EFFECTS OF POSTHARVEST TREATMENTS AND PACKAGING MATERIALS ON QUALITY AND SHELF LIFE OF BANANA

MD. SHAHRIA HOSSAIN

DEPARTMENT OF HORTICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

MD. SHAHRIA HOSSAIN

REGISTRATION NO. 14-05822

shahriahossain73@gmail.com

01737356165

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Approved by:

Dr. Md. Nazrul Islam	**Dr. Shormin Choudhury**
Professor	Associate Professor
Department of Horticulture	Department of Horticulture
Sher-e-Bangla Agricultural	Sher-e-Bangla Agricultural
University, Dhaka	University, Dhaka
Supervisor	**Co-Supervisor**

Prof. Dr. Khaleda Khatun

Chairman
Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka

Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

PABX: +88029144270-9
Fax: +88029112649
Web site: www.sau.edu.bd

CERTIFICATE

This is to certify that the thesis entitled, **"EFFECTS OF POSTHARVEST TREATMENTS AND PACKAGING MATERIALS ON QUALITY AND SHELF LIFE OF BANANA"** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural university, Dhaka, in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE IN HORTICULTURE** *embodies the results of a piece of bona fide research work carried out by* ***MD. SHAHRIA HOSSAIN****, bearing Registration No.* **14-05822** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.*

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.

Dated: December, 2021

Place: Dhaka, Bangladesh

(Prof. Dr. Md. Nazrul Islam)
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka- 1207
Supervisor

Indeed, in the creation of the heavens and the earth and the alternation of the night and the day are signs for those of understanding. (Surah Aal-e-Imran 3:190)

DEDICATED TO
MY BELOVED
PARENTS
All that I am, or hope to be, I owe to them

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ABSTRACT

The experiment was carried out in the Postharvest Laboratory of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of different postharvest management practices of banana to increase shelf life and quality in ambient condition. Two factors experiment viz. Factor A:- P_0: No packaging, P_1: non perforated polythene bag, P_2: Perforated polythene bag, P_3: Newspaper and Factor B:- R_0: no treatment, R_1: 1- methylcyclopropene (250ppb 1-MCP), R_2: 4% $CaCl_2$, R_3: Aloe vera gel, R_4: Ginger extract, R_5: Hot water at 45^0C for 5 minutes were initiated for the experiment. The experiment was laid out in completely randomized design with four replications. Various data on physical and chemical properties were collected during and at the end of shelf life. In case of packaging material, P_1 showed best performance and showed the highest shelf life (14.44 days) compared to P_0 (9.06 days). Regarding treatment, R_1 gave the best results on studied parameters and showed highest shelf life (14.42 days) compared to other treatments and shortest shelf life (9.33 days) was recorded from R_0. In case of combined effect of packaging materials and treatments, at 15 days after storage (DAS), the lowest percent weight loss (0.97%) was found from P_1R_0 whereas the highest weight loss (23.28%) was found in P_0R_0. The highest percent dry matter content (20.73%), percent total soluble solid (21.0%) and percent non reducing sugar content (6.96%) were also found from the treatment combination P_2R_1 at 15 DAS whereas P_0R_0 showed the lowest results (17.50%, 17.17%, 5.47% respectively) on the respected parameters. Similarly, the lowest pulp peel ratio (2.12), percent moisture content (79.23%), percent total sugar (18.52%), percent reducing sugar (11.56%), percent tritable acidity (0.29%) and percent decay (31.00%) were found from P_2R_1 whereas P_0R_0 showed the highest results (4.33, 82.50%, 22.43%, 16.96%, 0.45% and 75% respectively). Likewise, the highest shelf life (15.00 days) was also recorded from P_2R_1 whereas the lowest (9.00 days) was from P_0R_0. So, the treatment combination P_2R_1 can be considered the best postharvest treatment for banana.

