EFFECT OF POSTHARVEST MANAGEMENT ON SHELF LIFE AND QUALITY OF GUAVA

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EFFECT OF POSTHARVEST MANAGEMENT ON SHELF LIFE AND QUALITY OF GUAVA

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CERTIFICATE

*This is to certify that the thesis entitled "**Effect of Postharvest Management on Shelf Life and Quality of Guava**" submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Horticulture**, embodies the result of a piece of bona-fide research work carried out by **Nahidul Islam**, **Registration No. 13-05351** 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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LIST OF ABBREVIATIONS OF SYMBOLS AND TERMS

2,4,5-T = 2,4,5-Trichlorophenoxyacetic acid

2,4-D = 2,4-Dichlorophenoxyacetic acid

AA = Ascorbic acid

ACC = 1-aminocyclopropane-1-carboxylic acid

BARI = Bangladesh Agricultural Research Institute

BAU = Bangldesh Agricultural University

Ca = Calcium

CEO = Cinnamon essential oil

CRD = Completely randomized design

DAE = Department of Agricultural Extension

DAS = Day after storage

DW = Distilled water

et al. = and others

FAO = Food and Agriculture Organization

GA = Gum Arabic

GA3 = Gibberellic acid

HDL = High density Lipoprotein

i.e = That is

LDL = Low density lipoprotein

LEO= Lemongrass essential oil

LSD = Least Significant Difference

MDA = Malondialdehyde

MH = Methylhydrazine

mL = Mililiter

mM = Milimolar

NS = Non significant

pH = Hydrogen ion concentration

PLW = physiological loss in weight

PPO = Polyphenoloxidase

RH = Relative Humidity

SAU = Sher-e-Bangla Agricultural University

SSC = Soluble solid content

TA = Titratable acidity

TSS = Total Soluble Solid

viz. = Namely

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The Author

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ABSTRACT

The experiment was carried out in the Postharvest Laboratory of Sher-e-Bangla Agricultural University, Dhaka during the period of January 2019 to June 2019 to find out the effect of different postharvest management practices of guava to increase shelf life and quality in ambient condition. Two factor experiment viz. Factor A: P_0 (no packaging) and P_1 (perforated polythene) and Factor B: T_0 (no preservatives), T_1 (Propolis 5%), T_2 (Chitosan 1%), T_3 (Gum Arabic 5%), T_4 (Propolis 5% + Gum arabic 5%), T_5 (Propolis 5% + Chitosan 1%), T_6 (Cinnamon oil 2%), T_7 (Lemongrass oil 2%) and T_8 (Cinnamon oil 2% + Lemongrass oil 2%) were initiated for the experiment. The experiment was laid out in completely randomized design (CRD) with three replications. Various data on physical and chemical properties were collected. In case of the effect of packaging material, P_1 (perforated polythene) showed best performance and showed the highest shelf life (9.78 days) compared to P_0 (no packaging) (7.89 days). Regarding preservatives, T_1 (Propolis 5%) gave the best results on studied parameters and showed highest shelf life (12 days) compared to other treatments and shortest shelf life was recorded from T_0 (5.5 days). In case of combined effect of packaging materials and preservatives, at 12 days after storage (DAS), the lowest percent weight loss (6.46%) and percent dry matter content (14.63%) were found from P_1T_1 whereas the highest weight loss (10.23%) and dry matter content (21.08%) was found in P_0T_0. Similarly, the highest percent moisture content (85.37%), percent titratable acidity (2.23%), vitamin C content (196.60 mg/100g), percent total soluble solid (7.76%), firmness (4.30 kg/cm^2) and percent total sugar content (9.17%) were also found from the treatment combination of P_1T_1 at 12 DAS whereas P_0T_0 showed the lowest results (78.92%, 0.701%, 144.4mg/100g, 5.16%, 2.10 kg/cm^2, 5.361%, respectively) on the respected parameters. Likewise, the highest shelf life (13.00 days) was also recorded from P_1T_1 whereas the lowest (5.00 days) was from P_0T_0. So, the treatment combination of P_1T_1 can be considered the best postharvest treatment for guava.

CHAPTER 1

INTRODUCTION

Guava (*Psidium guajava* L.), the apple of tropics, is a very well-known edible tree fruits grown widely in more than sixty countries throughout the world. It is a perennial tree of tropics and subtropics, having great economic value (Usman *et al.*, 2013). Guava belongs to family Myrtaceae and its cultivation areas are Mexico, Brazil, Central America, South America, Peru and Colombia. Guava is cultivated over an area of 62.3 thousand hectares with annual production of 512.3 thousand tons and yield of 8.2 tons per hectare yield in world (FAO, 2011).

Guava is one of the most delicious and popular fruits grown in Bangladesh. It has a unique position in respect of nutritional quality, taste, consumers' preference etc. among fifty kinds of fruits grown in Bangladesh. Its food value greatly depends on the chemical composition such as dry matter, titratable acidity, total sugar, total soluble solid and ascorbic acid that facilitates the development of postharvest quality such as flavor and taste, transportability and processing (Salunkhe and Desai, 1984). Guava cultivation is increasing day by day in Bangladesh. In 2006-07, 4.74 lakh hectares of land were under guava cultivation yielding 87.86 lakh tonnes, according to DAE. The acreage has since jumped to 7.24 hectares, with an output of 1.21 crore tonnes in 2017-18. In these 11 years, fruit production went up by 33.26 lakh tonnes. (Daily Star, 21 May, 2019).

Guava has great morphological and anatomical peculiarities. It is a climacteric fruit crop and due to its climacteric nature, the fruit has high respiration rate and short shelf life. High respiration rate results in early deterioration during storage. Increase in PLW, TSS and sensory rating while decrease in firmness, acidity and vitamin C have been reported by Deepthi *et al.* (2016) in storage under ambient conditions. Every year 3.4−15.1% of total guava fruits lost due to lack of effective postharvest management (Madan and Ullasa, 1993). Under

ambient conditions, guava fruit become overripe and mealy within a week, whereas, in cold storage the shelf life can be extended up to 2 weeks at 6-8^{0}C and 90-95% Relative Humidity (Mahajan *et al.*, 2009). The quality of guava is directly affected by temperature and humidity. In a country like Bangladesh where sufficient refrigeration facilities are not available, the alternative means for increasing shelf life of fruits for a short period are likely to prove more beneficial. Scientists have modelled different postharvest tools and techniques to prolong the shelf life as well as to improve the quality of guava. Edible coatings are the transparent films that cover the product surface and act as a barrier to humidity and oxygen which are responsible for postharvest deterioration. Coatings can provide an alternative means for extending shelf life of fresh fruits. Several types of edible coating such as chitosan, gum arabic, propolis, lemongrass oil, cinnamon oil has been known to protect perishable goods from deterioration by reducing transpiration, respiration and maintaining quality. Coatings play an important role in the quality, safety, transportation, storage and display of a wide range of fresh and processed foods (Daniel *et al.*, 2007; Elizabeth *et al.*, 1995). Besides, perforated polythene is a good mean to reduce transpiration loss of fruits (Olivas *et al.*, 2005). They act as barriers to moisture and oxygen during handling and storage. For maintaining the quality and shelf life of guava fruits, postharvest application of coatings like chitosan, gum arabic, propolis, lemongrass oil, cinnamon oil may show fruitful results as these are known to increase quality and shelf life of guava fruits. So keeping all these in view, an experiment was conducted to assess the suitability of various postharvest treatments on the shelf life and quality of guava with the following objectives-

1. To study the effect of different postharvest treatments on physico-chemical characteristics of guava at different storage periods

2. To find out effective postharvest treatment to extend the shelf life of guava

CHAPTER 2

REVIEW OF LITERATURE

Guava is very delicious and usually picked fresh from the tree when ripe or mature. Fruits are used for fresh consumption and processed in the form of drink, nectar, jam and jelly. 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. On contrary to other major fruits, guava requires little agriculture inputs but gives good economic return. 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. Its 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 cultivars 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).

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).

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).

2.3 Nutritional Profile of Guava Fruit

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).

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 B1, B2, B3, B5 and vitamin A are also present in appreciable amount.

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 is predominant (about 59%), followed by 35% glucose and 5% sucrose (Yusof, 2003).

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).

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.

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).

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

2.4 Health Benefits of Guava

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.

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%, triacylglycerides by 8%, and with increase in the levels of good cholesterol up to 8%.

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.

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.

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).

Besides antioxidant activity carotenoids are also anticarcinogenic, immunogenic and protect the body against cardiovascular diseases and diabetes (Rich *et al.*, 2003).

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.

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.

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

Rishika and Sharma (2012) showed that guava leaf extract is used for achne vulgrais, a chronic inflammatory disease, caused by propinobacterium 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.

2.5 Postharvest physiology of guava

Ripening and factors associated climacteric fruits is regulated by ethylene synthesis. Ethylene (C_2H_4) 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 associated with it.

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).

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).

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).

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).

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

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.

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

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

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

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

Shelf life of guava fruit under the normal atmospheric condition is very short. Hence, edible coatings can be used to maintain the quality and 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)

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-methylesterase 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.

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

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.

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 colour values in case of the coated samples as compared to the control for 20 days at 10 °C.

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

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.

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

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.

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

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.

2.8 Effect of polythene bag

Mortuza *et al* (2002) noted that the polythene bag wrapping caused maximum reduction in incidence of fungal diease 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.

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.

Momen *et al.* (1993) showed that perforated or non-perforated polythene with or without Dithane M-45 increased shelf life of banana (cv. Sabri and Amritasagar). They reported that non-perforated polythene packaging delayed ripening and increased the storage life of banana significantly.

Ahlawat *et al.* (1978) carried out an experiment and reported that guava cv. Sardar packed in 30×45 cm polythene bags into which CO_2 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.

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.

2.9 Physico-chemical changes of guava during storage

Guava is very nutritious fruits among most other fruits available around the world especially vitamin C. Besides vitamin C, it contains, flavonoids, lycopene and other phenolic compounds that make it unique from others.

2.9.1 Physical changes of guava during storage

2.9.1.1 Fruit size and volume

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.

Ali *et al.* (2011) found that water loss of papaya can be reduced by coating with chitosan and it resulted in minimum shrinkage of the fruits.

2.9.1.2 Weight loss

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.

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

Shaha (1971) concluded that weight loss of mature green fruits was retarded by both MH and GA3 treatments but was accelerated with 2,4-D and 2,4,5-T treatments.

Ahlawat *et al.* (1978) found that guava cv. Sardar harvestd at light green stage and packed in 30×45cm polythene bags into 5g CO_2 was placed. The weight loss was greatly reduced during storage period.

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.

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.

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.

Gasper *et al.* (1997) suggested that mature green guava (cv. Kumagi) stored at 8 ℃ 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 week of storage respectively.

2.9.1.3 Moisture Content

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.

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.

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 ℃.

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.

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

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.

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

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

2.9.1.4 Dry Matter Content

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

Adrees *et. al* (2010) did an experiment on 8 guava varieties viz. Sufaida, Surahi, Surkha, 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 Surkha.

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.

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).

2.9.1.5 Firmness

The ripening of the fruits corresponds to a series of physiological, biochemical and structural factors and variations such as changes in color, firmness, production of volatile compounds, accumulation of sugars, organic acid oxidation and decrease of alkaloids (Rhodes, 1980).

The decrease in firmness during ripening has been due to the modifications and degradation of the components of the cell wall (Carvalho, 2001) as well as to the decrease of the fruit integrity (Chitarra and Chitarra, 2005).

The texture firmness of guava fruit tends to decline progressively during ripening (Bashir and Abu-Goukh, 2003).The firmness of fruit was dropped by eight folds from the hard mature green stage to the final soft ripe stage. The decrease in the flesh firmness occured during the first 10 days.

Unripe fruit is firm in touch, starchy, sour in taste and dry due to its low sugar and high polyphenol contents. On contrary, when the fruit ripens, it becomes soft, sweet, non-acidic and its skin becomes thin and edible (Malo and Campbell, 1994).

Akhtar *et al.* (2010) described that the loquat fruits treated with $CaCl_2$ showed greater firmness and shelf life than untreated fruits.

Manganaris *et al.* (2007) suggested 62.5mM $CaCl_2$ immersion treatment for increasing the tissue firmness of whole peaches.

Another work done by Manganaris *et al.* (2005) stated that calcium treated fruit showed 34.2-44.7% greater firmness when compared to the non-treated fruits.

Firmness loss during climacteric fruit ripening is directly related to degradation of cell wall components (Lohani *et al.*, 2003) and modification of pectin fractions mainly, with an increase in pectin solubilization (Huber, 1983).

