 179.26 and 172.16 mg/100g respectively) was recorded in T_1 while the minimum vitamin C content (177.29, 171.97 and 165.98 mg/100 g, respectively) was found in T_0 (Fig. 9). The results are similar to the findings of Rawat *et al*. (2010), Jatinder *et al.,* (2017); Mitra (1997).

In respect of vitamin C content, significant variation was recorded among packaging treatments (Fig. 10 and Appendix VII). Decreasing trend in vitamin C content was found from 3 DAS to 12 DAS. At 3 DAS, the highest vitamin C content was 198.17 mg/100 g which decreased to 175.71 mg/100 g at 12 DAS in P_1 (perforated polythene) while in control treatment P_0 (no packaging) at 3 DAS and 12 DAS, the vitamin C content were 180.38 and 156.89 mg/100 g, respectively which was lower compared to P_1 (Fig. 10). At 6 and 9 DAS, the highest vitamin C content (195.57 and 186.7 mg/100 g, respectively) was found in P_1 whereas the lowest vitamin C content (173.53 and 161.97 mg/100 g, respectively) was recorded in P_0 (no packaging).

The interaction effect of packaging and preservative treatments on vitamin C content was significant at 3, 6, 9 and 12 DAS (Table 6 and Appendix VII). At 3 DAS, the highest vitamin C content (209.2 mg/100 g) was in T_3P_1 whereas the lowest vitamin C content (172.6 mg/100 g) was recorded in P_0T_0 which was significantly different from other treatments. Decreasing trend of vitamin C content was recorded for increased storage duration for all the treatment combinations

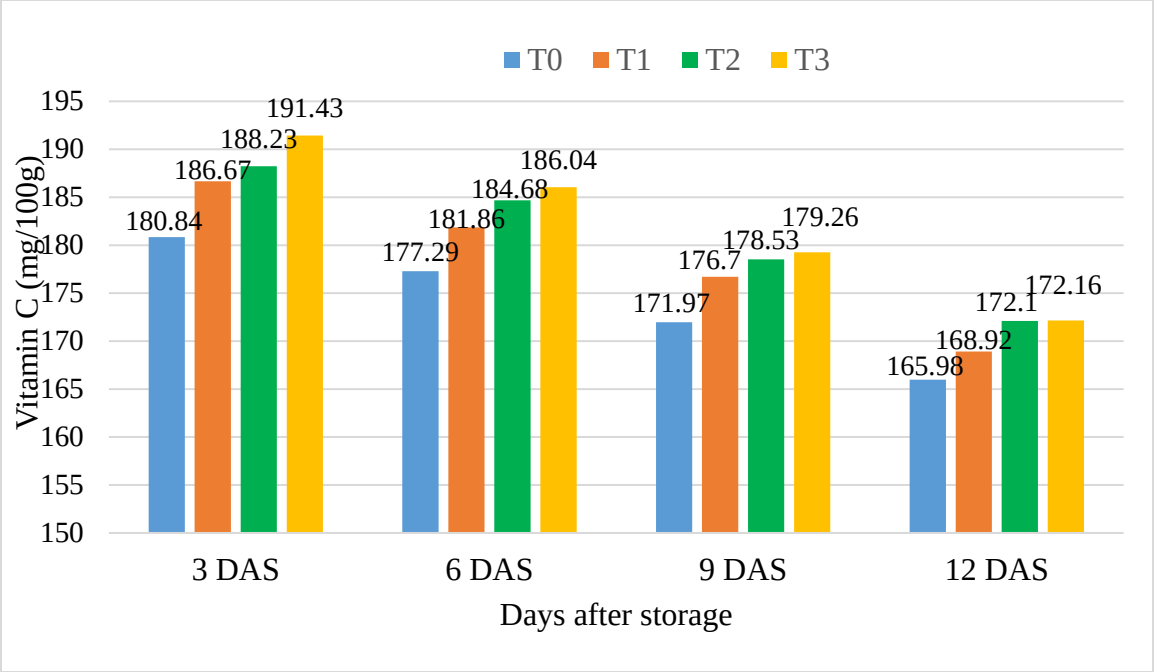

Fig. 9. Effect of postharvest treatments on vitamin C content of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

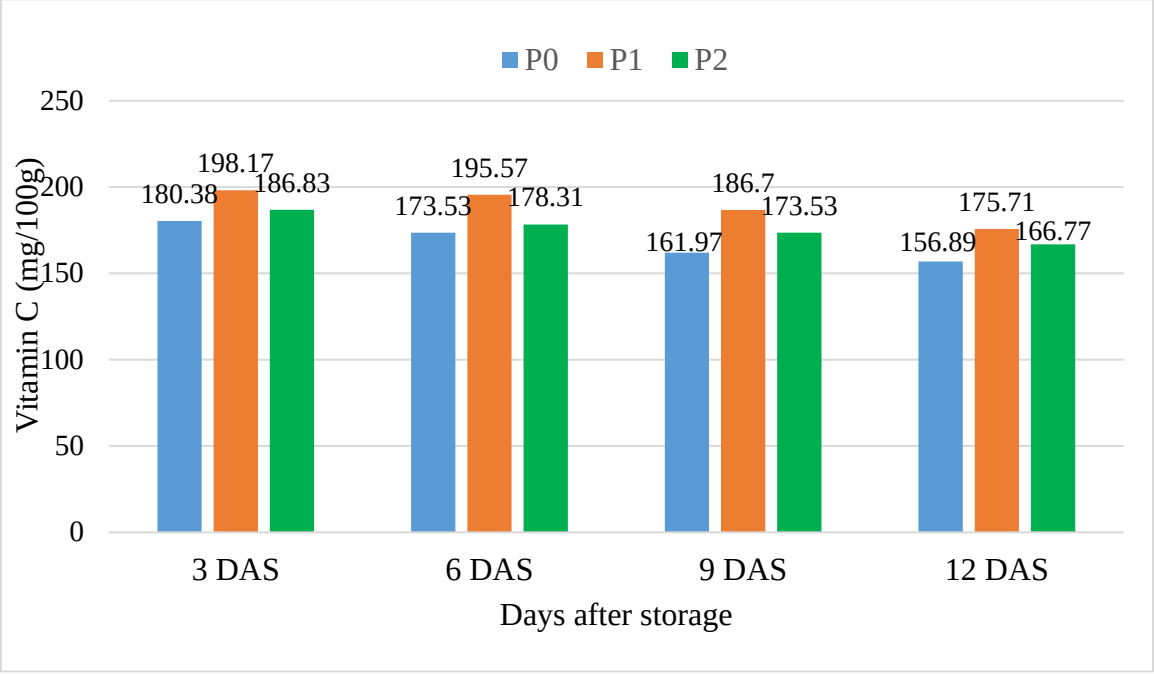

Figure 10. Effect of packaging materials on vitamin C content of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 5. Vitamin C content of guava as influenced by postharvest treatments and packaging material

Treatment Combinations	Vitamin C content(mg/100g)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	172.6 j	166.23 i	159.4 g	149.33 j
T_0P_1	191.2 d	187.23 d	181.2 c	178.2 d
T_0P_2	178.7 i	178.40 ef	175.3 d	170.4 e
T_1P_0	180.4 hi	172.27 h	166.27 f	159.23 h
T_1P_1	197.2 b	196.00 b	192.5 b	186.23 b
T_1P_2	182.4 fgh	177.30 f	171.33 e	161.3 gh
T_2P_0	185.2 e	180.33 e	171.6 e	162.87 fg
T_2P_1	195.0 c	193.47 c	191.53 b	183.23 c
T_2P_2	184.4 ef	180.23 e	172.47 e	170.2 e
T_3P_0	183.3 efg	175.27 g	165.1 f	156.13 i
T_3P_1	209.2 a	205.57 a	201.37 a	195.17 a
T_3P_2	181.8 gh	177.30 f	171.3 e	165.17 f
LSD (0.05)	0.0448	0.0776	0.0223	0.0225
CV%	0.42	0.4	0.52	0.64

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

. At 6, 9 and 12 DAS, the maximum vitamin C content (205.57, 201.37 and 195.17 mg/100g, respectively) was recorded in T_3P_1 whereas the minimum vitamin C content (166.23, 159.4 and 149.33 mg/100 g, respectively) was found in P_0T_0 (Table 6).The decrease in vitamin C content in all treatments and control during storage period may be due to the oxidation of ascorbic acid. Similar result was also recorded by Mitra (1997) who reported that the ascorbic acid content is higher in the skin and declines towards the middle portion. He also mentioned that vitamin C content is more influenced by the fruit's variety than by its ripening stage and storage conditions.