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LIST OF ABBREVIATIONS

1-MCP= 1-Methylcyclopropene

BARI= Bangladesh Agricultural Research Institute

BAU = Bangladesh Agricultural University

BBS= Bangladesh Bureau Statistics

CRD = Completely Randomized Design

DAE= Department of Agricultural Extension

DAS = Days After Storage

DNS = 3,5-Dinitrosalicylic Acid

DW = Distilled water

et al. = and others

FAO = Food and Agriculture Organization

GA_3 = Gibberellic Acid

i.e = That is

LSD = Least Significant Difference

mL = Milliliter

NS = Non significant

pH = Hydrogen ion concentration

PLW = physiological loss in weight

ppb = Parts Per Billion

ppm = Parts Per Million

RH = Relative Humidity

SAU = Sher-e-Bangla Agricultural University

TA = Titratable Acidity

TSS = Total Soluble Solids

CHAPTER I

INTRODUCTION

Banana (*Musa sp*.) is an important fruit crop in Bangladesh. It belongs to the family Musaceae. Banana is a principal horticultural crop of the tropic's region. It is an economically very important fruit. Banana is available throughout the year in Bangladeshi market. Currently, over 49302.43 ha of land in Bangladesh are used for banana farming, with an annual production of roughly 817908 metric tons (BBS, 2020). Banana is also grown in India, Pakistan, Philippines, Thailand, Mexico, Costa Rica, Panama, Colombia etc. and many other countries of tropics and subtropics (Hassan, 2010). Bananas are notable for their high calorie and nutritional content. It has five times the vitamin A and iron of an apple, four times the protein, three times the phosphorus, twice the carbohydrate, and all other vitamins and minerals (Gasster, 1963).

Since bananas are a tropical and perishable fruit, their post-harvest losses are always significant. For a developing country like Bangladesh, the post-harvest situation is a major source of concern. Banana postharvest losses in Bangladesh range from 25-40% due to environmental factors (high temperature and humidity), compared to approximately 5-25% in affluent countries (Khader, 1996). It cannot be maintained for a longer period of time after harvesting because it is a delicate, perishable fruit. Bangladesh loses a significant amount of money each year as a result of the shortened post-harvest life of bananas. Fruit losses after harvest due to pest illness are a severe concern all over the world. Fruit and vegetable post-harvest losses are as high as 30 to 40 percent worldwide, and even greater in some impoverished nations (Mondal, 2000) Bananas are a perishable fruit with 25-50 percent post-harvest losses (Amiruzzaman, 1990).

Bananas are climacteric fruits, meaning they ripen with an increase in respiration and ethylene production. The fruit's perishability is attributable to undesirable physiological changes, such as weight loss due to respiration and transpiration, softening of the flesh, and microbial attack resistance. As a result of the high amount of postharvest loss, fruit supply per capita is further lowered. Postharvest losses can be reduced by extending the shelf life of fruits, which can help to improve the situation.

Slowing down the ripening process and, if feasible, halting the breakdown and fermentation processes that induce senescence after ripening are all part of extending a fruit's shelf life. At different phases of ripening, the physico-chemical properties of the fruit change. Softness, sweetness of flesh, skin color, and flavor differ between kinds and stages.

Postharvest losses can be reduced by extending the shelf life of fruits, which can help to improve the situation. One of the most essential techniques for reducing banana post-harvest losses is to provide adequate storage conditions. To prevent post-harvest losses, the shelf life of bananas must be extended. Several methods exist for extending shelf life, including the use of packaging materials, hot water, and ethylene absorbent, which is utilized for optimal storage. To minimize pest or disease-causing organisms, hot water treatment is used (Sivakumar and Falik, 2013; Theodosy and Kimaro, 2011). In addition, a hot water dip inhibits the growth of some fungi and inactivates enzyme activity that speed up the ripening of the fruit. Perforated polythene, non-perforated polythene, and newspaper wrapping are also effective ways to prevent fruit loss due to transpiration (Olivas *et al*., 2005). Different plant extracts have been used to reduce banana postharvest losses and extend shelf life while maintaining quality (Habiba, 2012). Plant extracts such as ginger, aloe vera, garlic, neem, onion, and others are used in treatment (Anjum *et al*., 2016). Some horticultural commodities have been treated with 1-methylcyclopropene (1-MCP) to extend their shelf life. 1-Methylcyclopropene inhibited fruit ripening, preserved quality, and extended banana shelf life via binding to ethylene receptors (Golding *et al*., 1998). Calcium chloride helps to keep fresh cut bananas solid (Vilas-Boas and Kader, 2006) and increase banana quality during storage by lowering respiration rates, illness incidence, and weight loss. As a result, rigorous research on the postharvest behavior of Bangladesh's commercial banana types is critical. With all of this in mind, an experiment was done to determine the applicability of various postharvest treatments on the shelf life and quality of bananas. Therefore, the present study was done to fulfill the following objectives:

a) To find out the suitable postharvest treatment on quality and shelf life of Banana.

b) To determine the appropriate packaging material on quality and shelf life of Banana.

c) To evaluate the suitable combination of postharvest treatment and packaging material on quality and shelf life of Banana.

CHAPTER II
REVIEW OF LITERATURE

Banana fruit quality is substantially determined by postharvest handling, and various postharvest treatments, which are primarily used to improve fruit storability. Understanding the physico-chemical changes in bananas is critical for improving postharvest quality and shelf life. Numerous studies on various elements of the banana have been conducted in various parts of the world. Although there is a lot of literature on shelf-life extension, postharvest loss reduction, and physico-chemical changes in bananas during storage and ripening, little research has been done in Bangladesh on these topics. This chapter reviews several key research findings that are pertinent to the current investigation.

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

The ripening of bananas can be significantly slowed by keeping them in both perforated and non-perforated polythene covers. When bananas are stored in a perforated polythene cover, nitrogen, oxygen, and carbon dioxide are allowed to pass through, and the pressure inside recovers to atmospheric pressure. On the other hand, the concentration of oxygen is reduced and the concentration of carbon dioxide is increased within the non-perforated polythene cover, which helps to delay banana ripening.

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

Hardenburg (1971) investigated the use of film wrapping to reduce fruit weight loss. He further claimed that the reduced weight loss was related to a decrease in the rate of transpiration. It was suggested that increasing the number of perforations in polythene bags might reduce the risk of rotting fruits caused by increased humidity inside the bags.

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

Zica and Brune (1973) conducted an experiment with the parta banana cultivar and found that when the fruits were withdrawn from the bag containing an ethylene absorbent and stored between 25 and 29°C for 35 days, they ripened normally, whereas the fruits in the control had gone decayed. They also discovered that storing fruits in perforated polythene bags at room temperature can delay ripening by roughly 5 days.

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

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

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

Sarananda (1989) found that after 15 days of storage in a sealed polythene bag, no peel color development was detected, however fingers in perforated polythene bags and in open polythene bags showed full peel color development by the 9^{th} day. Fruits stayed solid in sealed polythene bags for up to 12 days, but were very soft after 7 days in perforated and open bags. Tan *et al.* (1990) reported that up to 12 days of storage in a polythene bag had no effect on the visual quality rating, taste, or flavor of the fruits.

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

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

Zhang *et al*. (1992) reported banana fruits cv. Dwarf Cavendish when packed in polythene bags, the CO_2 and ethylene levels gradually increased, with the peak occurring 3 or 4 days earlier at 30°C than at 20°C.

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

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

Wei *et al*. (1993) studied diploid banana packaging in a changed environment (*Musa* AA). They found that packing with polythene film and keeping at 14°C resulted in a shelf life of 21-28 days, which was equivalent to that obtained commercially for Cavendish bananas (*Musa* AAA). Increased CO_2 concentrations that caused toxic effects after 3 weeks if the film was not adequately permeable (200 gauge). Harvesting closer to maturity resulted in a lower shelf life, but matured fruits had a greater flavor.

Elzayat (1996) stated that banana cultivar Magrabi when pretreated with thiobendazole (400ppm) and packed in polythene cartons all packaged fruits remained in good condition for one month in storage and had a shelf life of 5-7 days under ambient conditions. In terms of TSS, moisture content, acidity, and organoleptric features, these fruits matured normally during storage. After storage, the shape of the control fruits was altered and they deteriorated.