2.9.2 Chemical changes of guava during storage

2.9.2.1 Vitamin C (Ascorbic Acid)

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/cm^2, 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.

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

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).

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) reported increased quantity of ascorbic acid from 30mg to 145mg/100g in mature fruit.

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.

2.9.2.2 Titratable Acidity (TA)

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.

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

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.

2.9.2.3 Total Sugars

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 condtions.

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%.

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 %).

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.

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.

2.9.2.4 Total Soluble Solids (TSS)

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

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.

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℃ 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.

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

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

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

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

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 nL/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).

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℃.

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.

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 ℃.

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.

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.

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.

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.

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

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.

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 CO_2 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.

CHAPTER 3

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 2019 to June 2019. Treatment of the fruits along with some physic-chemical analyses was done at the postharvest laboratory. The rest of the chemical analyses was done at Bangladesh Agricultural Research Institute (BARI), Gazipur. The details of the materials used and methodologies adopted during present study are described in this chapter.

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 27 ± 2^{o} C during the experiment. Relative humidity (RH) was 85-90%.

3.3 Experimental Materials

Guava was used as experimental material in the research work. Thai guava used was collected from farmer's field from Rajshahi. Commercially mature fruits of guava were harvested from farmer's field on January 15, 2019. 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: Packaging materials

   a. P_o= Control (No packaging material)
   b. P_1= Perforated polythene bag

2. Factor B: Preservatives

a. T_0= Control (No preservative)
b. T_1= Propolis (5%)
c. T_2= Chitosan (1%)
d. T_3= Gum Arabic (5%)
e. T_4= Propolis (5%) + Gum arabic (5%)
f. T_5= Propolis (5%) + Chitosan (1%)
g. T_6= Cinnamon essential oil (2%)
h. T_7= Lemongrass essential oil (2%)
i. T_8= Cinnamon essential oil (2%) + Lemongrass essential oil (2%)

3.5 Experimental Design

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

3.6 Methods

A total of 120 fresh guava fruits, more or less physically similar i.e. uniform in size, shape and color were harvested manually from farmer's field from Rajshahi. The fruits were carefully selected to ensure homogeneity. The fruits were cured just after harvesting to make sure the temperature of the fruits was stable. Then the skin of the fruits was cleaned with soft cloth and water.

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-

Control (P_0)

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

Perforated polythene (P_1)

Fruits were stored in 5% perforated polythene bag 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 perforated polythene bags. After that, the fruits were stored on the shelf on hard white paper.

Control (T_0)

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

Propolis (5%, T_1)

Propolis or bee glue is a resinous mixture that honey bees produce by mixing saliva and beeswax with exudate gathered from tree buds, sap flows, or other botanical sources. This was collected from the bee research centre of SAU, from Dept. of Entomology. 5% Propolis extract was prepared by using ethanol (100%). Being resinous in nature and sticky, it doesn't dissolve in water. That's why 10g of Propolis was put in a beaker with 100ml ethanol and left for 48 hours for through extraction process. The extract was collected and filtered using a filter paper. Then the solution volume was made 200ml with ethanol to make 5% solution of propolis.

Chitosan (1%, T_2)

Chitosan is highly viscous in nature. That's why making a solution of chitosan in bare hand is very difficult. But it can be prepared by using a hot plate magnetic stirrer. What this device does is continuously agitates and the same time it also heats up the solution to a certain temperature. The temperature can be set from meter of the device. 5g of chitosan was taken and slowly added to the beaker with 500ml water placed on magnetic stirrer which was already

stirring and gradually heating up. After adding full amount of chitosan powder to the beaker, 500ml chitosan solution was prepared. If there was still solubility issue, glacial acetic acid was added to the solution.

Gum Arabic (5%, T_3)

5% gum Arabic solution was prepared by dissolving 25g of GA powder in 500 mL water. The solution was stirred with low heat 40℃ for 30 min using a hot plate magnetic stirrer, and subsequently the fruits were soaked for 5 minutes and later dried before it was moved to storage

Propolis (5%) + Gum arabic (5%) {T_4}

Previously made stock solution of propolis (5%) and GA (5%) was used to make this combination. 100ml of Propolis (5%) and 100ml of GA (5%) was withdrawn separately from their stock solution and taken into a new beaker. The solution was then thoroughly mixed with a glass rod stirrer.

Propolis (5%) + Chitosan (1%) {T_5}

Previously made stock solution of propolis (5%) and Chitosan (1%) was used to make this combination. 100ml of Propolis (5%) and 100ml of chitosan (1%) was withdrawn separately from their stock solution and taken into a new beaker. The solution was then thoroughly mixed with a glass rod stirrer.

Cinnamon essential oil (2%, T_6)

Cinnamon oil is not soluble in water. That's why ethanol was first used to dissolve and then water was added to volume up. 2ml of cinnamon oil and 10ml ethanol was taken in a volumetric flask and stirred. After the oil was dissolved, the volume was made to 100mL with DW.

Lemongrass essential oil (2%, T_7)

2mL of lemongrass oil and 10mL of ethanol was taken in a 100mL volumetric flask and stirred well to dissolve. Then the volume was made up to the mark with DW.

Cinnamon oil (2%) + Lemongrass essential oil (2%) {T_8}

Stock solution of LEO and CEO was used to prepare the combined solution. 50mL 2% CEO and 50mL 2% LEO was taken in a conical flask and mixed well.

3.8 Stage of physico-chemical analyses during storage

The period of storage were 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.

Physical parameters

a. Color
b. Weight loss
c. Moisture content
d. Dry matter
e. Firmness

Chemical parameters

a. Ascorbic acid/Vitamin C (mg/100g)
b. Titratable acidity (%)
c. Total sugar (%)
d. Total soluble solids (%)

Shelf life

a. Storage duration (days)

3.10 Methods of studying physico-chemical properties

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

3.10.1 Physical properties

3.10.1.1 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) -

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

Here,

IW= Initial/Fresh weight

FW= Final weight

3.10.1.2 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)-

Moisture content (%) = $\frac{IW-FW}{IW} \times 100$

Here,

IW= Initial weight of fruit pulp

FW= Final weight of the fruit pulp

3.10.1.3 Firmness

Fruit texture analysis in term of penetration force/firmness was done with texture analyzer according to the method of Mizrach (2008). The texture of the guava fruit was measured by using the texture measuring system fitted with needle probe. The fruits were randomly selected from each treatment and

placed at the base of texture analyzer (Mod. TA-XT2, stable micro system, Surrey, UK). The force required to penetrate the fruit surface up to a depth of 6mm was recorded and expressed in terms of the Kg/cm^2.

3.10.1.4 Dry matter content (%)

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

Dry matter content (%) = 100 − % Moisture content

3.10.2 Chemical parameters

3.10.2.1 Vitamin C

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 (HPO_3) 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. Phenophthalein 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-

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

Here, T= Titre

D= Dye factor

V_2= Volume made up

V_1= Volume taken for titration

W= Weight of the sample taken for estimation

3.10.2.2 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% phenophthalein 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 (%) = $\frac{T \times N \times V1 \times E}{V2 \times W \times 1000} \times 100$

T = Titre

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

3.10.2.3 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 2 g 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 Whatmann 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) = $\frac{Amount\ of\ sugar\ obtained}{Weight\ of\ the\ pulp} \times 100$

3.10.2.4 Total Soluble Solid (TSS)

The total soluble solids of the thoroughly mixed guava fruit pulp was 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).

3.11 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.

3.12 Statistical analysis

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

CHAPTER 4

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 Ripening behavior and color change

Guava being a green fruit when mature doesn't change color that much during storage. Rather it loses water and turns slightly towards brown color followed by softening of the skin. This happens frequently under control condition. But when different postharvest treatments were applied with/without perforated polythene packaging, a noticeable change was observed in case of different treatments.

In case of color change, packaging material, P_o (No packaging material) and P_1 (Perforated polythene package) had no significant impact on the ripening behavior and color change of the fruits. But when combined with preservatives, all of the treatments showed better results than control. The best result was found from treatment P_1T_2 (Chitosan 1% + perforated polythene) followed by P_1T_1 (Propolis 5% + peforated polythene) and the lowest was from P_1T_o (No preservative + perforated polythene). In case of P_1T_o, fruit color changed into brown in 5 days, while P_1T_2 was able to retain its color up to 13 days followed by P_1T_1 (12 days) (Plate 1). At 3 DAS, only P_1T_o started to lose its color slightly towards browning. At 6 DAS, all the treated fruits were in good condition but some turned slightly to pale coloring. At 9DAS, P_1T_5, P_1T_6, P_1T_7 and P_1T_8 started to turn brown and lose their color and at 12 DAS, P_1T_1 and P_1T_2 was able to keep good color that can be accepted to the market and consumers (Plate 1).

P_1T_o at 3 DAS

P_1T_o at 5 DAS

P_1T_1 at 3 DAS

P_1T_1 at 9 DAS

P_1T_1 at 12 DAS

P_1T_2 at 3 DAS

P_1T_2 at 9 DAS

P_1T_2 at 13 DAS

P_1T_3 at 3 DAS

P_1T_3 at 6 DAS

P_1T_3 at 11 DAS

P_1T_4 at 3 DAS

P_1T_4 at 6 DAS

P_1T_4 at 10 DAS

P_1T_5 at 3 DAS

P_1T_5 at 9 DAS

P_1T_5 at 9 DAS

P_1T_6 at 3 DAS

P_1T_6 at 6 DAS

P_1T_6 at 9 DAS

P_1T_7 at 3 DAS

P_1T_7 at 6 DAS

P_1T_7 at 9 DAS

P_1T_8 at 3 DAS

P_1T_8 at 6 DAS

P_1T_8 at 8 DAS

Plate 1. Stages of ripening and color change as affected by the combined effect of perforated polythene and different preservatives

4.2 Changes in physiological characteristics of guava during storage

4.2.1 Percent weight loss

Effect of packaging materials

In respect of percent weight loss, non-significant variation was recorded between two packaging treatments (Fig. 1 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 6.70% which increased to 8.87% 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 were 6.58 and 8.52%, respectively which was lowest compared to control treatment P_0 (Fig. 1). At 6 and 9 DAS, the highest percent weight loss (7.58 and 8.36%, respectively) was found in P_0 whereas the lowest percent weight loss (7.27 and 8.06%, respectively) was recorded in P_1.

Effect of preservatives

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. 2 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_1 (Propolis 5%). At 3 DAS, the highest percent weight loss (8.31%) was found in control treatment T_0 (no preservatives) and the lowest percent weight loss (5.18%) was recorded in the fruits in T_1 (Propolis 5%) treatment (Fig. 2).

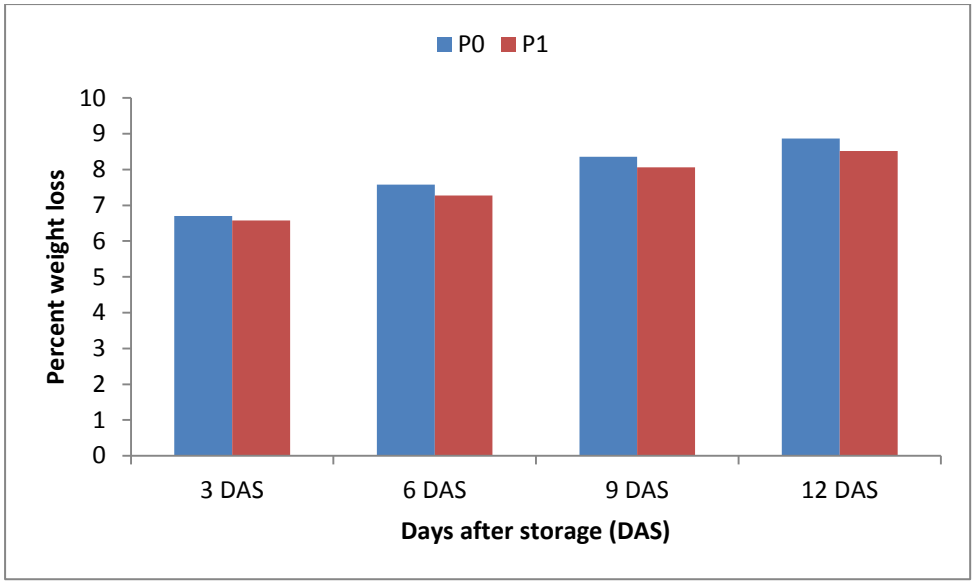

Fig. 1: Percent weight loss of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