4.6 Total soluble solid (%)

The results on percent total soluble solid showed that there was a significant variation among the postharvest treatments of guava in relation to storage intervals (Fig. 11 and Appendix VIII). Lower rate of increasing trend in percent total soluble solid was recorded only on control treatment while higher increasing rate on percent total soluble solid was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent total soluble solid (5.00%) was found in T_3 (1-MCP 250 ppb) treatment followed by T_3 (1-MCP 250 ppb) and whereas the lowest percent total soluble solid total soluble solid (4.14%) was in the fruits under control treatment P_0 (no packaging) (Fig. 11). At 6, 9 and 12 DAS, the maximum percent total soluble solid (5.45, 6.39 and 7.29%, respectively) was also recorded in T_3 and the minimum percent total soluble solid (4.68, 5.63 and 6.62%, respectively) was found in T_0 (Fig. 11). The results are similar to the findings of Rawat *et al*. (2010), Jatinder *et al.,* (2017).

Regarding percent total soluble solid, significant variation was recorded among packaging treatments (Fig. 12 and Appendix VIII). However, increasing trend in percent total soluble solid was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent total soluble solid was 5.09% which increased to 8.27% at 12 days after storage (DAS) in P_1 (perforated polythene) while in control treatment P_0 (no packaging), at 3 DAS and 12 DAS, the percent total soluble solid total soluble solid were 4.04 and 5.93%, respectively which was lower compared to P_1 (Fig. 12). At 6 and 9 DAS, the highest percent total soluble solid (5.92 and 6.95%, respectively) was found in P_1 whereas the lowest percent total soluble solid (4.67 and 5.41%, respectively) was found in P_0.

The interaction effect of packaging and preservative treatments on percent total soluble solid was significant at 3, 6, 9 and 12 DAS (Table 6 and Appendix VIII). At 3 DAS, the highest percent total soluble solid (5.83%) was in T_3P_1 which was significantly different from other treatment combinations whereas the lowest percent total soluble solid (3.50%) was recorded in P_0T_0. Increasing trend of percent total soluble solid was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent total soluble solid (6.35, 7.32 and 8.90%, respectively) was recorded in T_3P_1 whereas the minimum percent total soluble solid (3.96, 4.85 and 5.70%,

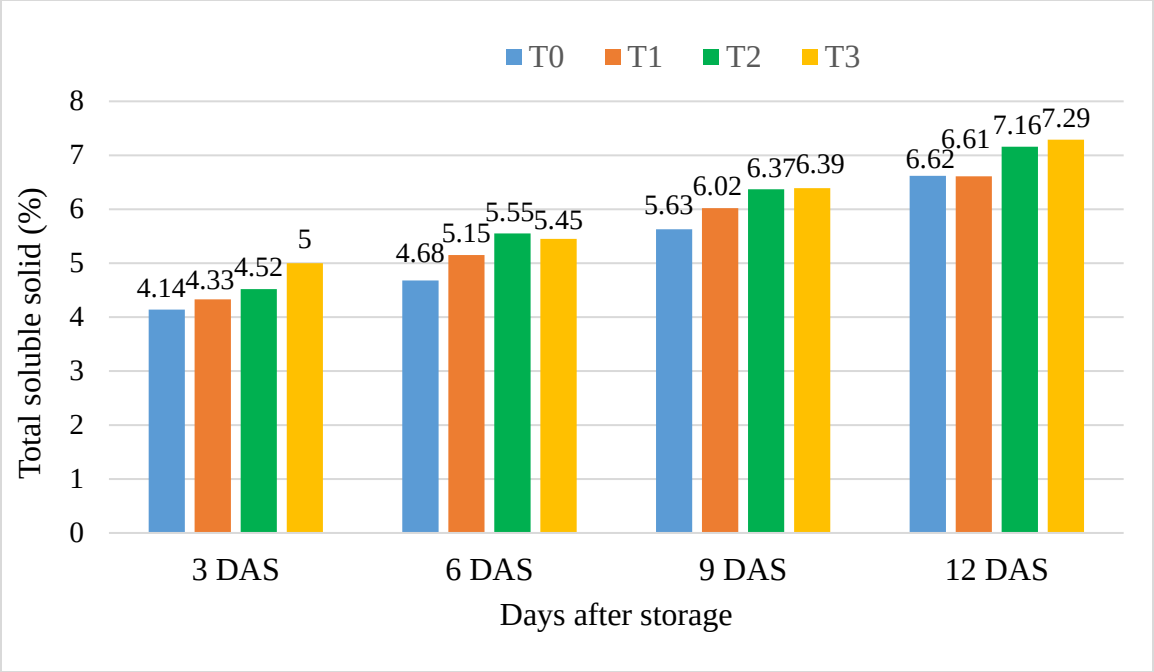

Figure 11. Effect of postharvest treatments on total soluble solid of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

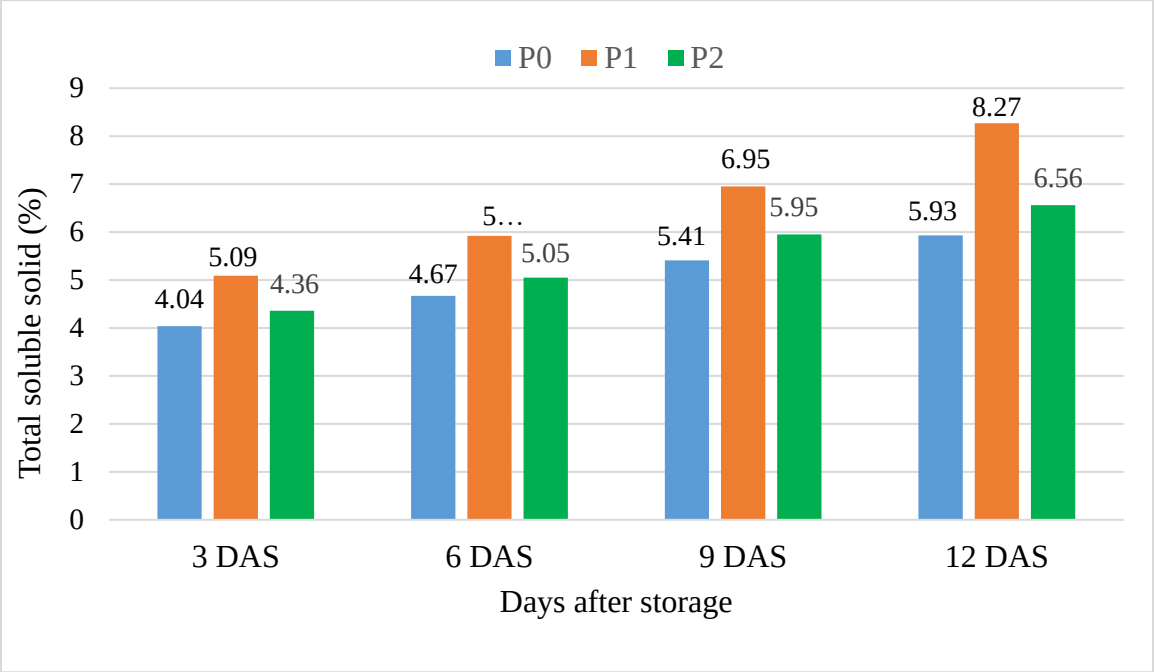

Figure 12. Effect of packaging materials on total soluble solid of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 6. Total soluble solid of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Total soluble solid (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	3.50 i	3.96 k	4.85 h	5.70 h
T_0P_1	4.71 c	5.31 d	6.37 c	7.89 c
T_0P_2	4.21 fg	4.78 i	5.66 f	6.28 f
T_1P_0	3.93 h	4.63 j	5.28 g	5.74 h
T_1P_1	4.92 b	5.77 c	6.82 b	7.77 c
T_1P_2	4.15 g	5.06 gh	5.97 e	6.31 f
T_2P_0	4.28 ef	5.11 fg	5.90 e	6.23 f
T_2P_1	4.92 b	6.23 b	7.29 a	8.52 b
T_2P_2	4.36 de	5.20 e	5.93 e	6.72 e
T_3P_0	4.46 d	4.97 h	5.60 f	6.06 g
T_3P_1	5.83 a	6.35 a	7.32 a	8.90 a
T_3P_2	4.72 c	5.16 ef	6.23 d	6.92 d
LSD (0.05)	0.2046	0.1996	0.193	0.2398
CV%	0.9	0.6	0.66	0.64

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

respectively) was found in P_0T_0 (Table 6). The increase in TSS content was found in the present investigation in similar findings of Augustin *et al.* (1988) and Jitender-Kumar *et al.* (2003). They recorded that gradually increasing of total soluble solid content with increasing storage period all treatments which was possibly due to hydrolysis of starch into sugar. Agarwal *et al.* (2002) also reported that the TSS value increased during ripening. Increase of TSS may be due to the increase in the activity of enzymes responsible for starch hydrolysis and for reduction in the rate of sugar breakdown by respiration.