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

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

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

2.2 Effect of different postharvest treatments on shelf life of banana

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

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

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

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

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

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

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

2.2.2 Effect of $CaCl_2$ for prolonging shelf life

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

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

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

Sanjay Sahay *et al*. (2015) found that fruits treated with $CaCl_2$ (4 %) + polyethylene bag had the highest retention of bio-chemical constituents such as

total soluble solids, titratable acidity, and reducing sugars, as well as an extended shelf-life of up to 16 days.

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

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

2.2.3 Effect of plant extract (Aloe vera, Ginger) as coating materials for prolonging shelf life

Baldwin *et al*. (1995) found that to generate a changed environment and decrease weight loss during transport and storage, edible coatings are used.

Avena-Bustillos *et al*. (1997) and Mchugh *et al*. (2000) applied edible coatings to the product surface in addition to or as a substitute for natural protective waxy coatings provide a barrier to moisture, oxygen, and solute movement for the food and provide a barrier to moisture, oxygen, and solute movement for the food. They are dipped, sprayed, or brushed directly onto the food surface.

Olivas *et al*. (2005) explained that in general, edible coatings are used to slow gas transfer, reduce moisture and aroma loss, postpone color changes, and improve the overall look of fruits, vegetables, and minimally processed products during storage. The edible coating placed to the surface of fruits, vegetables, and their fresh-cut products aims to enhance the shelf life of the products.

Pranoto *et al*. (2005) have published one of the first studies on the incorporation of essential oils into edible coatings using the agar diffusion method, these researchers investigated the antibacterial activity of garlic oil applied to an alginate-based film against Staphylococcus aureus and B. cereus. Garlic oil was tested against *Escherichia coli, Staphylococcus aureus, Salmonella enteritidis, Listeria monocytogenes,* and *Lactobacillus plantarum* by Seydim and Sarikus (2006) using whey protein isolate films, but it was shown to be significantly less active than oregano essential oil.

Lin and Zhao (2007) found that consumers all over the world want high-quality food that is free of chemical preservatives and has a long shelf life. As a result, more effort is being put into developing novel natural preservatives and antimicrobials. To prolong the selling distances and holding times for commodities after harvest, a variety of storage systems have been devised. Various preservation techniques have been developed.

Tzortzakis (2007) has been studied for pears, citrus, bananas, strawberries, tomato, cherries, and grapes, the influence of essential oils and their constituents on postharvest illnesses.

Vargas *et al*. (2008) and Lin and Zhao (2007) stated that edible coatings of various compositions have been investigated and utilized to extend the storage life of fruit because they can provide an additional protective layer, which inhibits microbial development, as well as a protective barrier that reduces respiration and transpiration rates, which slows senescence. Edible coatings are split into three types based on their components: hydrocolloids, lipids, and composites. Proteins and polysaccharides are examples of hydrocolloids. Waxes, acylglycerols, and fatty acids are all lipids. Composites contain both hydrocolloid and lipid components.

Adetunji *et al.* (2012) conducted a study to determine the impact of Aloe vera gel as an edible coating on weight loss, ascorbic acid, pH, and firmness in order to increase the shelf-life of pineapple stored at 27°C and 55-60% relative humidity for seven weeks. However, in the pineapple coated with Aloe vera gel, the following characteristics that are associated to post-harvest quality loss were significantly minimized. Orange fruit's shelf life was also prolonged by seven weeks. The application of A. vera gel as a pineapple coating was found to be a viable alternative to chemical post-harvest treatments.

Misir *et al*. (2014) found that its film-forming capabilities, antibacterial effects, biodegradability, and biochemical features, Aloe vera gel has been demonstrated to be one of the finest edible and biologically safe preservation coatings for many types of foods, according to. It is mostly formed of polysaccharides and functions as a natural barrier against moisture and oxygen, which are the primary causes of fruit and vegetable deterioration. They also discovered that Aloe vera gel can extend the shelf life of fruits and vegetables by reducing respiration and retaining qualitative features (color, flavor etc.). It contains antifungal and antibacterial properties, making it a good defense against microbial contamination of fruits and vegetables.