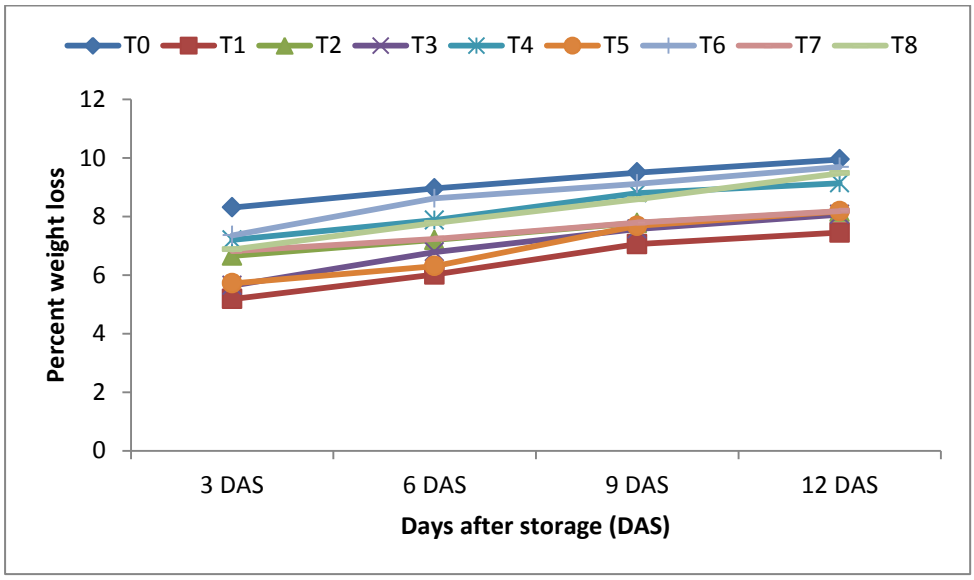

Fig. 2: Percent weight loss of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

At 6, 9 and 12 DAS, the maximum weight loss (8.96, 9.50 and 9.95%, respectively) was recorded in control treatment T_0 (no preservatives) and the minimum weight loss (6.02, 7.06 and 7.45%, respectively) was shown in T_1 (Propolis 5%) (Fig. 2).

Combined effect of packaging materials and preservatives

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 (8.43%) was in P_0T_0 which was statistically identical with P_1T_0 whereas the lowest percent weight loss (4.64%) was recorded in P_1T_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 (9.06, 9.87 and 10.23%, respectively) was recorded in P_0T_0 whereas the minimum percent weight loss (5.20, 6.06 and 6.46%, respectively) was found in P_1T_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).

Table 1. Percent weight loss of guava as influenced by packaging material and preservatives

Treatments	Percent weight loss			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	8.43 a	9.06 a	9.87 a	10.23 a
P_0T_1	5.63 e	7.46 c	8.407 c	8.98 c
P_0T_2	6.58 d	7.25 cd	7.70 de	8.02 e
P_0T_3	5.71 e	6.83 de	8.05 cd	8.43 de
P_0T_4	6.74 cd	7.13 cd	7.72 de	8.16 e
P_0T_5	4.73 f	6.49 ef	7.54 e	7.98 e
P_0T_6	7.87 b	8.62 ab	9.06 b	9.72 b
P_0T_7	6.79 cd	7.32 c	7.94 de	8.44 de
P_0T_8	6.96 c	8.25 b	9.50 ab	9.91 ab
P_1T_0	8.18 a	8.87 a	9.50 ab	9.98 ab
P_1T_1	4.64 f	5.20 g	6.06 g	6.46 g
P_1T_2	6.74 cd	7.14 cd	7.87 de	8.30 de
P_1T_3	5.64 e	6.12 f	6.74 f	7.16 f
P_1T_4	7.65 b	8.63 ab	9.30 b	10.12 ab
P_1T_5	6.71 cd	6.14 f	7.81 de	8.39 de
P_1T_6	6.84 cd	8.62 ab	9.17 b	9.66 b
P_1T_7	6.85 cd	7.15 cd	7.65 de	7.93 e
P_1T_8	6.80 cd	7.31 c	7.87 de	8.72 cd
$LSD_{0.01}$	0.252	0.412	0.406	0.460
CV (%)	2.28	2.78	2.71	3.52

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

4.2.2 Percent moisture content

Effect of packaging materials

In respect of percent moisture content, non-significant variation was recorded between two packaging treatments (Fig. 3 and Appendix III). However, decreasing trend in percent moisture content was found from 3 DAS to 12 DAS. At 3 DAS, the lowest percent moisture content was 84.38% which decreased to 80.89% at 12 DAS in control treatment P_0 (no packaging) while in P_1 (perforated polythene) treatment, at 3 DAS and 12 DAS, the percent moisture content were 85.59 and 82.08%, respectively which was the highest compared to control treatment P_0 (no packaging) (Fig. 3). At 6 and 9 DAS, the

lowest percent moisture content (83.05 and 82.07%, respectively) was found in control treatment P_0 (no packaging) whereas the highest percent moisture content (84.24 and 82.96%, respectively) was found in P_1 (perforated polythene) treatment.

Effect of preservatives

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. 4 and Appendix III). Higher rate of decreasing trend in percent moisture content was recoreded only on control treatment while slow decreased rate on percent moisture content was recorded for other treatments especially in case of T_1 (Propolis 5%). At 3 DAS, the lowest percent moisture content (83.54%) was found in control treatment T_0 (no preservatives) which was statistically identical with T_7 (Lemongrass oil 2%) and the highest percent moisture content (88.11%) was in the fruits under T_1 (Propolis 5%) treatment (Fig. 4). At 6, 9 and 12 DAS, the minimum percent moisture content (81.81, 80.74 and 79.75%, respectively) was recorded in T_0 and the maximum percent moisture content (86.98, 85.63 and 84.66%, respectively) was recorded in T_1 (Propolis 5%) (Fig. 4).

Combined effect of packaging materials and preservatives

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 (82.68%) was in P_0T_0 which was statistically identical with P_1T_5 and P_1T_7 whereas the highest percent moisture content (89.22%) was recorded in P_1T_1 followed by P_0T_1. Decreasing trend of percent moisture content was recorded for the increase of storage duration for all the treatment combinations.

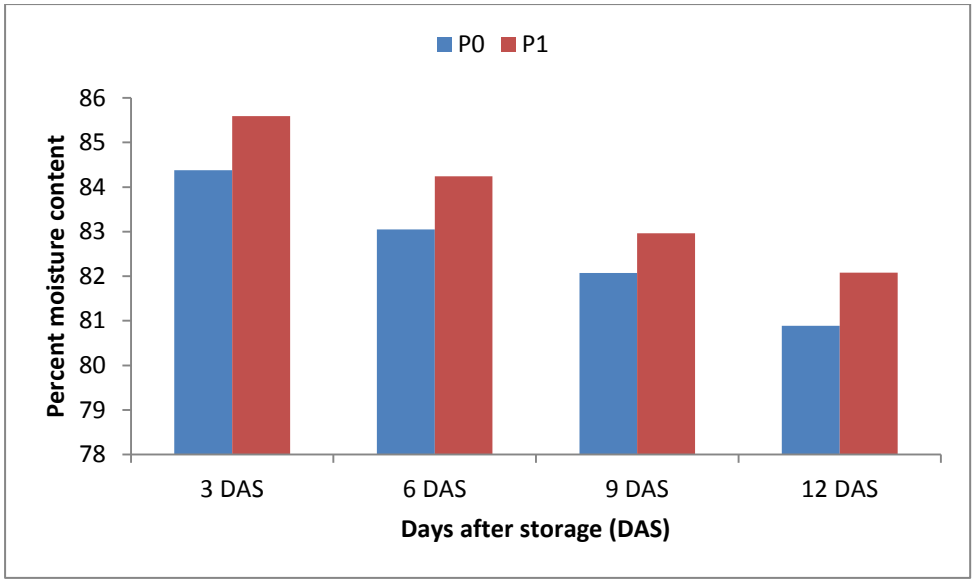

Fig. 3: Percent moisture content of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

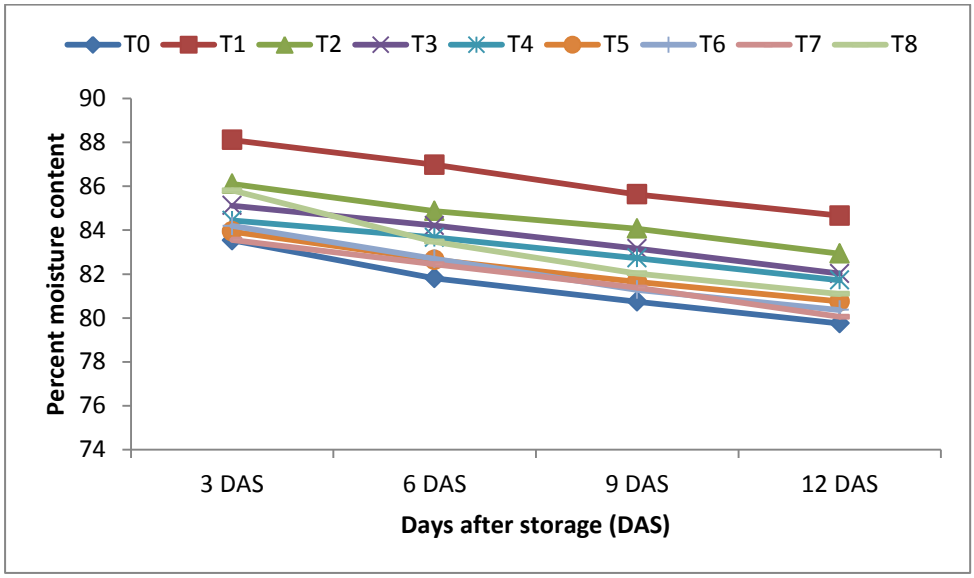

Fig. 4: Percent moisture content of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

At 6, 9 and 12 DAS, the minimum percent moisture content (81.10, 80.07 and 78.92%, respectively) was recorded in P_0T_0 whereas the maximum percent moisture content (87.98, 86.36 and 85.37%, respectively) was found in P_1T_1 (Table 2).

Table 2. Percent moisture content of guava as influenced by packaging material and preservatives

Treatments	Percent moisture content			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	82.68 h	81.10 j	80.07 l	78.92 h
P_0T_1	87.00 b	85.98 b	84.92 b	83.96 b
P_0T_2	86.32 c	85.32 c	84.44 c	83.49 b
P_0T_3	85.39 d	84.58 d	83.48 de	82.54 c
P_0T_4	84.83 e	84.08 e	83.12 ef	82.25 c
P_0T_5	84.72 ef	83.39 f	82.30 g	81.53 d
P_0T_6	84.13 g	83.05 fg	81.43 ij	80.72 ef
P_0T_7	84.39 efg	83.28 fg	81.92 gh	80.72 ef
P_0T_8	84.44 efg	82.52 h	81.40 ij	80.58 f
P_1T_0	84.78 e	82.99 g	81.81 hi	80.70 ef
P_1T_1	89.22 a	87.98 a	86.35 a	85.37 a
P_1T_2	85.89 c	84.41 d	83.70 d	82.37 c
P_1T_3	84.86 e	83.83 e	82.84 f	81.50 d
P_1T_4	84.06 g	83.26 fg	82.35 g	81.18 de
P_1T_5	83.16 h	81.92 i	80.99 jk	79.97 g
P_1T_6	84.25 fg	82.34 h	81.12 jk	80.00 g
P_1T_7	82.72 h	81.61 i	80.85 k	79.38 h
P_1T_8	86.83 b	83.94 e	82.25 g	81.47 d
$LSD_{0.01}$	0.4693	0.3277	0.4064	0.4922
CV (%)	3.98	2.89	2.99	1.94

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (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.

4.2.3 Percent dry matter content

Effect of packaging materials

In terms of percent dry matter content, significant variation was recorded between two packaging treatments (Fig. 5 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 15.66% which increased to 19.11% at 12 DAS in control treatment P_0 (no packaging) while in P_1 (perforated polythene) treatment, at 3 DAS and 12 DAS, the percent dry matter content were 14.38 and 17.88%, respectively which was the lowest compared to control treatment P_0 (no packaging) (Fig. 5). At 6 and 9 DAS, the highest percent dry matter content (16.95 and 17.93%, respectively) was recorded in P_0 whereas the lowest percent dry matter content was recorded (15.76 and 17.04%, respectively) in P_1.

Effect of preservatives

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. 6 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_1 (Propolis 5%). At 3 DAS, the highest percent dry matter content (16.60%) was found in control treatment T_0 (no preservatives) which was statistically identical with T_7 (Lemongrass oil 2%) and the lowest percent dry matter content (11.89%) was in the fruits in T_1 (Fig. 6).