4.7 Total sugar (%)

The results on percent total sugar content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 13 and Appendix IX). Lower rate of increasing trend in percent total sugar content was recorded only on control treatment while higher increased rate on percent total sugar content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent total sugar content (4.00%) was found in T_3 (1-MCP 250 ppb) treatment and the lowest percent total sugar content (3.31%) was in the fruits under control treatment T_0 (no preservative) (Fig. 13). At 6, 9 and 12 DAS, the maximum percent total sugar content (5.00, 6.15 and 7.34%, respectively) was recorded in T_3 and the minimum percent total sugar content (4.48, 5.24 and 6.10%, respectively) was found in control T_0 (Fig. 16). This is in conformity with the studies conducted by Augustin *et al.* (1988); Jitender-Kumar *et al.* (2003); Singh *et al*. (2004); Martinez *et al*. (2009); Jatinder *et al.*, (2017).

In respect of percent total sugar content, significant variation was recorded among packaging treatments (Fig. 14 and Appendix IX). However, increasing trend in percent total sugar content was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent total sugar content was 4.24% which increased to 7.43% at 12 DAS in P_1 (perforated polythene) while in control treatment P_0 (no packaging), at 3 DAS and 12 DAS, the percent total sugar content was 2.78 and 5.60%, respectively which was lower compared to P_1 (perforated polythene) (Fig. 14). At 6 and 9 DAS, the highest percent total sugar content (5.40 and 6.39%, respectively) was recorded in P_1 whereas the lowest percent total sugar content (3.94 and 4.79%, respectively) was found in P_0.

The interaction effect of packaging and preservative treatments on percent total sugar content was significant at 3, 6, 9 and 12 DAS (Table 8 and Appendix IX). At 3 DAS, the highest percent total sugar content (4.90%) was in T_3P_1 whereas the lowest percent total sugar content (2.34%) was recorded in P_0T_0. Increasing trend of percent total sugar content was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent total sugar content (6.31, 7.80 and 9.06%, respectively) was recorded in T_3P_1 whereas the minimum percent total sugar

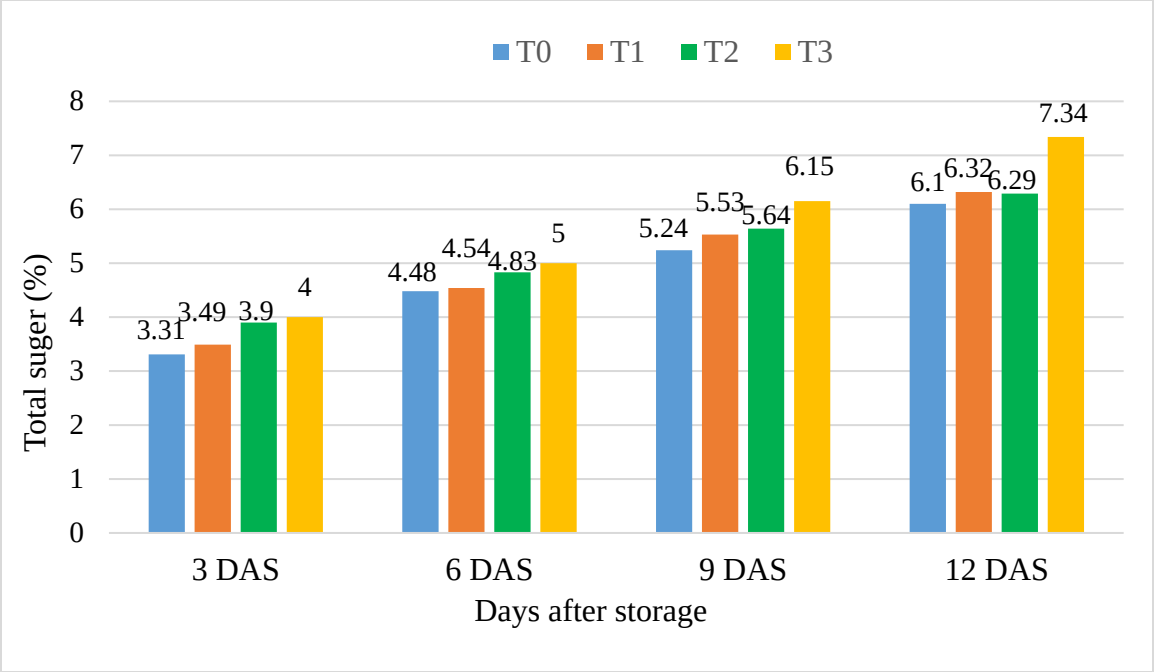

Figure 13. Effect of postharvest treatments on total sugar content of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

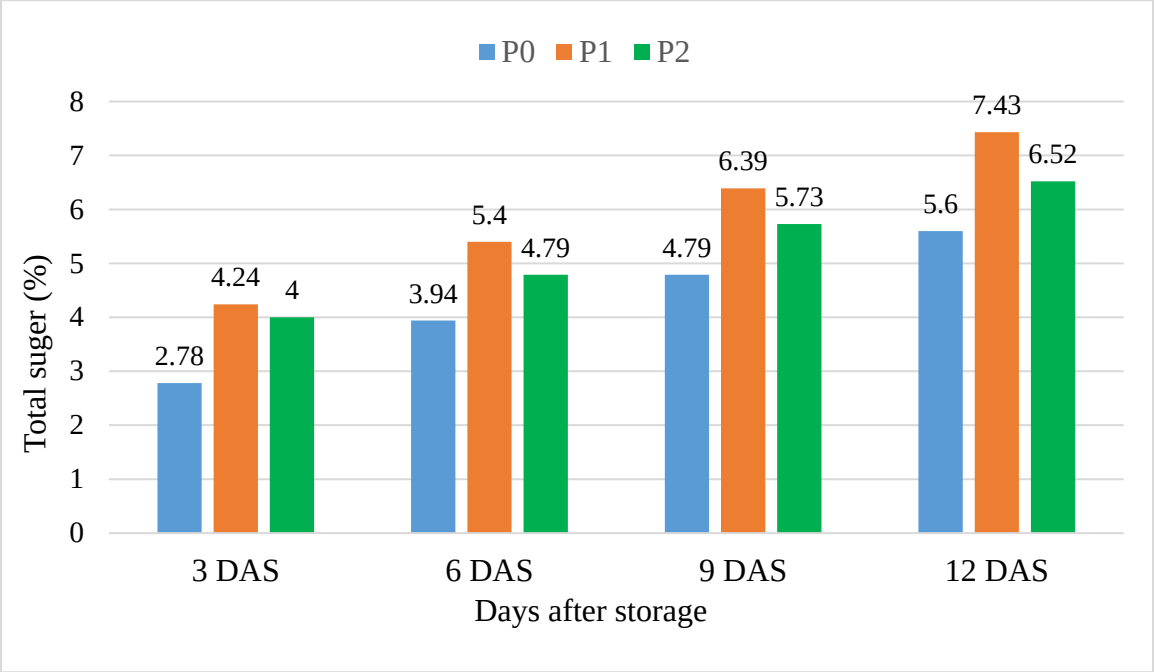

Figure 14. Effect of packaging materials on total sugar content of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 7. Total sugar of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Total sugar (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	2.34 i	3.75 i	4.71 j	5.41 g
T_0P_1	3.50 f	4.93 d	5.64 f	6.77 c
T_0P_2	4.10 c	4.76 e	5.37 g	6.13 e
T_1P_0	2.48 h	3.92 h	4.83 hi	5.66 f
T_1P_1	4.14 c	5.08 c	5.98 c	6.80 c
T_1P_2	3.85 e	4.62 f	5.77 e	6.52 d
T_2P_0	3.18 g	4.15 g	4.86 h	5.18 h
T_2P_1	4.44 b	5.28 b	6.16 b	7.08 b
T_2P_2	4.07 cd	5.05 c	5.89 d	6.62 d
T_3P_0	3.12 g	3.94 h	4.75 ij	6.14 e
T_3P_1	4.90 a	6.31 a	7.80 a	9.06 a
T_3P_2	3.97 de	4.74 e	5.88 d	6.81 c
LSD (0.05)	0.0388	0.0162	0.0193	0.0192
CV%	1.31	0.83	0.56	0.8

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

content (3.75, 4.71 and 5.41%, respectively) was found in P_0T_0 (Table 7). Under the present study total sugar content increased during storage period which is similar to the observation of Augustin *et al.* (1988) and he reported that storing guava at ambient temperature showed significant increase in total sugar content. Blankenship and Dole (2003) found similar result.

4.8 Reducing sugar (%)

The results on percent reducing sugar content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 15 and Appendix IX). Lower rate of increasing trend in percent reducing sugar content was recorded only on control treatment while higher increased rate on percent reducing sugar content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent reducing sugar content (2.24%) was found in T_3 (1-

MCP 250 ppb) treatment and the lowest percent reducing sugar content (1.25%) was in the fruits under control treatment T_0 (no preservative). At 6, 9 and 12 DAS, the maximum percent reducing sugar content (3.11, 4.27 and 5.45%, respectively) was recorded in T_3 and the minimum percent reducing sugar content (2.12, 3.21 and 4.23%, respectively) was found in control T_0 treatment (Fig. 15). This is in conformity with the studies conducted by Augustin *et al.* (1988); Singh *et al*. (2004); Martinez *et al*. (2009); Jatinder *et al.,* (2017).