Alberio *et al*. (2015) did a study to see how an edible film made from a commercial Aloe vera extract affected the quality of minimally processed grapes from three distinct varietals (Sugar One, Victoria and Black Magic). All of the characteristics studied were determined in extracts made from minimally processed grapes that were packaged in normal air and stored at 24°C for 15 days. When compared to untreated samples, samples dipped in Aloe vera exhibited significant differences (p.0.05). The calculation of such characteristics, as well as the assessment of customer acceptability, were useful in determining the efficacy of Aloe vera post-harvest therapy during a 15-day storage period.

Borah *et al.* (2016) stated that Aloe vera possesses antibacterial capabilities and does not contribute unfavorable characteristics to food. They conducted research to determine the combined effect of Aloe vera gel coating and bagging of mature unripe fruits in extending tomato shelf life. The shelf life of untreated control tomato fruits maintained at room temperature was 8 days. When Aloe vera gel coating was applied to mature unripe tomato fruits, ripening was delayed by 4 days, and the fruits were able to keep their consumer-acceptable quality for a period of 12 days. Poly galacturonase activity, respiratory and transpiration loss in fruit weight, chlorophyll breakdown, and consumer acceptable fruit texture may all be inhibited by aloe vera coating followed by bagging of fruits for 40 days. Based on the findings, it was determined that the use of edible Aloe vera gel coating in combination with the bagging of mature unripe fruits could be useful for commercial acceptance, shelf life extension, and marketing of climacteric fruits.

2.2.4 Effect of hot water treatment on shelf life of banana

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

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

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

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

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

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

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

Fruits treated with hot water had good texture and color, according to the findings.

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

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

2.3 Effect of treatments on physical changes during storage of banana

2.3.1 Total weight loss

Weight loss is a common banana fruit requirement. Bananas lost weight during storage and ripening, according to the majority of the researchers.

Haque (1985) conducted an experiment with 'Amritasagar' to investigate weight loss during ripening. The results revealed that the weight loss of mature bunches harvested in mid-August was higher and faster than that of mature bunches gathered in October. The former lost 4.70% of their body weight in 5 days, while the latter lost 4.04% in 7 days. According to the data, the loss in August was double that of October for the same time period.

Bhardra and Sen (1997) described that polythene bagging with $KMnO_4$ was determined to be the optimum for preventing physiological weight loss for custard apple curing storage.

Patil and Hulamani (1998) conducted an experiment and found that using a fungicide in combination with $KMnO_4$ (an ethylene absorbent) minimized physiological weight loss in bananas during storage.

Bairwa and Dashora (1999) observed that half-ripe fruits were dipped in $AgNO_3$ solution (50 ppm) for 5 minutes and dried under a fan. The treated fruits were stored in corrugated paper boxes wrapped in $KMnO_4$ (0.5 and 1.0) soaked sheets. The largest weight loss in half-ripe fruits was 7.28 % on the eighth day of storage.

Pathak and Sanwal (1999) estimated that weight of a complete banana fruit decreases as it ripens.

Rouf and Mondal (2011) conducted a study to see how different postharvest treatments affected the physicochemical changes in bananas. In four banana varieties, he utilized six postharvest treatments: control, Dithane M-45 (0.2

percent), hot water (50°C for 10 minutes), perforated polythene bag, un perforated polythene bag, and un perforated polythene bag containing $KMnO_4$. Sabri, Amritasagar, Mehersagar, and Gerasundori are some of the most well-known names in India. They discovered that $KMnO_4$-treated bananas lost the least amount of weight (7.29 %) during storage, while untreated bananas lost the most (15.61 %).

Mondal *et al*. (2012) conducted a study to see how different plant extracts affected the weight loss of banana cv. Amritasagar and Mehersagar. At 12 days of storage, Amritasagar had a smaller weight loss (17.26 %) than Mehersagar (18.29 %).