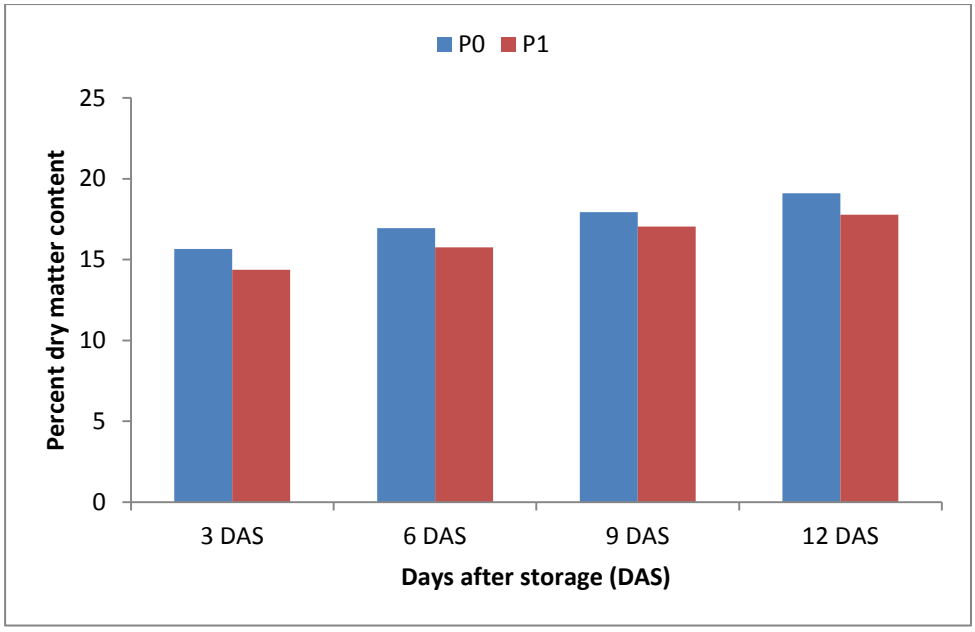

Fig. 5: Percent dry matter content of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

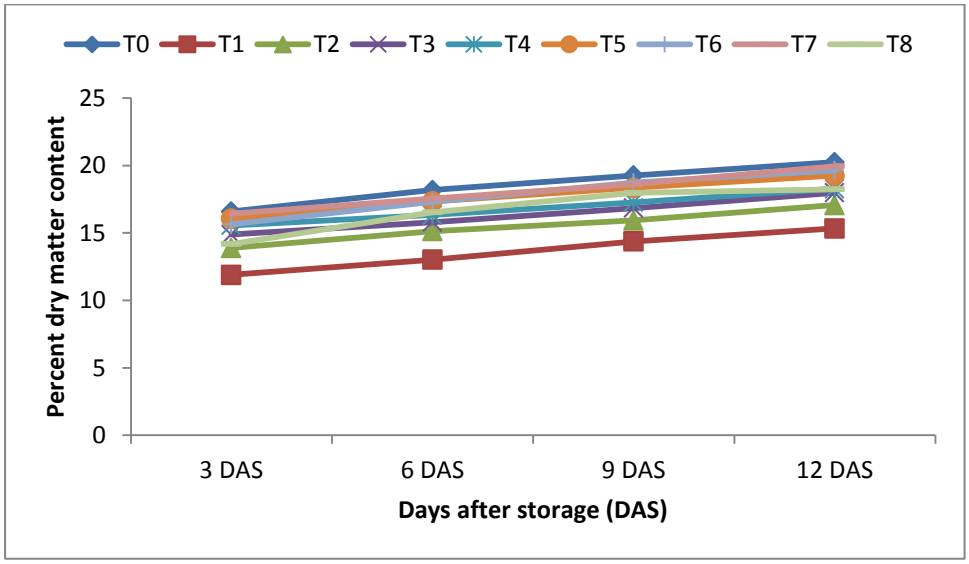

Fig. 6: Percent dry matter content of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

At 6, 9 and 12 DAS, the maximum percent dry matter content (18.19, 19.27 and 20.25%, respectively) was recorded in T_0 (no preservatives) and the minimum percent dry matter content (13.02, 14.37 and 15.34%, respectively) was shown in T_1 (Propolis 5%) (Fig. 6).

Table 3. Percent dry matter content of guava as influenced by packaging material and preservatives

Treatments	Percent dry matter content			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	17.65 a	18.90 a	19.94 a	21.08 a
P_0T_1	13.17 h	16.06 e	17.75 e	17.20 g
P_0T_2	13.68 g	14.68 h	15.56 h	16.51 h
P_0T_3	14.61 e	15.42 g	16.52 g	17.46 fg
P_0T_4	15.17 d	15.92 ef	16.88 f	17.75 f
P_0T_5	15.28 d	16.61 d	17.70 e	18.47 e
P_0T_6	15.53 cd	16.95 d	18.57 c	19.28 cd
P_0T_7	15.61 cd	16.72 d	18.10 d	19.28 cd
P_0T_8	15.56 cd	17.48 c	18.60 c	19.42 c
P_1T_0	13.00 h	14.02 i	15.08 i	16.04 h
P_1T_1	10.78 i	12.02 j	13.65 j	14.63 i
P_1T_2	14.11 f	15.59 fg	16.30 g	17.63 fg
P_1T_3	15.14 d	16.17 e	17.16 f	18.50 e
P_1T_4	15.94 c	16.74 d	17.65 e	18.82 de
P_1T_5	16.84 b	18.08 b	19.01 b	20.03 b
P_1T_6	15.75 c	17.66 c	18.88 bc	20.00 b
P_1T_7	17.28 a	18.39 b	19.15 b	20.62 a
P_1T_8	15.22 d	17.01 d	18.19 d	19.30 cd
$LSD_{0.01}$	0.4165	0.3673	0.3014	0.4723
CV (%)	5.97	4.53	4.68	5.64

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Combined effect of packaging materials and preservatives

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 (17.65%) was in P_0T_0 which was statistically identical with P_1T_7 whereas the lowest percent dry matter content (10.78%) was recorded in P_1T_1. 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 (18.90, 19.94 and 21.08%, respectively) was recorded in P_0T_0 whereas the minimum percent dry matter content (12.02, 13.65 and 14.63%, respectively) was found in P_1T_1 (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.

4.2.4 Firmness (kg/cm^2)

Effect of packaging materials

In respect of firmness, non-significant variation was recorded between two packaging treatments (Fig. 7 and Appendix V). However, decreasing trend in firmness was found from 3 DAS to 12 DAS. At 3 DAS, the highest firmness was 4.27 kg/cm^2 which decreased to 3.73 kg/cm^2 at 12 DAS (DAS) in P_1 (perforated polythene) while in control treatment P_0 (no packaging), at 3 DAS and 12 DAS, the firmness were 4.18 and 3.66 kg/cm^2, respectively which was lowest compared to P_1 (perforated polythene) (Fig. 7). At 6 and 9 DAS, the highest firmness (4.15 and 3.97 kg/cm^2, respectively) was recorded in P_1 whereas the lowest firmness (4.14 and 3.84 kg/cm^2, respectively) was measured in P_0.

Effect of preservatives

The results on firmness showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration (Fig. 8 and Appendix V). Higher rate of decreasing trend in firmness was recorded only on control treatment while slow decreased rate on firmness was recorded for other treatments especially in case of T_1 (Propolis 5%). At 3 DAS, the highest firmness (4.55 kg/cm^2) was found in T_1 (Propolis 5%) treatment followed by 4.45 kg/cm^2 in T_2 (Chitosan 1%) and the lowest firmness (3.8 kg/cm^2) in the fruits under control treatment T_0 (no preservative) (Fig. 8). At 6, 9 and 12 DAS, the maximum firmness (4.50, 4.36 and 4.20 kg/cm^2, respectively) was recorded in T_1 (Propolis 5%) treatment and the minimum firmness (3.75, 3.40 and 3.30 kg/cm^2, respectively) was found in control treatment T_0 (Fig. 8).

Combined effect of packaging materials and preservatives

The interaction effect of packaging and preservative treatments on firmness was significant at 3, 6, 9 and 12 DAS (Table 4 and Appendix VIII). At 3 DAS, the highest firmness (4.60 kg/cm^2) was in P_1T_1 followed by P_0T_1 whereas the lowest firmness (3.70 kg/cm^2) was recorded in P_0T_0 which was significantly different from other treatment combinations. Decreasing trend of firmness was recorded for increasing of storage duration for all the treatment combinations. At 6, 9 and 12 DAS, the maximum firmness (4.55, 4.47 and 4.30 kg/cm^2, respectively) was also recorded in P_1T_1 whereas the minimum firmness (3.03, 2.85 and 2.10 kg/cm^2, respectively) was found in P_0T_0 (Table 4).

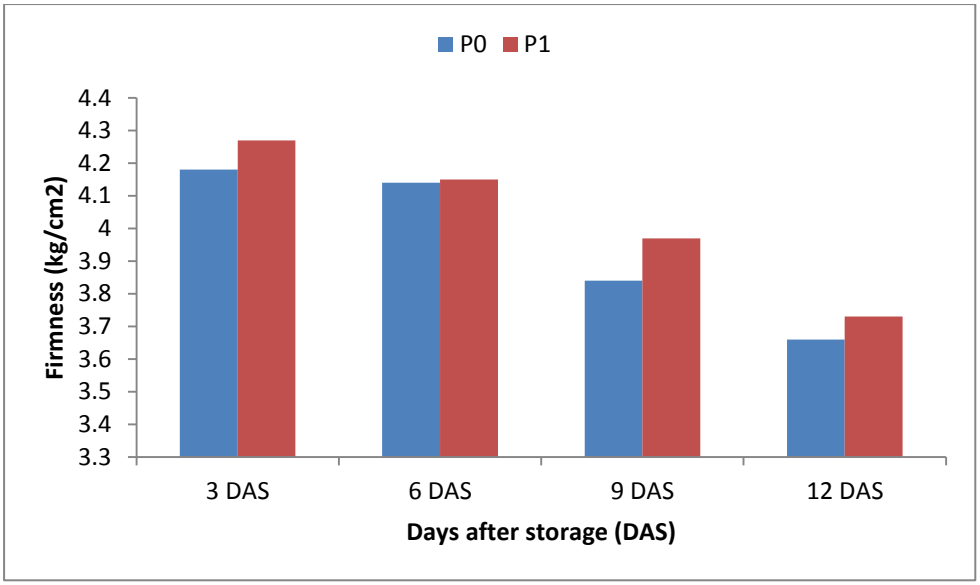

Fig. 7: Firmness of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

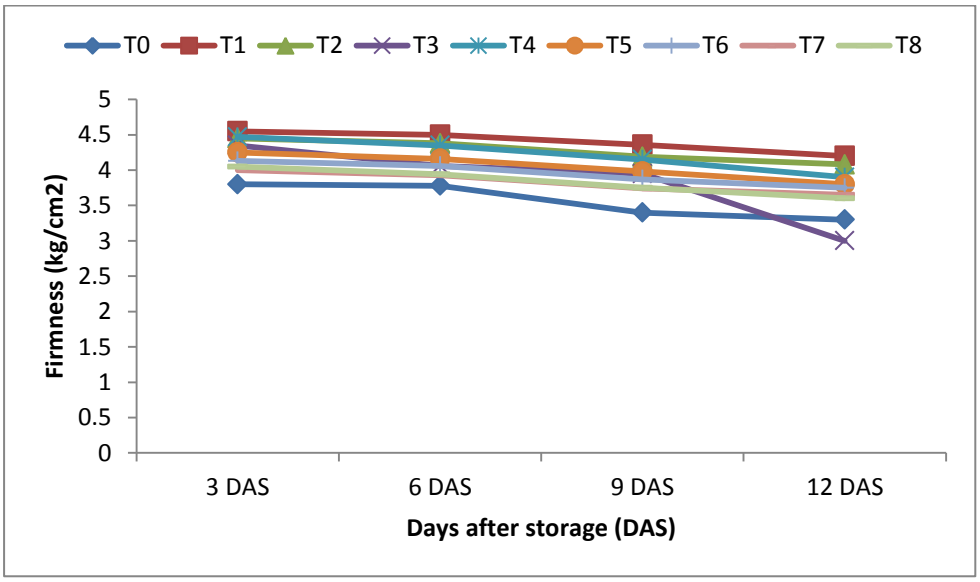

Fig. 8: Firmness of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Table 4. Firmness of guava as influenced by packaging material and preservatives

Treatments	Firmness (kg/cm^2)			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	3.70 i	3.03 i	2.85 h	2.10 j
P_0T_1	4.50 b	4.45 b	4.25 b	4.10 b
P_0T_2	4.40 c	4.30 c	4.10 c	4.00 c
P_0T_3	4.30 d	4.22 d	4.08 c	3.90 d
P_0T_4	4.45 bc	4.23 d	4.11 c	3.80 e
P_0T_5	4.20 e	4.11 e	3.90 e	3.70 f
P_0T_6	4.10 f	4.01 f	3.88 e	3.70 f
P_0T_7	4.00 g	3.86 gh	3.70 f	3.60 g
P_0T_8	4.00 g	3.93 g	3.70 f	3.60 g
P_1T_0	3.90 h	3.80 h	3.55 g	3.40 h
P_1T_1	4.60 a	4.55 a	4.47 a	4.30 a
P_1T_2	4.50 b	4.44 b	4.24 b	4.15 b
P_1T_3	4.40 c	3.88 gh	3.75 c	3.20 i
P_1T_4	4.50 b	4.40 b	4.20 b	4.00 c
P_1T_5	4.30 d	4.21 d	4.07 c	3.90 d
P_1T_6	4.15 ef	4.10 e	3.91 e	3.80 e
P_1T_7	4.00 g	3.95 f	3.80 ef	3.70 f
P_1T_8	4.10 f	3.95 f	3.75 f	3.60 g
$LSD_{0.01}$	0.074	0.014	0.012	0.074
CV (%)	3.12	4.27	4.88	6.44

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

The decrease in firmness during ripening and at storage condition has been due to the modifications and degradation of the components of the cell wall as well as to the decrease of the fruit integrity (Chitarra and Chitarra, 2005).