In respect of percent reducing sugar content, significant variation was recorded among packaging treatments (Fig. 16 and Appendix IX). However, increasing trend in percent reducing sugar content was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent reducing sugar content was 2.01% which increased to 5.29% at 12 DAS in P_1 (perforated polythene) while in control treatment P0 (no packaging), at 3 DAS and 12 DAS, the percent reducing sugar content were 1.42 and 4.23% respectively which was lower compared to P_1 (perforated polythene) (Fig. 16). At 6 and 9 DAS, the highest percent reducing sugar content (3.01 and 4.17%, respectively) was recorded in P_1 whereas the lowest percent reducing sugar content (2.12 and 3.21%, respectively) was found in P_0.

The interaction effect of packaging and preservative treatments on percent reducing sugar content was significant at 3, 6, 9 and 12 DAS (Table 8 and Appendix IX). At 3 DAS, the highest percent reducing sugar content (2.65%) was in T_3P_1 whereas the lowest percent reducing sugar content (0.92%) was recorded in P_0T_0. Increasing trend of percent reducing sugar content was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent reducing sugar content (3.74, 5.10 and 6.05%, respectively) was recorded in T_3P_1 whereas the minimum percent reducing sugar content (1.66, 2.55 and 3.71%, respectively) was found in P_0T_0 (Table 8). Under the present study reducing sugar content increased during storage period which is similar to the observation of Augustin *et al.* (1988) and he reported that storing guava at ambient temperature showed significant increase in reducing sugar content.

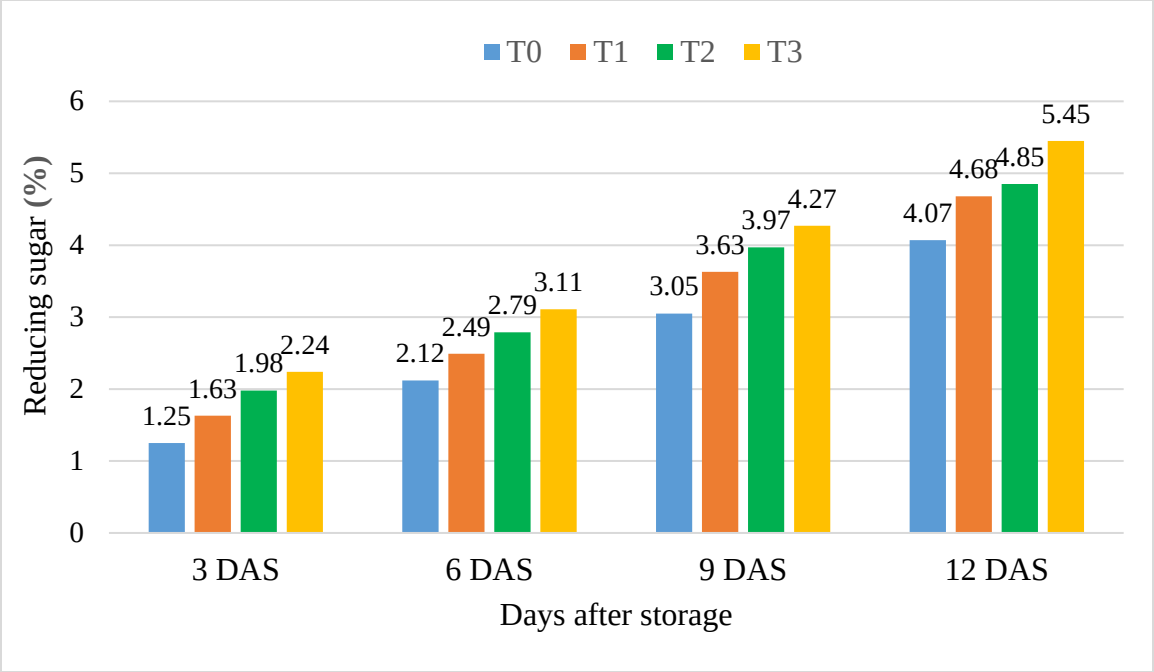

Figure 15. Effect of postharvest treatments on reducing sugar content of guava.

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

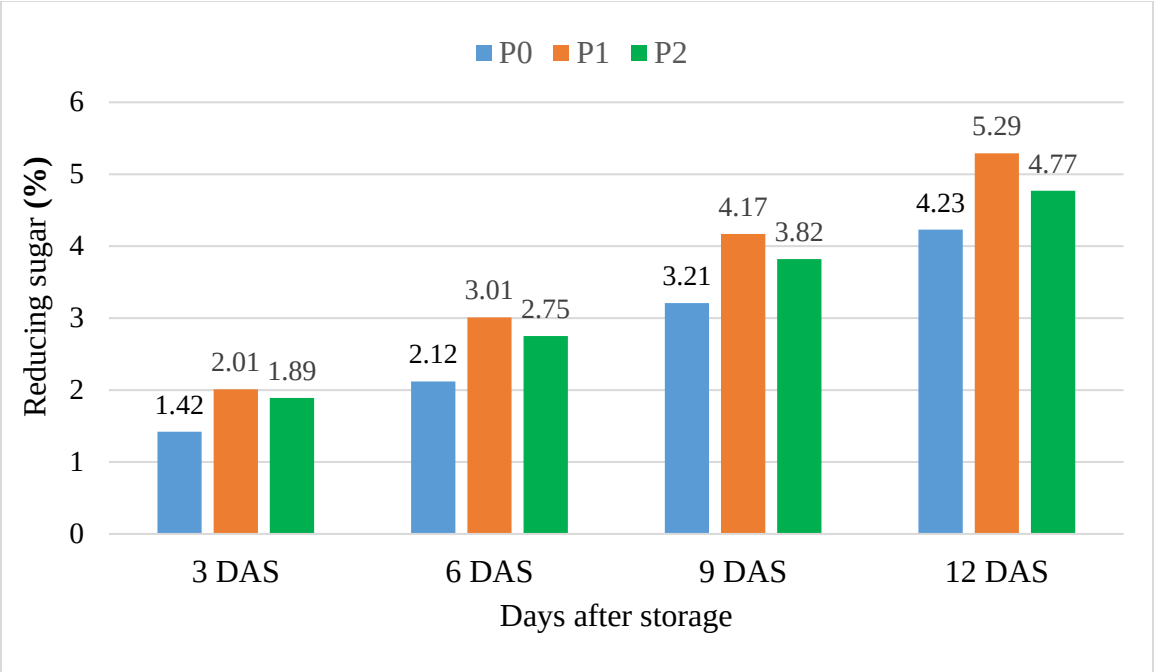

Figure 16. Effect of packaging materials on reducing sugar content of guava.

P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 8. Reducing sugar content of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Reducing sugar (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	0.92 h	1.66 k	2.55 i	3.71 j
T_0P_1	1.18 g	2.32 h	3.14 h	4.36 g
T_0P_2	1.66 e	2.37 h	3.45 g	4.13 i
T_1P_0	1.29 f	2.14 j	3.18 h	4.18 h
T_1P_1	1.90 c	2.80 d	3.89 d	5.11 d
T_1P_2	1.69 de	2.53 f	3.82 e	4.76 f
T_2P_0	1.71 de	2.46 g	3.55 f	4.16 hi
T_2P_1	2.32 b	3.16 c	4.56 b	5.65 b
T_2P_2	1.91 c	2.74 e	3.81 e	4.74 f
T_3P_0	1.76 d	2.24 i	3.54 f	4.86 e
T_3P_1	2.65 a	3.74 a	5.10 a	6.05 a
T_3P_2	2.30 b	3.35 b	4.19 c	5.46 c
LSD (0.05)	0.1772	0.1728	0.1672	0.2077
CV%	2.07	0.81	0.46	0.31

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

4.9 Non-reducing sugar (%)

The results on percent non-reducing sugar content showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 17 and Appendix IX). Lower rate of increasing trend in percent non-reducing sugar content was recorded only on control treatment while higher increased rate on percent non-reducing sugar content was recorded for other treatments especially in case of T_3 (1-MCP 250 ppb). At 3 DAS, the highest percent non-reducing sugar content (2.06%) was found in T_3 (1-MCP 250 ppb) treatment and the lowest percent non-reducing sugar content (1.44%) was in the fruits under control treatment T_0 (no preservative) (Fig. 17).