2.3.2 Pulp to peel ratio

Palmer (1971) found that during ripening, the osmotic pressure of the peel rises from 61.5 atmosphere pressure to 25-27 atmospheric pressure, but the osmotic pressure of the pulp rises from 6 to 25-27 atmospheric pressure. The weight ratio of pulp to peel changes from 1.2-1.6 in green fruit to 2.0-2.7 in mature fruit as a result of the pressure differential.

Tripathi *et al*. (1981) reported that pulp to peel ratio increased throughout ripening. Loesecke (1950) explained why this is the case. According to him, the weight of the pulp increases as the water content increases. This is derived from the peel and, most likely, the stalk. This results in a decrease in peel weight and an increase in the pulp to peel ratio.

Hernandez *et al*. (1993) stated that fruits of banana cultivars dwarf Cavendish Grand Nain and Williams were held at ambient temperature (20°C) in a ripening chamber for up to 35 days. Peel color, pulp stiffness, and anthracnose development were all measured (pathogen unspecified). In terms of peel color and hardness, Withams and Grand Nain fruits had a longer shelf life than dwarf Cavendish fruits.

Burdon *et al.* (1995) reported that peel comprised 85-90 % and 2860 mg DM/ cm2 surface area. The proportion of fruit pulp to peel varied with variety (1.18-2.28). Because the peel loses water both to the atmosphere and to the pulp during ripening, the moisture content of the pulp decreases while that of the pulp grows (Dadzie and Orchard, 1997).

Simmonds (1996) found that there are several explanations for the increase in pulp to peel ratio. During ripening, sugar production occurs more quickly in the pulp than in the peel, resulting in a differential increase in osmotic pressure. As a result, the pulp draws water from the skin, resulting in a rise in the pulp to peel ratio.

Pathak and Sanwal (1999) investigated chemical modulation of banana ripening and discovered that the pulp to peel ratio of banana fruits rose as they ripened.

The change in sugar concentration in the tissues was linked to the pulp to peel ratio. Sugar increased more quickly in the pulp than in the peel, therefore water was drained from the peel and the pulp to peel ratio increased as osmotic pressure changed.

2.3.3 Dry matter and Moisture content

Stratton and Loesecke (1990) observed that moisture content of the banana pulp rose during storage. They stated that the carbohydrate used in respiration provided more water. They discovered that the moisture content of Gros Michel increased from 74.4 % to 77.4 %, that of lady finger increased from 66.7 % to 73.5 %, that of red banana increased from 71.8 % to 74.2 %, and that of planting decreased from 63.9 %.

Krishnamurthy (1993) noted that during ripening, the moisture content of the pulp of banana fruits increased from (69-75%) to (25-31%) and that of the peel declined.

Elzayat (1996) conducted an experiment, and the results revealed that the banana pulp had adequate moisture and dry matter content after one month of storage under ambient circumstances while the fruits were wrapped in polythene before being packed in cartons.

Simmonds (1996) discovered that the water content of the banana pulp changes during ripening as a result of at least four processes, two of which, starch hydrolysis and transportation, tend to decrease it while the other two, osmotic withdrawal from the peel and starch breakdown to water and CO_2, tend to increase it. The latter two processes take precedence, resulting in a modest rise in water content as the fruit matures from green to completely ripe.

El-Mahmudi and Eisawi (1998) observed during ripening, Dwarf Cavendish bananas have a higher moisture content. The moisture percentage of unripe banana pulp is reported as 69.0% and ripe banana pulp is given as 71.6% in the food composition table for East Asia (Anonymous, 1972), demonstrating an overall rise in percent moisture content.

Mondal and Rob (2011) found that dry matter content increased when bananas were treated with potassium permanganate, but it decreased when the same banana variety was treated with a control treatment.

2.4 Effect of treatments on chemical changes during storage of banana

2.4.1 Total soluble solids (TSS)

Total soluble solids of banana fruit pulp include sugars, soluble fraction of starch, organic acids, soluble pectin, and vitamin C.

Karikari *et al*. (1979) explained that softening to the pulp was practically complete by the mid-climacteric period of banana ripening, but conversion of alcohol insoluble solids to sugar was limited until senescence, when alcohol insoluble solids were at their lowest levels.

Manasque and Mendoza (1990) stated that total soluble solids rose during ripening.