4.3 Changes in chemical characteristics of guava during storage

4.3.1 Percent titratable acidity

Effect of packaging materials

In respect of percent titratable acidity, non-significant variation was recorded between two packaging treatments (Fig. 9 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 1.73% which decreased to 1.46% 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 were 1.72 and 1.42%, respectively which was lowest compared to P_1 (Fig. 9). At 6 and 9 DAS, the highest percent titratable acidity (1.62 and 1.53%, respectively) was found in P_1 (perforated polythene) whereas the lowest percent titratable acidity (1.59 and 1.51%, respectively) was found in P_0.

Effect of preservatives

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. 10 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_1 (Propolis 5%). At 3 DAS, the highest percent titratable acidity (2.38%) was found in T_1 (Propolis 5%) treatment followed by T_2 (Chitosan 1%) and the lowest percent titratable acidity (1.44%) in the fruits under control treatment T_0 (no preservative) (Fig. 10). At 6, 9 and 12 DAS, the maximum percent titratable acidity (2.27, 2.19 and 2.14%, respectively) was recorded in T_1 treatment and the minimum percent titratable acidity (1.24, 1.01 and 0.79%, respectively) was found in T_0 (Fig. 10).

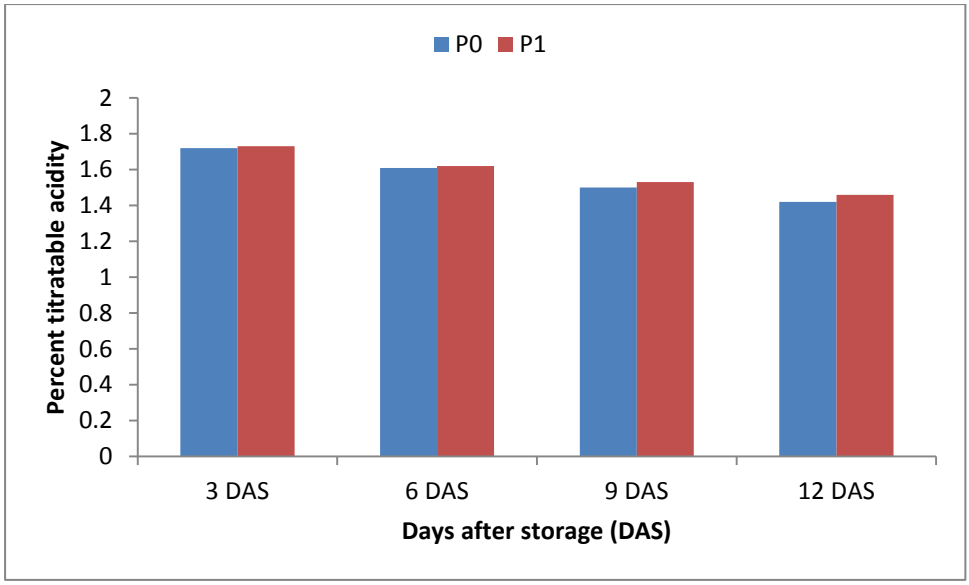

Fig. 9: Percent titratable acidity of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

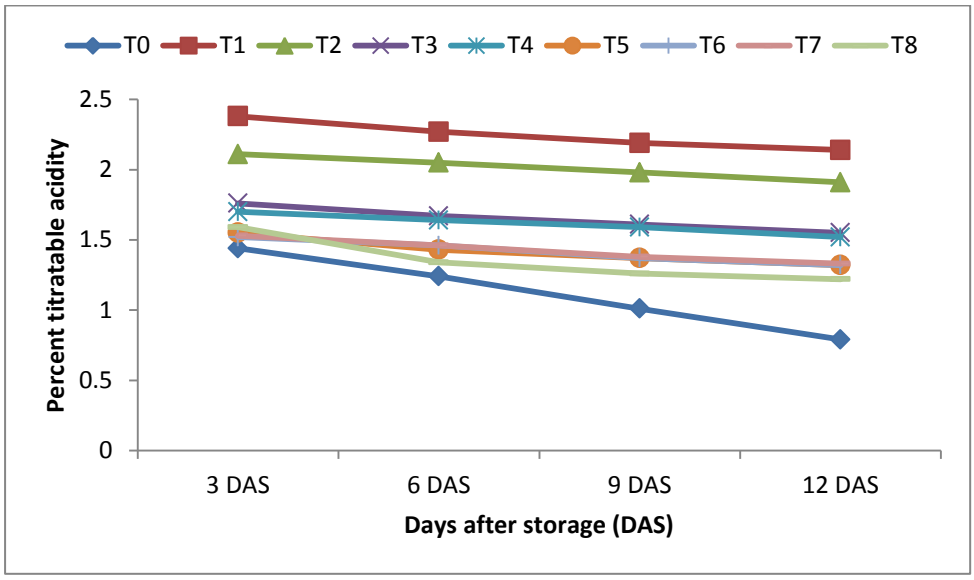

Fig. 10: Percent titratable acidity of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Combined effect of packaging materials and preservatives

The interaction effect of packaging and preservative treatments on percent titratable acidity was significant at 3, 6, 9 and 12 DAS (Table 5 and Appendix VI). At 3 DAS, the highest percent (2.43%) was in P_1T_1 which was statistically identical with P_0T_1 whereas the lowest percent titratable acidity (1.41%) was recorded in P_0T_0 which was statistically identical with P_1T_7.

Table 5. Percent titratable acidity of guava as influenced by packaging material and preservatives

Treatments	Percent titratable acidity			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	1.41 g	1.23 j	0.97 k	0.70 l
P_0T_1	2.32 a	2.17 b	2.11 b	2.05 b
P_0T_2	2.14 b	2.07 c	2.01 c	1.95 bc
P_0T_3	1.65 de	1.56 fg	1.51 f	1.47 ef
P_0T_4	1.70 d	1.67 e	1.62 de	1.55 de
P_0T_5	1.56 ef	1.41 i	1.37 hi	1.31 hi
P_0T_6	1.56 ef	1.47 ghi	1.33 hi	1.25 ij
P_0T_7	1.65 de	1.53 fgh	1.48 fg	1.43 fg
P_0T_8	1.47 fg	1.41 i	1.31 hi	1.27 hij
P_1T_0	1.63 de	1.23 j	1.04 k	0.87 k
P_1T_1	2.43 a	2.36 a	2.27 a	2.23 a
P_1T_2	2.07 b	2.03 c	1.95 c	1.87 c
P_1T_3	1.86 c	1.78 d	1.71 d	1.63 d
P_1T_4	1.70 d	1.61 ef	1.56 ef	1.48 ef
P_1T_5	1.55 ef	1.45 hi	1.36 hi	1.33 ghi
P_1T_6	1.48 fg	1.44 hi	1.41 gh	1.38 fgh
P_1T_7	1.41 g	1.38 i	1.27 ij	1.23 ij
P_1T_8	1.55 ef	1.27 j	1.21 j	1.16 j
$LSD_{0.01}$	0.117	0.091	0.092	0.105
CV (%)	7.15	5.39	2.46	1.64

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (No packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

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 (2.36, 2.27 and 2.23%, respectively) was recorded in P_1T_1 whereas the minimum percent titratable acidity (1.23, 0.97 and 0.70%, respectively) was found in P_0T_0 (Table 5).

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).

4.3.2 Vitamin C content

Effect of packaging materials

In respect of vitamin C content, significant variation was recorded between two packaging treatments (Fig. 11 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 187.14 mg/100 g which decreased to 166.92 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 183.96 and 163.17 mg/100 g, respectively which was lower compared to P_1 (Fig. 11). At 6 and 9 DAS, the highest vitamin C content (180.74 and 173.58 mg/100 g, respectively) was found in P_1 whereas the lowest vitamin C content (177.63 and 1171.33 mg/100 g, respectively) was recorded in P_0 (no packaging).

Effect of preservatives

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. 12 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

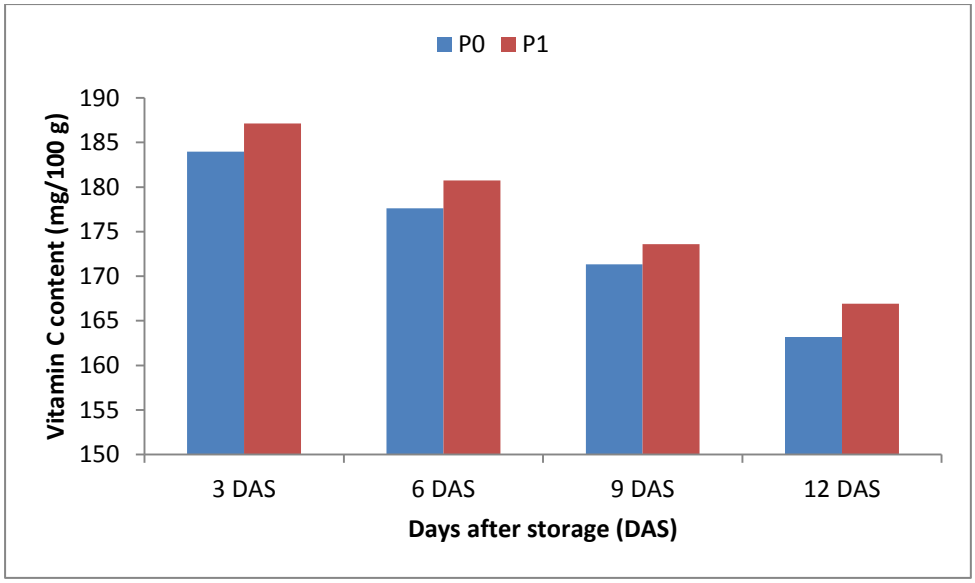

Fig. 11: Percent vitamin C content of guava as influenced by packaging material

P_0 = Control (No packaging), P_1 = Perforated polythene

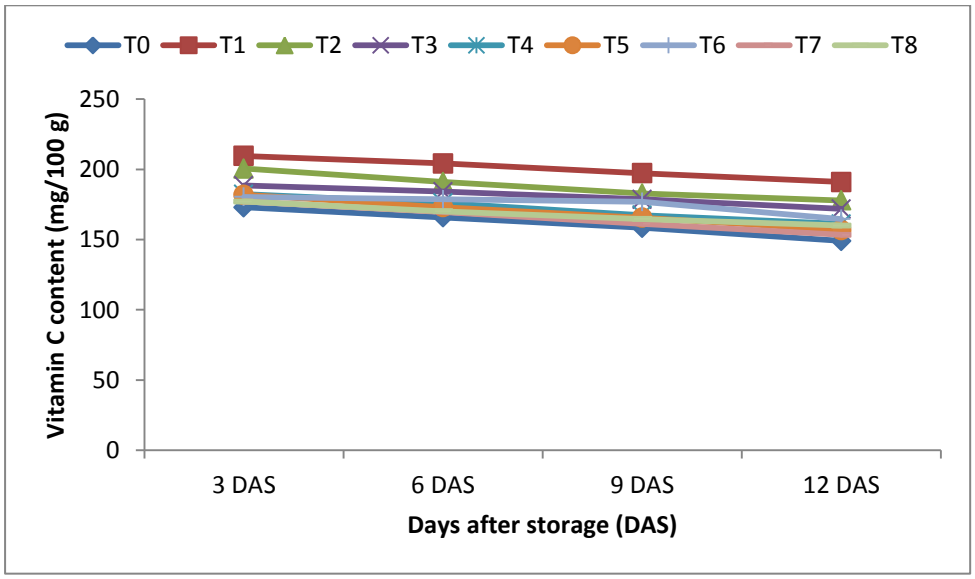

Fig. 12: Percent vitamin C content of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

in case of T_1 (Propolis 5%). At 3 DAS, the highest vitamin C content (209.50 mg/100 g) was found in T_1 (Propolis 5%) treatment followed by T_2 (Chitosan 1%) and the lowest vitamin C content (173.00 mg/100 g) in the fruits under control treatment T_0 (no preservative) (Fig. 12). At 6, 9 and 12 DAS, the maximum vitamin C content (204.20, 197.20 and 190.90 mg/100g respectively) was recorded in T_1 while the minimum vitamin C content (165.80, 158.30 and 149.00 mg/100 g, respectively) was found in T_0 (Fig. 12).