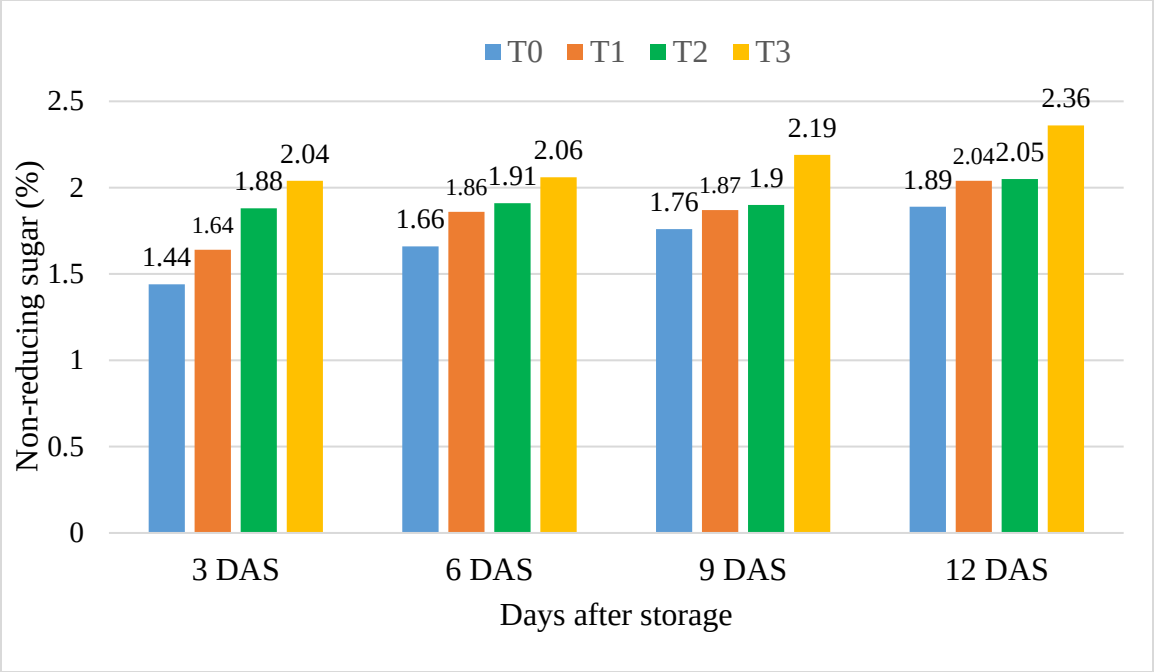

Figure 17. Effect of postharvest treatments on non-reducing sugar of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

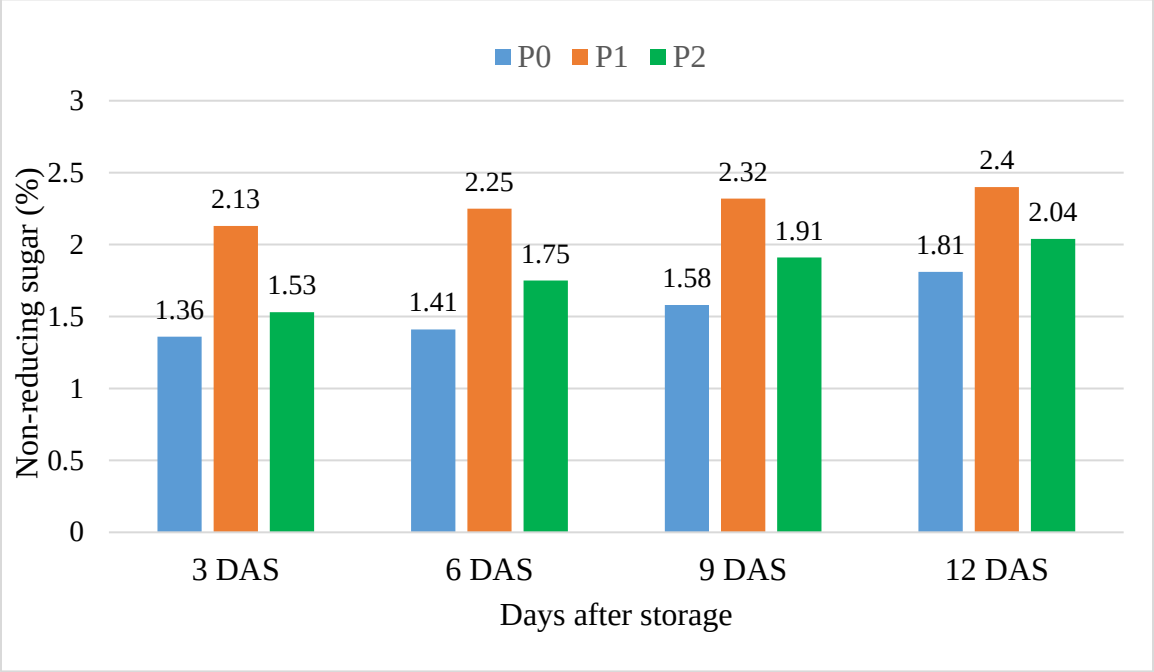

Figure 18. Effect of packaging materials on non-reducing sugar content of guava.
P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 9. Non-reducing sugar content of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Non-reducing sugar (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
T_0P_0	1.19 g	1.21 h	1.29h	1.37 g
T_0P_1	1.23 f	1.02 i	1.31 g	1.69 i
T_0P_2	1.46 e	1.48 f	1.65 ef	1.84 g
T_1P_0	1.36 f	1.43 fg	1.60 f	1.78 h
T_1P_1	1.86 e	1.69 e	1.95 d	2.13 f
T_1P_2	1.47 f	1.65 gh	1.69 e	2.09 fg
T_2P_0	2.11 d	1.70 e	2.01 d	2.28 e
T_2P_1	2.16 cd	1.88 cd	2.09 c	2.30 d
T_2P_2	2.16 cd	1.76 de	2.08 c	2.29 d
T_3P_0	2.24 bc	1.93 c	2.16 c	2.39 c
T_3P_1	2.56 a	2.67 a	2.71 a	3.01 a
T_3P_2	2.31 b	2.41 b	2.49 b	2.61 b
LSD (0.05)	0.0361	0.0387	0.0259	0.0274
CV%	2.32	2.71	1.66	1.61

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

At 6, 9 and 12 DAS, the maximum percent non-reducing sugar content (2.06, 2.19 and 2.36%, respectively) was recorded in T_3 and the minimum percent non-reducing sugar content (1.66, 1.76 and 1.89%, respectively) was found in control T_0 treatment (Fig. 17). This is in conformity with the studies conducted by Augustin *et al.* (1988); Singh *et al*. (2004); Martinez *et al*. (2009); Jatinder *et al.,* (2017).

In respect of percent non-reducing sugar content, significant variation was recorded among packaging treatments (Fig. 18 and Appendix IX). However, increasing trend in percent non-reducing sugar content was found from 3 DAS to 12 DAS. At 3 DAS, the highest percent non-reducing sugar content was 2.13% which increased to 2.40% at 12 DAS in P_1 (perforated polythene) while in control treatment P0 (no packaging), at 3 DAS

and 12 DAS, the percent non-reducing sugar content were 1.36 and 1.81%, respectively which was lower compared to P_1 (perforated polythene) (Fig. 18). At 6 and 9 DAS, the highest percent non-reducing sugar content (2.25 and 2.32%, respectively) was recorded in P_1 whereas the lowest percent non-reducing sugar content (1.41 and 1.58%, respectively) was found in P_0. This is in conformity with the studies conducted by Blankenship and Dole (2003); Singh *et al*. (2004); Jatinder *et al.,* (2017).

The interaction effect of packaging and preservative treatments on percent non-reducing sugar content was significant at 3, 6, 9 and 12 DAS (Table 9 and Appendix IX). At 3 DAS, the highest percent non-reducing sugar content (2.56%) was in T_3P_1 whereas the lowest percent non-reducing sugar content (1.19%) was recorded in P_0T_0. Increasing trend of percent non-reducing sugar content was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum percent non-reducing sugar content (2.67, 2.71 and 3.01%, respectively) was recorded in T_3P_1 whereas the minimum percent non-reducing sugar content (1.21, 1.29 and 1.37%, respectively) was found in P_0T_0 (Table 9). Under the present study non-reducing sugar content increased during storage period which is similar to the observation of Augustin *et al.* (1988) and he reported that storing guava at ambient temperature showed significant increase in non-reducing sugar content.

4.10 Shelf life (days)

The results on shelf life showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 19 and Appendix X). The highest shelf life (11.00 days) was found in T_3 (1-MCP 250 ppb) treatment and the lowest shelf life (6.67 days) was in the fruits under control treatment T_0 (no preservative) (Fig. 19). This is in conformity with the studies conducted by Blankenship and Dole (2003); Singh *et al*. (2004); Martinez *et al*. (2009); Jatinder *et al.,* (2017).

The postharvest treatment used in the present study exhibited pronounced effect extending shelf life of guava during storage and it was statistically significant and it was recorded among packaging treatments (Fig. 20 and Appendix IX). The highest shelf life was 10.92 days in P_1 (perforated polythene) treatment while lowest (7.25 days) in control treatment P_0 (no packaging).