Deka and Harmize (1997) studied biochemical changes in bananas at various phases of development (25, 50, 75, 100, and 125 days after the formation of the finger). The findings revealed that the biochemical constituents of bananas varied significantly during development. Total soluble solids increased from 4.8 to 11.5 %, according to their findings.

Pinaki *et al*. (1997) studied banana fruits cv. 'Dwarf Cavendish' that had been treated with substances such as % $CaCl_2$, gibberellic acid (GA_3, 250 ppm), and Bavistin (100 ppm) separately or in combination, and maintained at room temperature (20, 30°C) in paper boxes. GA_3 alone and in conjunction with Bavistin decreased the rate of rise in total soluble solids, according to the researchers.

Reis *et al*. (2004) the effect of chemical dip, calcium chloride plus ascorbic acid, and modified atmospheric storage improved the total soluble solids of banana pulp.

Mondal *et al*. (2011) conducted an experiment to determine the impact of various plant extracts on banana total soluble solids.

2.4.2 Total sugars, reducing sugars and non-reducing sugar

Tandon *et al*. (1985) observed that fructose concentration of banana pulp rose throughout ripenin. The breakdown of starches to glucose and fructose by the activities of amylase and maltose caused the increase in reducing sugar with the progression of ripening as well as storage duration (Wills *et al*., 1981).

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

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

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

Selvaraj (1993) conducted an experiment and found that starch, which made up 85 to 95 % of the dry matter of unripe banana pulp, was rapidly degraded once

ripening began, resulting in ripening banana pulp (dry matter) containing (5 to 15) % starch and free sugars, such as glucose, fructose, and sucrose.

Robinson (1996) stated that the conversion of starch to sugars was the most significant change in fruit pulp during ripening. The amount of starch in the ripe fruits decreased from roughly 20-30% during harvest to 1-2%. Sugar consumption increased by nearly the same amount. The sugar ratio was around 65:20:15 during the early stages of ripening (sucrose: glucose: fructose).

Bhardra and Sen (1999) conducted an experiment and found that as the storage period advanced, the total reducing sugar content of banana pulps rose. Chacon *et al*. (1997) conducted an experiment and found that total sugar content in green bananas was 1.32 % and 19.7 % in ripe bananas, respectively, while lowering sugar content in green and ripe bananas was 0.52 % and 10.3 %.

2.4.3 Titratable acidity

Selveraj (1993) conducted an experiment, and the results revealed that acidity rose as the fruit matured. According to Munasane and Mendoza (1990), titratable acidity rose until color index 3 (greener than yellow) and then fell as the fruit turned yellow.

Elzayat (1996) reported that when banana fruits were wrapped in polythene before being packed in cartons, found that after one month of storage, satisfactory quality in terms of acidity was reached. Sarker *et al*. (1995) observed a similar result when the fruits were treated with Dithane M-45.

Deka and Harmize (1997) reported that tritatable acidity increased from 1.75 to 2.06% during development.

Pinaki *et al*. (1997) conducted an experiment in which ripe and fully developed banana fruits of uniform size were dipped in GA_3 150 ppm and discovered that GA_3 retained increased titratable acidity while lowering ascorbic acid during storage.

Resis *et al.* (2004) stated that effect of chemical dip, calcium chloride + ascorbic acid, and modified atmosphere storage loss the titratable acidity.

2.4.4 Shelf life

Banana is a popular fruit in Bangladesh. However, it has a significant postharvest loss rate. According to the preceding reviews, several research studies have been carried out around the world, however findings on the shelf-life extension and nutritional qualities of bananas, particularly indigenous kinds,

are sparse in Bangladesh. As a result, the purpose of this study was to look at the shelf life and nutritional value of bananas.

The most significant feature of fruit loss reduction biotechnology is shelf life. Fruits have a natural tendency to degrade to the simpler inorganic compound (CO_2, H_2O, and NH_3) from which they were synthesized in the first place through spontaneous bio-chemical reactions that occur with a decrease in free energy and an increase in the randomness (entrophy) of the system, reducing shelf life and other fruit qualities. Fruit preservation has been one of mankind's primary priorities throughout recorded history, according to Salunkhe and Desai (1984).