Table 6. Percent vitamin C content of guava as influenced by packaging material and preservatives

Treatments	Vitamin C content (mg/100 g)			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	170.3 l	165.4 j	154.8 j	144.4 k
P_0T_1	207.6 b	201.0 b	192.9 b	185.3 b
P_0T_2	197.7 d	185.2 de	178.2 e	175.7 d
P_0T_3	186.5 f	182.5 f	177.8 e	167.7 e
P_0T_4	181.1 h	175.3 gh	163.9 h	158.6 g
P_0T_5	178.9 ij	171.1 i	163.7 h	155.3 hi
P_0T_6	183.5 g	183.5 ef	183.5 d	163.5 f
P_0T_7	174.3 k	167.4 j	158.6 i	151.5 j
P_0T_8	175.6 k	166.3 j	161.8 h	157.4 gh
P_1T_0	175.6 k	166.3 j	161.7 h	153.6 i
P_1T_1	211.3 a	207.5 a	201.5 a	196.6 a
P_1T_2	203.4 c	196.7 c	187.1 c	180.1 c
P_1T_3	190.2 e	185.7 d	179.4 e	175.8 d
P_1T_4	183.5 g	176.7 g	170.9 f	163.6 f
P_1T_5	184.7 g	175.1 gh	167.3 g	158.4 g
P_1T_6	177.4 j	173.9 h	170.1 fg	165.7 e
P_1T_7	179.6 hi	171.8 i	163.8 h	155.1 i
P_1T_8	178.6 ij	173.9 h	167.3 g	162.5 f
$LSD_{0.01}$	1.727	1.905	2.864	2.054
CV (%)	8.09	10.29	7.00	9.30

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Combined effect of packaging materials and preservatives

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 (211.30 mg/100 g) was in P_1T_1 followed by P_0T_1 whereas the lowest vitamin C content (170.30 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. At 6, 9 and 12 DAS, the maximum vitamin C content (207.50, 201.50 and 196.60mg/100g, respectively) was recorded in P_1T_1 whereas the minimum vitamin C content (165.40, 154.80 and 144.40mg/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.

4.3.3 Percent total soluble solid

Effect of packaging materials

Regarding percent total soluble solid, non-significant variation was recorded between two packaging treatments (Fig. 13 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 4.46% which increased to 6.07% 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 4.35 and 5.82%, respectively which was lower compared to P_1 (Fig. 13). At 6 and 9 DAS, the highest percent total soluble solid (4.95 and 5.47%, respectively) was found in P_1 whereas the

lowest percent total soluble solid (4.73 and 5.25%, respectively) was found in P_0.

Effect of preservatives

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. 14 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_1 (Propolis 5%). At 3 DAS, the highest percent total soluble solid (5.01%) was found in T_1 (Propolis 5%) treatment followed by T_2 (Chitosan 1%) and T_4 (Propolis 5% + Gum arabic 5%) whereas the lowest percent total soluble solid total soluble solid (3.59%) was in the fruits under control treatment P_0 (no packaging) (Fig. 14). At 6, 9 and 12 DAS, the maximum percent total soluble solid (5.45, 6.79 and 7.32%, respectively) was also recorded in T_1 and the minimum percent total soluble solid (4.35, 4.83 and 5.40%, respectively) was found in T_0 (Fig. 14).

Combined effect of packaging materials and preservatives

The interaction effect of packaging and preservative treatments on percent total soluble solid was significant at 3, 6, 9 and 12 DAS (Table 7 and Appendix VIII). At 3 DAS, the highest percent total soluble solid (5.07%) was in P_1T_1 which was significantly different from other treatment combinations whereas the lowest percent total soluble solid (3.57%) was recorded in P_0T_0 which was statistically identical with P_1T_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 (5.53, 6.85 and 7.76%, respectively) was recorded in P_1T_1 whereas the minimum percent total soluble solid (4.28, 4.57 and 5.16%, respectively) was found in P_0T_0 (Table 7).

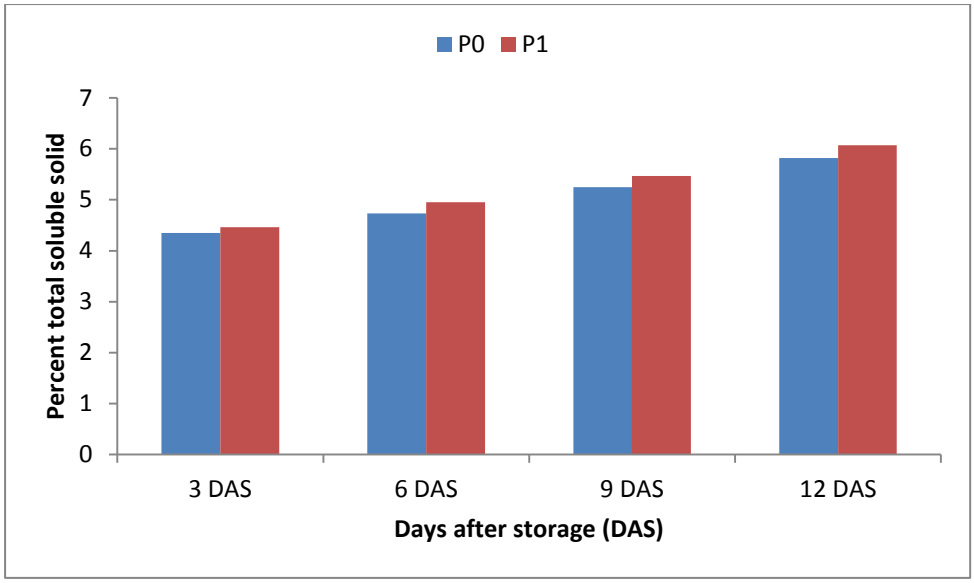

Fig. 13: Percent total soluble solid of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

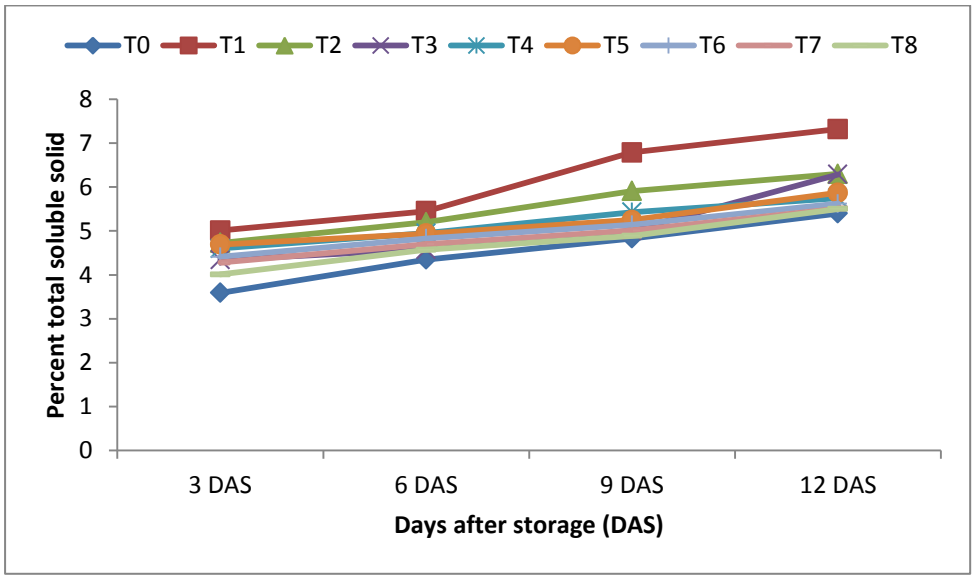

Fig. 14: Percent total soluble solid of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Table 7. Percent total soluble solid of guava as influenced by packaging material and preservatives

Treatments	Percent total soluble solid			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	3.57 k	4.28 j	4.57 j	5.16 j
P_0T_1	4.95 b	5.37 b	6.72 a	7.37 b
P_0T_2	4.66 d	5.13 c	5.85 b	6.88 d
P_0T_3	4.27 h	4.51 i	4.93 gh	5.40 i
P_0T_4	4.52 ef	4.87 ef	5.35 d	5.92 e
P_0T_5	4.63 de	4.78 fg	5.17 ef	5.67 fg
P_0T_6	4.34 gh	4.68 g	5.05 fg	5.31 ij
P_0T_7	4.23 h	4.54 hi	4.87 h	5.27 ij
P_0T_8	3.95 j	4.37 j	4.73 i	5.43 hi
P_1T_0	3.61 k	4.41 ij	5.21 de	5.23 j
P_1T_1	5.07 a	5.53 a	6.85 a	7.76 a
P_1T_2	4.80 c	5.27 b	5.97 b	5.63 fg
P_1T_3	4.41 fg	4.65 gh	5.08 ef	7.18 c
P_1T_4	4.67 d	5.03 cd	5.51 c	5.57 gh
P_1T_5	4.75 cd	5.10 cd	5.33 d	6.06 e
P_1T_6	4.47 f	4.97 de	5.23 de	5.93 e
P_1T_7	4.33 gh	4.85 ef	5.15 ef	5.74 f
P_1T_8	4.07 i	4.77 fg	4.92 gh	5.57 gh
$LSD_{0.01}$	0.117	0.129	0.139	0.148
CV (%)	4.28	4.17	3.85	5.06

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

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 TSS 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.

4.3.4 Percent total sugar content

Effect of packaging materials

In respect of percent total sugar content, non-significant variation was recorded between two packaging treatments (Fig. 15 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 3.54% which increased to 6.60% 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 were 3.39 and 6.37%, respectively which was lower compared to P_1 (perforated polythene) (Fig. 15). At 6 and 9 DAS, the highest percent total sugar content (4.61 and 5.69%, respectively) was recorded in P_1 whereas the lowest percent total sugar content (4.49 and 5.47%, respectively) was found in P_0.