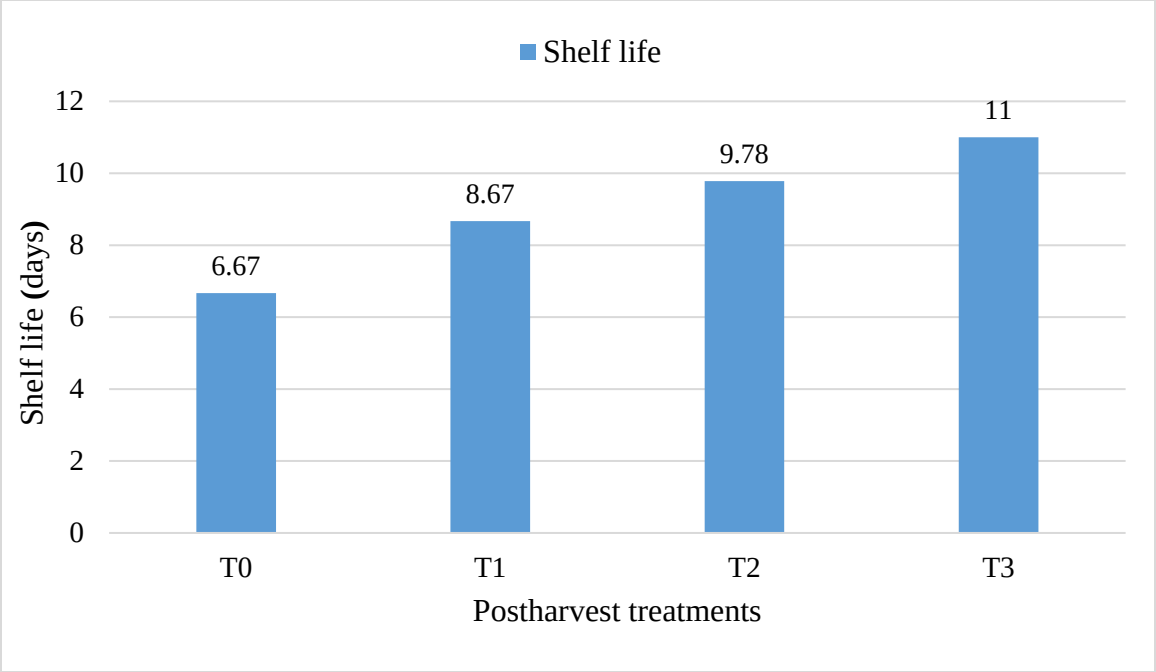

Figure 19. Effect of postharvest treatments on shelf life of guava.
T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb)

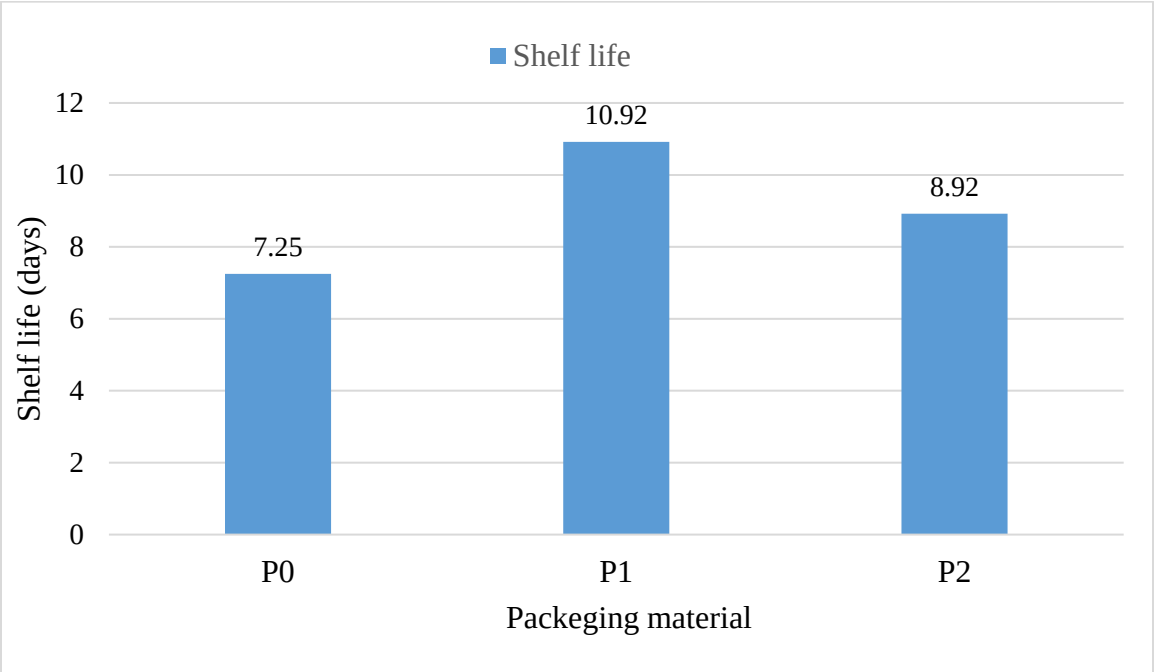

Figure 20. Effect of packaging materials on shelf life of guava.

P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

Table 10. Shelf life of guava as influenced by postharvest treatments and packaging materials

Treatment Combinations	Shelf life (Days)
T_0P_0	5.33 g
T_0P_1	8.33 de
T_0P_2	6.33 fg
T_1P_0	7.00 efg
T_1P_1	10.67 bc
T_1P_2	8.33 de
T_2P_0	7.33 ef
T_2P_1	12.00 ab
T_2P_2	10.00 cd
T_3P_0	9.33 cd
T_3P_1	12.67 a
T_3P_2	11.00 abc
LSD (0.05)	0.4855
CV%	6.59

T_0 = Control, T_1 = Hot water, T_2 = $CaCl_2$ (4%), T_3 = 1-MCP (250 ppb), P_0 = Control, P_1 = Perforated polythene bag and P_2 = Newspaper.

The interaction effect of packaging and preservative treatments on shelf life was significant (Table 10 and Appendix X). The highest shelf life (12.67 days) was in T_3P_1 whereas the lowest shelf life of guava (5.33 days) was recorded in P_0T_0. Increasing trend of percent non-reducing sugar content was recorded for increasing of storage duration for all the treatment combinations. (Table 10). The above results lead to the conclusion that different postharvest treatments influenced the shelf life of guava. The increase shelf life was probably due to the changes in the concentration of various gasses (increased level of O_2 and reduced level of CO_2) as well as slow down the process to the delay ripening by different postharvest treatments. The result was similar to the findings of Azad et al, (1987) and he reported that strong guava showed significantly increased shelf life in acceptable condition 10 days during storage at room temperature.

T_0P_0

T_0P_1

T_0P_2

T_1P_0

T_1P_1

T_1P_2

T_2P_0

T_2P_1

T_2P_2

T_3P_0

T_3P_1

T_3P_2

Plate 3: Photographs showing differences in external appearances of guava fruits under different postharvest treatments at 3rd day of storage

T_0P_0

T_0P_1

T_0P_2

T_1P_0

T_1P_1

T_1P_2

T_2P_0

T_2P_1

T_2P_2

T_3P_0

T_3P_1

T_3P_2

Plate 4: Photographs showing differences in external appearances of guava fruits under different postharvest treatments at 6th day of storage

T_0P_0

T_0P_1

T_0P_2

T_1P_0

T_1P_1

T_1P_2

T_2P_0

T_2P_1

T_2P_2

T_3P_0

T_3P_1

T_3P_2

Plate 5: Photographs showing differences in external appearances of guava fruits under different postharvest treatments at 9th day of storage

T_0P_0

T_0P_0

T_0P_2

T_1P_0

T_1P_1

T_1P_2

T_2P_0

T_2P_1

T_2P_2

T_3P_0

T_3P_1

T_3P_2

Plate 6: Photographs showing differences in external appearances of guava fruits under different postharvest treatments at 12th day of storage

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Postharvest Laboratory of Dept. of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, during the period from January 2022 to April 2022 to find out the postharvest management of guava to increase shelf life and quality. The objectives of the present study were to investigate the effect of packaging materials and postharvest treatments on shelf life and quality attributes of guava after storage. In this two factorial experiment postharvest treatments were denoted as Factor A and packaging materials were denoted as Factor B. Factor A: T_0 = No postharvest treatments, T_1 = Hot water, T_2 = $CaCl_2$ (4%) and T_3 = 1-MCP (250 ppb) and Factor B: P_0 = No packaging material, P_1 = Perforated polythene bag and P_2 = Newspaper. Treatment of the fruits along with some physio-chemical analyses was done at the postharvest laboratory. The experiment was laid out in completely randomized design (CRD) with three replications. Various data on physical and chemical properties were collected. Data on different parameters were recorded and analyzed statistically using MSTAT C software. Collected data on different parameters were affected significantly in most of the cases due to combined effect of packaging materials and preservatives where effect of packaging materials showed non-significant for most of the parameters.