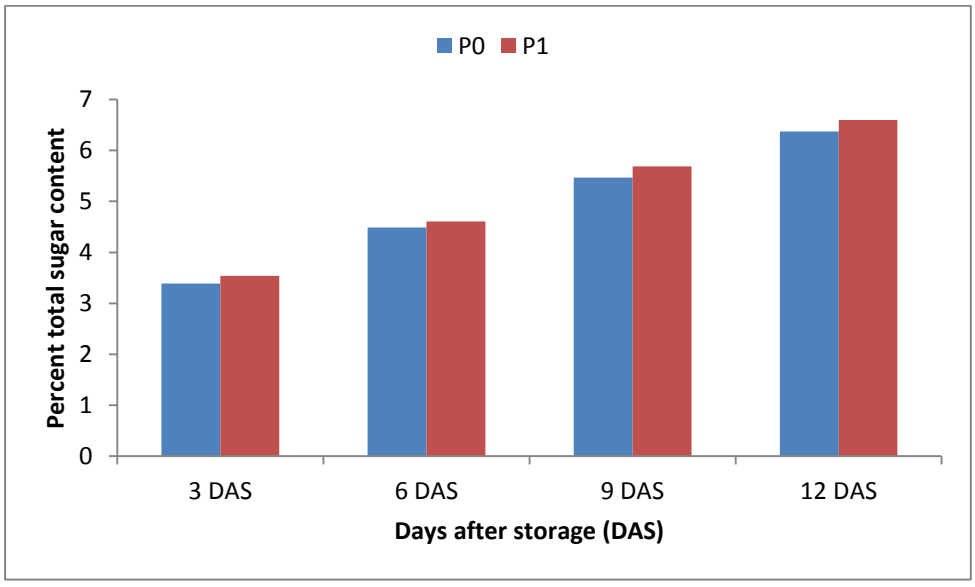

Fig. 15: Percent total sugar content of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

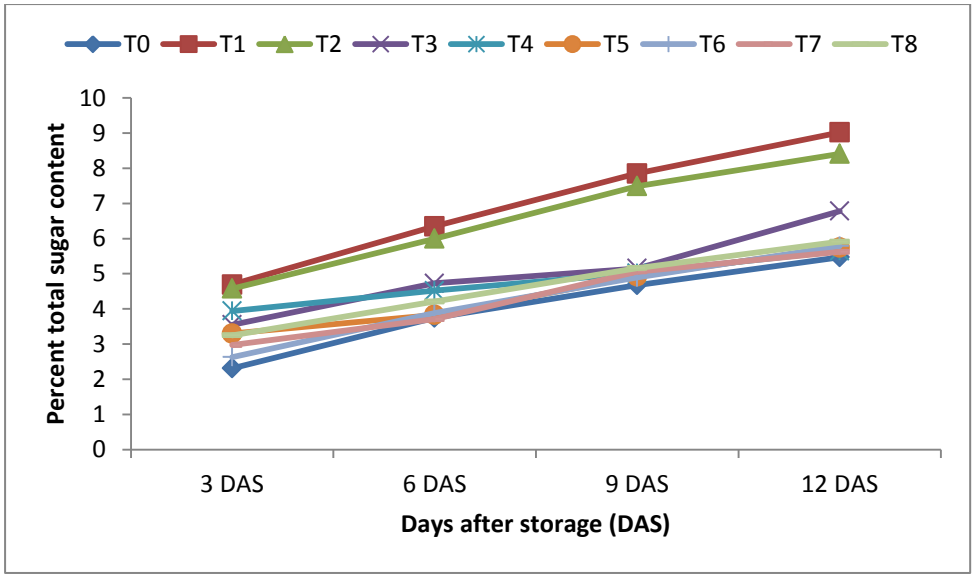

Fig. 16: Percent total sugar content of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Effect of preservatives

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. 16 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_1 (Propolis 5%). At 3 DAS, the highest percent total sugar content (4.69%) was found in T_1 (Propolis 5%) treatment which was statistically identical with T_2 (Chitosan 1%) and the lowest percent total sugar content (2.31%) was in the fruits under control treatment T_0 (no preservative) (Fig. 16). At 6, 9 and 12 DAS, the maximum percent total sugar content (6.35, 7.85 and 9.02%, respectively) was recorded in T_1 and the minimum percent total sugar content (3.75, 4.68 and 5.47%, respectively) was found in control T_0 (Fig. 16).

Table 8. Percent total sugar content of guava as influenced by packaging material and preservatives

Treatments	Percent total sugar content			
	3 DAS	6 DAS	9 DAS	12 DAS
P_0T_0	2.23 k	3.65 h	4.61 h	5.36 l
P_0T_1	4.63 a	5.93 c	7.78 a	8.87 b
P_0T_2	4.51 a	6.28 ab	7.42 b	8.18 d
P_0T_3	3.47 cd	4.63 de	5.07 cde	6.68 f
P_0T_4	3.85 b	4.47 e	4.93 efg	5.54 jk
P_0T_5	3.23 def	3.78 gh	4.61 h	5.67 ij
P_0T_6	2.55 ij	3.81 gh	4.83 fg	5.73 hi
P_0T_7	2.88 gh	3.68 h	4.95 ef	5.51 k
P_0T_8	3.16 ef	4.17 f	5.05 de	5.78 hi
P_1T_0	2.38 jk	3.81 gh	4.74 gh	5.57 jk
P_1T_1	4.75 a	6.41 a	7.91 a	9.17 a
P_1T_2	4.66 a	6.07 bc	7.56 b	8.63 c
P_1T_3	3.62 c	4.83 d	5.23 cd	6.87 e
P_1T_4	4.03 b	4.56 e	5.11 cde	5.76 hi
P_1T_5	3.37 de	3.87 gh	5.25 cd	5.82 h
P_1T_6	2.70 hi	3.95 g	4.96 ef	5.85 h
P_1T_7	3.05 fg	3.76 gh	5.17 cd	5.73 hi
P_1T_8	3.33 de	4.25 f	5.27 c	6.03 g
$LSD_{0.01}$	0.223	0.216	0.182	0.129
CV (%)	5.30	6.10	2.96	3.65

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Combined effect of packaging materials and preservatives

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 (4.75%) was in P_1T_1 which was statistically identical with P_0T_1, P_0T_2 and P_1T_2 whereas the lowest percent total sugar content (2.23%) was recorded in P_0T_0 which was statistically similar with P_1T_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 (6.41, 7.91 and 9.17%, respectively) was recorded in P_1T_1 whereas the minimum percent total sugar content (3.65, 4.61 and 5.36%, respectively) was found in P_0T_0 (Table 8).

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.

4.4 Shelf life

Effect of packaging materials

Significant variation was recorded between two packaging treatments in respect of shelf life of guava (Fig. 17 and Appendix X). The results showed that the highest shelf life (9.78 days) was recorded from P_1 (perforated polythene) treatment whereas the lowest shelf life (7.89 days) was found in P_0 (no packaging) treatment (Fig. 17).

Effect of preservatives

The postharvest treatments (preservative) used in the present study exhibited pronounced effect in extending shelf life of guava during storage and it was statistically significant (Fig. 18 and Appendix X). The longest shelf life (12 days) was recorded in fruits treated with T_1 (Propolis 5%) treatment followed by 11 days in the fruits treated with T_2 (Chitosan 1%) treatment whereas minimum shelf life (5.50 days) was recorded in T_0 (no preservative) treatment.

Combined effect of packaging materials and preservatives

The combined effect between packaging and preservatives, treatment combinations were significant in respect of shelf life (Table 9 and Appendix X). Considering the combined effect, the longest shelf life (13.00 days) was

obtained in P_1T_1 followed by P_1T_1 (12 days) (Table 9) whereas the shortest shelf life was recorded in P_0T_0.

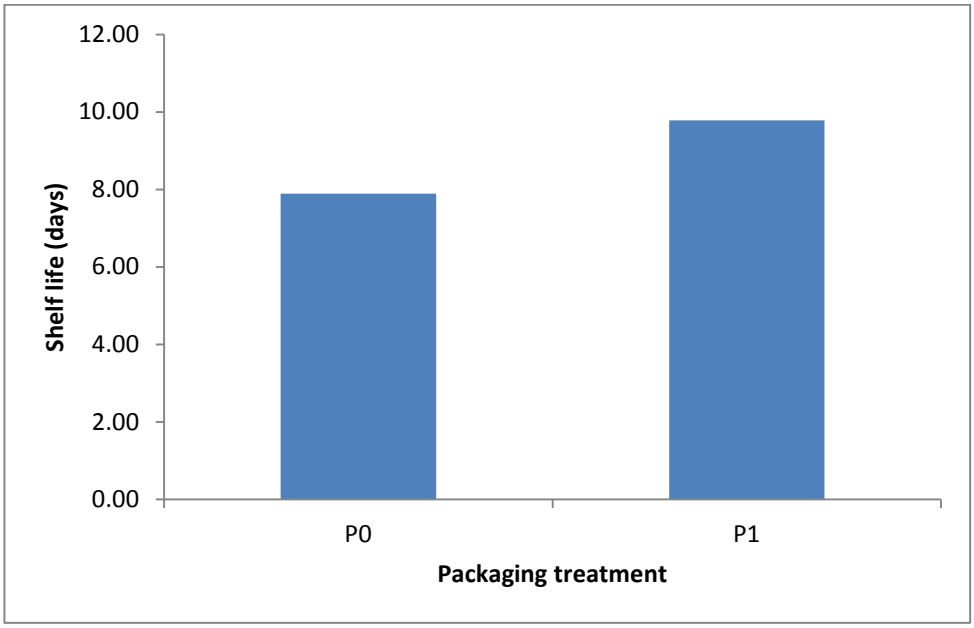

Fig. 17: Shelf life of guava as influenced by packaging material

P_0 = Control (no packaging), P_1 = Perforated polythene

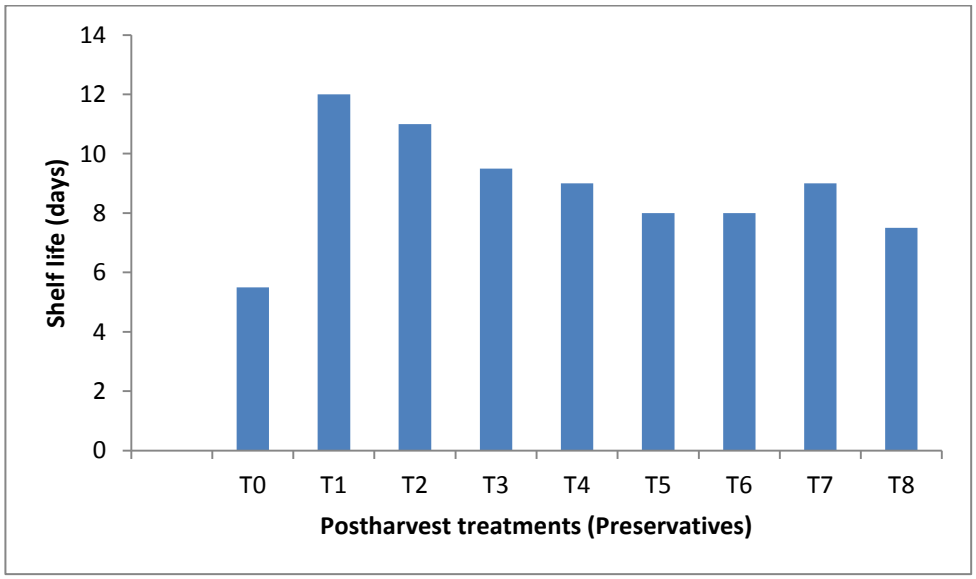

Fig. 18: Shelf life of guava as influenced by different preservatives

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

Table 9. Shelf life of guava as influenced by packaging material and preservatives

Treatments	Shelf life (days)
P_0T_0	5.00 i
P_0T_1	11.00 c
P_0T_2	10.00 d
P_0T_3	8.00 f
P_0T_4	8.00 f
P_0T_5	7.00 g
P_0T_6	8.00 f
P_0T_7	9.00 e
P_0T_8	9.00 e
P_1T_0	6.00 h
P_1T_1	13.00 a
P_1T_2	12.00 b
P_1T_3	11.00 c
P_1T_4	10.00 d
P_1T_5	9.00 e
P_1T_6	9.00 e
P_1T_7	10.00 d
P_1T_8	8.00 f
$LSD_{0.01}$	0.257
CV (%)	4.33

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no packaging), P_1 = Perforated polythene

T_0 = Control (no preservatives), T_1 = Propolis (5%), T_2 = Chitosan (1%), T_3 = Gum Arabic (5%), T_4 = Propolis (5%) + Gum arabic (5%), T_5 = Propolis (5%) + Chitosan (1%), T_6 = Cinnamon oil (2%), T_7 = Lemongrass oil (2%), T_8 = Cinnamon oil (2%) + Lemongrass oil (2%)

The above results lead to the conclusion that different postharvest treatments influenced the shelf life of guava. The increase in shelf life was probably due to the changes in the concentration of various gasses (increased level of O_2, C_2H_4 and reduced level of CO_2) as well as slowing down the process leading to delay ripening by different postharvest treatments. Similar result was also observed by Dutta *et al.* (1991).

CHAPTER 5

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 2019 to June 2019 to find out the postharvest management of guava to increase shelf- life and quality. Treatment of the fruits along with some physico-chemical analyses was done at the postharvest laboratory. The rest of the chemical analyses were done at Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment was 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.

In case of the effect of packaging materials, color change, percent weight loss, percent titratable acidity, percent total soluble solid, firmness (kg/cm^2) and percent total sugar content were not affected significantly.

Results showed that at 3, 6, 9 and 12 DAS the lowest percent weight loss (6.58, 7.27, 8.06 and 8.52%, respectively) and percent dry matter content (14.38, 15.76, 17.04 and 17.78%, respectively) were found from the treatment P_1 (perforated polythene). But at 3, 6, 9 and 12 DAS the highest percent moisture content (85.59, 84.24, 82.96 and 82.08%, respectively), percent titratable acidity (1.73, 1.62, 1.53 and 1.46%, respectively), vitamin C content (187.14, 180.74, 173.58 and 166.92 mg/100g, respectively), percent total soluble solid (4.46, 4.95, 5.47 and 6.07%, respectively), firmness (4.27, 4.15, 3.97 and 3.73 kg/cm^2, respectively) and percent total sugar content (3.54, 4.61, 5.69 and 6.60%, respectively) was found from the treatment P_1 (perforated polythene). On the other hand, at 3, 6, 9 and 12 DAS the highest percent weight loss (6.70,

7.58, 8.36 and 8.87%, respectively) and percent dry matter content (15.66, 16.95, 17.93 and 19.11%, respectively) were found from the control treatment P_0 (no packaging). But at 3, 6, 9 and 12 DAS the lowest percent moisture content (84.38, 83.05, 82.07 and 80.89%, respectively), percent titratable acidity (1.72, 1.59, 1.50 and 1.42%, respectively), vitamin C content (183.96, 177.63, 171.33 and 163.17 mg/100g, respectively), percent total soluble solid (4.35, 4.73, 5.25 and 5.40%, respectively), firmness (4.18, 4.14, 3.84 and 3.66 kg/cm^2, respectively) and percent total sugar content (3.39, 4.49, 5.47 and 6.37%, respectively) were found from the control treatment P_0 (no packaging).

In case of shelf life affected by different packaging materials, the highest shelf life (9.78 days) was also found from P_1 (perforated polythene) whereas the lowest shelf life (7.89 days) was also found from the control treatment P_0 (no packaging).

Regarding application of preservatives, at 3, 6, 9 and 12 DAS the lowest percent weight loss (5.18, 6.02, 7.06 and 7.45%, respectively) and percent dry matter content (11.89, 13.02, 14.37 and 15.34%, respectively) were found from the treatment T_1 (Propolis 5%). But at 3, 6, 9 and 12 DAS the highest percent moisture content (88.11, 86.98, 85.63 and 84.66%, respectively), percent titratable acidity (2.38, 2.27, 2.19 and 2.14%, respectively), vitamin C content (209.50, 204.20, 197.20 and 190.90 mg/100g, respectively), percent total soluble solid (5.01, 5.45, 6.79 and 7.32%, respectively), firmness (4.55, 4.50, 4.36, and 4.20 kg/cm^2, respectively) and percent total sugar content (4.69, 6.35, 7.85 and 9.02%, respectively) were found from T_1 (Propolis 5%) treatment. On the other hand, at 3, 6, 9 and 12 DAS the highest percent weight loss (8.31, 8.96, 9.50 and 9.95, respectively) and percent dry matter content (16.60, 18.19, 19.27 and 20.25%, respectively) were found from control treatment T_0 (no preservatives). But at 3, 6, 9 and 12 DAS the lowest percent moisture content (83.54, 81.81, 80.74 and 79.75%, respectively), percent titratable acidity (1.44, 1.23, 1.01 and 0.79%, respectively), vitamin C content (173.00, 165.80, 158.30 and 149.00 mg/100g, respectively), percent total soluble solid (3.59, 4.35, 4.83

and 5.40%, respectively), firmness (3.80, 3.78, 3.40 and 3.30 kg/cm^2, respectively) and percent total sugar content (2.31, 3.75, 4.68 and 5.47%, respectively) were found from control treatment T_0 (no preservatives).

In case of shelf life affected by different preservatives, the highest shelf life (12 days) was found from the treatment T_1 (Propolis 5%) whereas the lowest shelf life (5.50 days) was found from control treatment T_0 (no preservatives).

In case of combined effect of packaging materials and preservatives, at 3, 6, 9 and 12 DAS the lowest percent weight loss (4.64, 5.20, 6.06 and 6.46%, respectively) and percent dry matter content (10.78, 12.02, 13.65 and 14.63%, respectively) were found from the treatment combination of P_1T_1. But at 3, 6, 9 and 12 DAS the highest percent moisture content (89.22, 87.98, 86.35 and 85.37%, respectively), percent titratable acidity (2.34, 2.36, 2.27 and 2.23%, respectively), vitamin C content (211.30, 207.50, 201.50 and 196.60 mg/100g, respectively), percent total soluble solid (5.07, 5.53, 6.85 and 7.76%, respectively), firmness (4.60, 4.55, 4.47 and 4.30 kg/cm^2, respectively) and percent total sugar content (4.75, 6.41, 7.91 and 9.17%, respectively) was found from the treatment combination of P_1T_1. On the other hand, at 3, 6, 9 and 12 DAS the highest percent weight loss (8.43, 9.06, 9.87 and 10.23%, respectively) and percent dry matter content (17.65, 18.90, 19.94 and 21.08%, respectively) were found from the treatment combination of P_0T_0. But at 3, 6, 9 and 12 DAS the lowest percent moisture content (82.68, 81.10, 80.07 and 78.92%, respectively), percent titratable acidity (1.41, 1.23, 0.97 and 0.70%, respectively), vitamin C content (170.30, 165.40, 154.80 and 144.40 mg/100g, respectively), percent total soluble solid (3.57, 4.28, 4.57 and 5.16%, respectively), firmness (3.70, 3.03, 2.85 and 2.10 kg/cm^2, respectively) and percent total sugar content (2.23, 3.65, 4.61 and 5.36%, respectively) were found from the treatment combination of P_0T_0.

In case of shelf life affected by different affect by combined effect of packaging materials and preservatives, the highest shelf life (13.00 days) was

recorded from the treatment combination of P_1T_1 whereas the lowest shelf life (5.00 days) was found from the treatment combination of P_0T_0.

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

Percent weight loss, dry matter, TSS and total sugar content of guava fruits increased with the storage period under different treatments. On the other hand, moisture, titratable acidity, vitamin C content and firmness of fruits decreased as the storage period increased. The shelf life from the treatment P_1 (perforated polythene) could be extended up to 13.00 days by using T_1 (Propolis 5%). The fruits which had longer shelf life slowly changed its chemical components. From the results of the experiment and subsequent discussion, it may be suggested that more research works need to be conducted on physico- chemical changes of guava using different treatments to confirm the findings. Moreover, further experiment should also be conducted using more postharvest treatments to extend the shelf life to minimize the postharvest losses of guava.

Therefore, perforated polythene with Propolis (5%) can be recommended for better shelf life and quality of guava.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

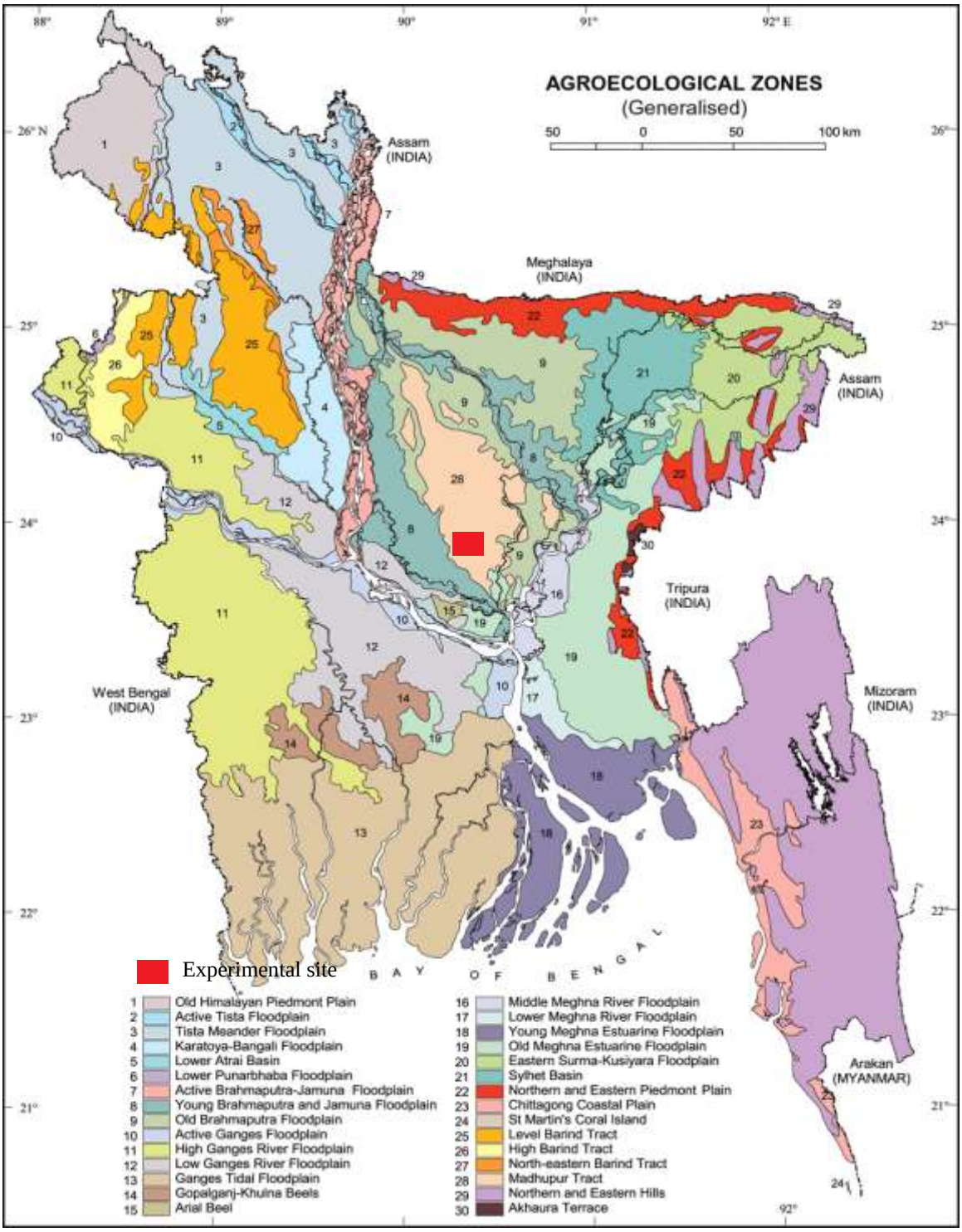

Fig. 19: Experimental site

Appendix II. Percent weight loss of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent weight loss			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	NS	NS	NS	NS
Factor B	8	5.764**	5.874**	4.015**	4.594**
AB	8	1.296**	1.295**	2.399**	2.386**
Error	34	0.023	0.043	0.050	0.048

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix III. Percent moisture content of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent moisture content			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	NS	NS	NS	NS
Factor B	8	13.34*	14.72*	14.69*	14.66 *
AB	8	1.012**	0.320**	0.252**	0.162**
Error	34	0.690	0.549	0.669	0.588

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IV. Percent dry matter content of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent dry matter content			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	22.272*	19.034**	10.738**	24.080*
Factor B	8	13.545*	14.729*	14.722**	14.566**
AB	8	0.947**	0.320**	0.253**	0.248**
Error	34	0.803	0.549	0.669	1.081

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Firmness of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square firmness (kg/cm^2)			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	NS	NS	NS	NS
Factor B	8	0.380**	0.521**	0.614**	0.829*
AB	8	0.004**	0.006**	0.012**	0.637**
Error	34	0.002**	0.003**	0.002**	0.057**

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Percent titratable acidity of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent titratable acidity			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	0.001**	0.001**	0.001**	0.007**
Factor B	8	0.585**	0.693**	0.805**	0.937*
AB	8	0.025**	0.025**	0.026**	0.031**
Error	34	0.015**	0.168**	0.001**	0.001**

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Percent vitamin C content of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square vitamin C content (mg/100 g)			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	136.70*	130.48*	68.614**	189.95*
Factor B	8	867.96*	892.60*	927.63*	1037.27*
AB	8	20.372**	53.459**	85.929**	46.617**
Error	34	4.081	5.318	7.979	2181.533

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Percent total soluble solid of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent total soluble solid			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	0.187**	0.700**	0.673**	0.851**
Factor B	8	1.072**	0.698**	2.366**	2.236**
AB	8	0.002**	0.016**	0.040**	1.702**
Error	34	0.036	0.011	0.023	0.033

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Percent total sugar content of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square percent total sugar content			
		3 DAS	6 DAS	9 DAS	12 DAS
Factor A	1	0.317**	0.205**	0.634**	0.742**
Factor B	8	4.023**	5.858**	8.576**	10.537*
AB	8	0.001**	0.002**	0.040**	0.014**
Error	34	0.127	0.077	0.003	0.002

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Shelf life of guava as influenced by packaging material and postharvest treatments

Sources of variation	Degrees of freedom	Mean square shelf life (days)
Factor A	1	0.667**
Factor B	8	24.375*
AB	8	1.042**
Error	34	0.824

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level