Total three packaging materials were applied in this experiment along with no packaging fruit marked as control. Among all those treatments the maximum weight loss (6.22%, 7.85%, 9.01%, and 9.78% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of storage, respectively), was found in P_0 (no packaging) and minimum (5.25%, 6.23%, 7.56% and 8.31% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of storage, respectively) was found in P_1 (perforated polythene bag). The highest (84.27%, 82.86%, 82.30% and 81.84% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) moisture content was found in P_0 (no packaging) and lowest (80.51%, 79.01%, 78.80% and 78.20% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) moisture was found in P_1 (Perforated polythene bags stored fruits). The highest (19.5%, 20.99%, 21.23% and 22.80% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) dry matter content was found in P_1 (perforated polythene bags fruits) and lowest (16.73%, 17.31%, 18.67% and 19.16% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) dry matter content was found in P_0 (no packaging). The maximum (2.09%, 2.00%, 1.92% and 1.80% at 3^{rd}, 6^{th}, 9^{th} and 12^{th}

DAS) TA content was found in P_1 (perforated polythene bags stored fruits) and minimum (1.55%, 1.40%, 1.26% and 1.12% at 3rd, 6th, 9th and 12th DAS) TA was found in P_0 (no packaging). The maximum vitamin C (198.17, 195.57, 186.70 and 175.71 mg/100 g at 3rd, 6th, 9th and 12th DAS) value was recorded from P_1 (perforated poly bags stored fruits). On the contrary, minimum (180.38, 173.53, 161.97 and 156.89 mg/100 g at 3rd, 6th, 9th and 12th DAS) value was obtained from P_0 (no packaging). TSS value which was an important quality parameter of guava, the maximum (5.09%, 5.92%, 6.95% and 8.27% at 3rd, 6th, 9th and 12th DAS) TSS content was found in P_1 (perforated polythene bags fruits) and minimum (4.04%, 4.67%, 5.41% and 5.93%) TSS content was found in P_0 (No packaging). The maximum (4.24%, 5.40%, 6.39% and 7.43% at 3rd, 6th, 9th and 12th DAS) total sugar content was found in P_1 (perforated polythene bags fruits) and minimum (2.78%, 3.94%, 4.79% and 5.60% at 3rd, 6th, 9th and 12th DAS) total sugar content was found in P_0 (no packaging). The maximum (2.01%, 3.01%, 4.17% and 5.29% at 3rd, 6th, 9th and 12th DAS) reducing sugar content was found in P_1 (perforated polythene bags stored fruits) and minimum (1.42%, 2.12%, 3.21% and 4.23% at 3rd, 6th, 9th and 12th DAS) reducing sugar content was found in P_0 (packaging fruits). The maximum (2.13%, 2.25%, 2.32% and 2.4% at 3rd, 6th, 9th and 12th DAS) non- reducing sugar content was found in P_1 (perforated polythene bags stored fruits) and minimum (1.36%, 1.41%, 1.58% and 1.81% at 3rd, 6th, 9th and 12th DAS) non-reducing sugar was found in P_0 (no packaging). In case of shelf life affected by different packaging materials, the highest shelf life (10.92 days) was found in P_1 (perforated polythene fruits) and lowest shelf life (7.25 days) was found in P_0 (no packaging fruits).

Regarding application of different postharvest treatments, the maximum loss in weight (4.4%, 5.58, 6.79 and 7.42% at 3rd, 6th, 9th and 12th day of storage, respectively) was found in T_0 (no preservatives) and the minimum (13.68%, 4.98, 5.51 and 6.04% at 3rd, 6th, 9th and 12th days after harvest, respectively) was found in T_3 (1-MCP 250 ppb). The highest moisture (84.88%, 84.13%, 83.90% and 82.34% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_0 (no preservatives) and minimum (80.10%, 79.70%, 79.34% and 78.04% at 3rd, 6th, 9th and 12th DAS) moisture content was found in T_3 (1-MCP 250 ppb). The highest dry matter (19.45%, 19.92%, 21.10% and 22.96% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (17.12%, 18.87%,

19.10% and 19.66% at 3rd, 6th, 9th and 12th DAS) dry matter content was found in T_0 (no preservatives). The highest TA (2.11%, 2.01%, 1.96% and 1.86% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (1.58%, 1.42%, 1.27% and 1.11% at 3rd, 6th, 9th and 12th DAS) TA content was found in T_0 (no preservatives). The highest vitamin C (191.43, 186.04, 179.26 and 172.16 mg/100g at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (180.84, 177.29, 171.97 and 165.98 mg/100g at 3rd, 6th, 9th and 12th DAS) vitamin C content was found in T_0 (no preservatives). The highest TSS (5.00%, 5.45%, 6.39% and 7.29% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (4.14%, 4.68%, 5.63% and 6.62% at 3rd, 6th, 9th and 12th DAS) TSS content was found in T_0 (no preservatives). The highest total sugar (4.00%, 5.00%, 6.15% and 7.24% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (3.31%, 4.48%, 5.24% and 6.10% at 3rd, 6th, 9th and 12th DAS) total sugar content was found in T_0 (no preservatives). The highest reducing sugar (2.24%, 3.11%, 4.27% and 5.45% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (1.25%, 2.12%, 3.05% and 4.07% at 3rd, 6th, 9th and 12th DAS) reducing sugar content was found in T_0 (no preservatives). The highest non- reducing sugar (2.04%, 2.06%, 2.19% and 2.36% at 3rd, 6th, 9th and 12th DAS) content was noticed in T_3 (1-MCP 250 ppb) and minimum (1.44%, 1.66%, 1.76% and 1.89% at 3rd, 6th, 9th and 12th DAS) non-reducing sugar content was found in T_0 (no preservatives). In case of shelf life affected by different postharvest treatments, the highest shelf life (11.00 days) shelf life was noticed in T_3 (1-MCP 250 ppb) and minimum (6.67 days) shelf life content was found in T_0 (no preservatives) treatment.

Combined effect of packaging materials and different postharvest treatment combinations had significant effect on storage condition of guava. The highest rate of weight loss (7.02%, 8.14%, 9.73% and 10.60% at 3rd, 6th, 9th and 12th DAS) was observed in T_0P_0 (control without packaging) combination and lowest weight loss (3.68%, 4.08%, 5.96% and 6.72% at 3rd, 6th, 9th, 12th and 15th DAS) rate was recorded in T_3P_1 (1-MCP 250 ppb with perforated polythene bag) combination. The maximum moisture content (84.63%, 84.13%, 83.59% and 83.43% at 3rd, 6th, 9th and 12th DAS) was found in T_0P_0 (control without packaging) treatment combination and minimum moisture content (78.60%,

78.28%, 78.01% and 77.11% at 3rd, 6th, 9th and 12th DAS) was recorded in T_3P_1 (1-MCP 250 ppb with perforated polythene bag) treatment combination. The maximum dry matter content (21.40%, 21.58%, 22.38% and 22.99% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1-MCP 250 ppb with perforated polythene bag) combination and minimum dry matter content (15.37%, 16.37%, 16.81% and 17.57% at 3rd, 6th, 9th and 12th DAS) was recorded in T_0P_0 (control without packaging) treatment combination. The maximum TA content (2.30%, 2.24%, 2.21% and 2.12% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1 -MCP 250 ppb with perforated poly bag) combination and minimum TA content (1.37%, 1.11%, 0.93% and 0.77% at 3rd, 6th, 9th and 12th DAS) was recorded in T_0P_0 (control without packaging) . The minimum vitamin C content (172.6, 166.23, 159.4 and 149.33 mg/100 g at 3rd, 6th, 9th and 12th DAS) was found in T_0P_0 (control without packaging) combination and maximum vitamin C content (209.2, 205.57, 201.37 and 195.17 mg/100 g at 3rd, 6th, 9th and 12th DAS) was recorded in T_3P_1 (1-MCP 250 ppb with perforated poly bag). The maximum TSS content (5.83%, 6.35%, 7.32% and 8.90% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1-MCP 250 ppb with perforated poly bag) combination and minimum TSS content (3.50%, 3.96%, 4.85% and 5.70% at 3rd, 6th, 9th and 12th DAS) was found in T_0P_0 (control without packaging) combination. The maximum total sugar content (4.90%, 6.31%, 7.80% and 9.06% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1-MCP 250 ppb with perforated poly bag) combination and minimum total sugar content (2.34%, 3.75%, 4.71% and 5.41% at 3rd, 6th, 9th and 12th DAS) was recorded in T_0P_0 (control without packaging) combination. The maximum reducing sugar content (2.65%, 3.74%, 5.10% and 6.05% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1-MCP 250 ppb with perforated poly bag) combination and minimum reducing sugar content (0.92%, 1.66%, 2.55% and 3.71% at 3rd, 6th, 9th and 12th DAS) was recorded in T_0P_0 (control without packaging) combination. The maximum non-reducing sugar content (2.56%, 2.67%, 2.71% and 3.01% at 3rd, 6th, 9th and 12th DAS) was found in T_3P_1 (1-MCP 250 ppb with perforated poly bag) combination and minimum non-reducing sugar content (1.19%, 1.21%, 1.29% and 1.37% at 3rd, 6th, 9th and 12th DAS) was recorded in T_0P_0 (control without packaging) combination. In case of shelf life affected by different affect by combined effect of packaging materials and postharvest treatments, the highest shelf life (12.67 days) was found in T_3P_1 (1-MCP 250 ppb with

perforated poly bag) combination and lowest shelf life (5.33 days) was recorded in T_0P_0 (control without packaging) combination.

Conclusion:

The findings of the present study can be concluded as follows:

Percent weight loss, dry matter, TSS and total sugar content, reducing sugar content, non-reducing sugar of guava fruits increased with the storage period under different treatments. On the other hand, moisture content of guava fruits decreased as the storage period increased. The shelf life from the treatment P_1 (perforated polythene) could be extended up to 12.67 days by using T_3 (250ppb 1-MCP). The fruits which had longer shelf life slowly changed its chemical components.

Therefore, perforated polythene with 1-MCP (250ppb) might be better shelf life and quality of guava.

Recommendation:

From the results of the experiment and subsequent discussion, it may be suggested that

1. More research works need to be conducted on physio-chemical changes of guava using different treatments to confirm the findings.
2. Further experiment should also be conducted using more postharvest treatments to extend the shelf life to minimize the postharvest losses of guava.

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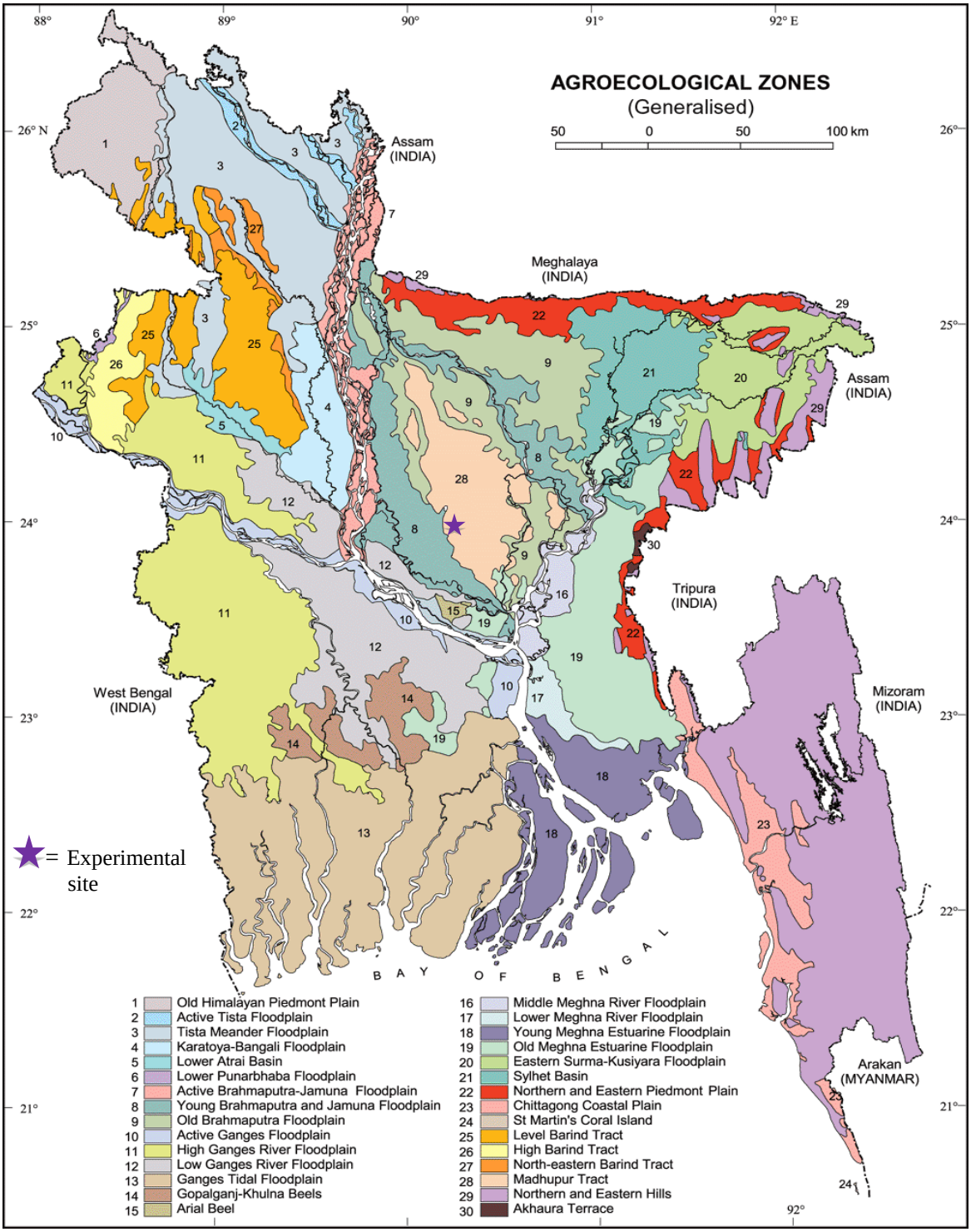
APPENDICES

Appendix I: Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II: Analysis of variance of effect of packaging materials and postharvest treatments on percent of weight loss of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.0013	0.014	0.017	0.011
Factor A	3	1.0927*	0.588*	2.6*	3.087*
Factor B	2	98.2071*	152.214*	194.502*	208.299*
AB	6	0.7398*	1.217*	1.582*	1.551*
Error	22	0.009	0.001	0.002	0.002

* = Significant at 5% level

Appendix III: Analysis of variance of effect of packaging materials and postharvest treatments on percent of moisture content of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.9108	0.0621	0.3014	0.4553
Factor A	3	2.2476*	1.2317*	2.3725*	3.3642*
Factor B	2	43.9409*	46.5821*	39.4769*	42.6126*
AB	6	2.3331*	2.265*	2.4865*	2.4713*
Error	22	0.1885	0.1792	0.1677	0.2588

* = Significant at 5% level

Appendix IV: Analysis of variance of effect of packaging materials and postharvest treatments on percent of dry matter content of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.9324	0.1068	0.2098	0.4553
Factor A	3	2.2455*	1.3321*	2.1933*	3.3642*
Factor B	2	43.9705*	42.4116*	40.9055*	42.6391*
AB	6	2.3415*	2.6513*	2.4332*	2.4673*
Error	22	0.1895	0.1994	0.1701	0.2586

* = Significant at 5% level

Appendix V: Analysis of variance of effect of packaging materials and postharvest treatments on percent of titratable acid content of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.01403	0.02525	0.00776	0.0011
Factor A	3	0.46582*	0.57531*	0.81521*	0.94686*
Factor B	2	0.85903*	1.11442*	1.38173*	1.4283*
AB	6	0.0181*	0.02029*	0.0427*	0.04131*
Error	22	0.00519	0.00086	0.0041	0.00365

* = Significant at 5% level

Appendix VI: Analysis of variance of effect of packaging materials and postharvest treatments on vitamin C content of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	21.48	24.17	12.1	20.36
Factor A	3	177.03*	134.62*	96.8*	78.65*
Factor B	2	1170.25*	1613.13*	2182.11*	2573.41*
AB	6	56.46*	74.66*	96.64*	114.95*
Error	22	0.61	0.52	0.83	1.18

* = Significant at 5% level

Appendix VII: Analysis of variance of effect of packaging materials and postharvest treatments on percent of total soluble solid of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.0595	0.05673	0.04941	0.0631
Factor A	3	1.23237	1.3699	1.14951	1.1344
Factor B	2	3.48111	4.91891	7.3395	17.5708
AB	6	0.1261	0.09977	0.11071	0.1016
Error	22	0.00165	0.00097	0.00163	0.0019

* = Significant at 5% level

Appendix VIII: Analysis of variance of effect of packaging materials and postharvest treatments on percent of total sugar of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.00597	0.02709	0.02704	0.0152
Factor A	3	0.95296	0.53699	1.28862	2.7904
Factor B	2	7.37141	6.48244	7.81884	10.0377
AB	6	0.34343	0.40745	0.84564	0.7886
Error	22	0.00233	0.00152	0.001	0.0027

* = Significant at 5% level

Appendix IX: Analysis of variance of effect of packaging materials and postharvest treatments on percent of reducing sugar of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.01964	0.02002	0.01777	0.03206
Factor A	3	1.65203	1.61952	2.5039	2.9295
Factor B	2	1.18341	2.46144	2.87277	3.41373
AB	6	0.14156	0.17722	0.2914	0.112
Error	22	0.00135	0.00045	0.00029	0.00022

* = Significant at 5% level

Appendix X: Analysis of variance of effect of packaging materials and postharvest treatments on percent of non-reducing sugar of guava at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		3 DAS	6 DAS	9 DAS	12 DAS
Replication	2	0.00437	0.00058	0.001	0.00468
Factor A	3	0.14173	0.35831	0.43157	0.61508
Factor B	2	2.65263	1.03334	1.22597	1.74048
AB	6	0.12125	0.26019	0.45665	0.70686
Error	22	0.00195	0.00113	0.00101	0.00225

* = Significant at 5% level