According to Youlin *et al.* (1997), mano cv. Zihua fruit dipped in growth regulators (GA_3) had a longer shelf life and enhanced acceptance.

Pinaki *et al*. (1997) found that dipping mature completely developed banana fruits of uniform size in gibberellic acid (GA_3) 150ppm was the most efficient treatment for extending banana fruit shelf life.

Patil and Hulamani (1998a) discovered that Bavistin + GA_3, this treatment extended the shelf life of bananas.

Paull and Chen (2004) explained that down regulation of ethylene production enzymes in bananas delayed ripening.

Reis *et al*. (2004) found that chemical dip, calcium chloride +ascorbic acid, and changed atmosphere storage improved banana quality and shelf life.

Romphophak *et al*. (2004) stated that the shelf life of bananas detected by senescent peel spots in PVC packaging was 6-7 days compared to 3-4 days in the control.

CHAPTER III

MATERIALS AND METHODS

3.1 Site of Experimentation

The experiment was carried out at the Postharvest Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, during November 2020 to January 2021. At the postharvest laboratory, the fruits were treated as well as some physico-chemical analyses. This chapter goes into the specific of the materials used and the procedures used in the current investigation.

3.2 Climate

With the use of a digital thermometer, the temperature of the postharvest lab was measured every day at 10 AM and 5 PM, and it ranged from 20 to 25° C during the experiment. The relative humidity (RH) was 75 -85%.

3.3 Experimental Material

For the experiment, one banana cultivar, BARI Kola 1, was used as the experimental material. The banana fruits used in the experiment were obtained from Sher-e-Bangla Agricultural University's Horticulture Farm, Dhaka. The experiment used fruits that were at their green mature stage. Fresh fruits were harvested and transported to the Central Laboratory by manual trolley with care to avoid harm, and then deposited in the Postharvest Laboratory. The bunches were cooled by fan to swiftly remove the heat. To keep a constant shape and size, the upper and lower 1-2 hands were both chopped off. 120 fingers were used in the experiment after individual fingers were severed from the hands of bunches.

3.4 Methods

The bananas were chosen at similar mature stage. Just prior to setting the experiment, the banana peels were wiped using soft tissue paper.

3.5 Experimental Design

The experiment was set up with four replications in a completely randomized design (CRD). In each replication, the treatments were assigned at random, with randomly picked fruits included in each treatment combination.

3.6 Experimental treatments

The experiment consisted of two factors:

Factor A: Different packaging materials

P_0: No packaging

P_1: Non perforated polythene bag

P_2: Perforated polythene bag

P_3: Newspaper

Factor B: Different postharvest treatments

R_0: Control

R_1: 250ppb 1- methylcyclopropene (1-MCP)

R_2: 4% $CaCl_2$

R_3: Aloe vera gel

R_4: Ginger extract

R_5: Hot water @ 45^0C for 5 minutes

3.7 Application of the treatments

The postharvest treatments for the selected banana fruits were assigned at random in the study. The fruits were stored at room temperature on a white paper that had been laid on a laboratory table prior to the treatments. Each treatment consisted of four-finger replications. The following were the processes for administering postharvest treatments to the fruits:

3.7.1 Different packaging materials:

3.7.1.1 Control (P_0)

No packaging was used in P_0, and the fruits were left on white paper of the shelf, exposed to the ambient room temperature condition.

3.7.1.2 Non perforated polythene (P_1)

After being treated with various procedures, the fruits were stored in a non-perforated polythene bag (14inch×10inch). The fruits were first coated then left to absorb and/or dry out the coatings before being placed in the non-perforated polythene bags.

3.7.1.3 Perforated polythene (P_2)

After being treated with various procedures, the fruits were preserved in perforated polythene bags (8 holes per bag). The fruits were first coated then left to absorb and/or dry out the coatings before being placed in perforated polythene bags.

3.7.1.4 Newspaper (P_3)

After being treated with various methods, fruits were wrapped in newspaper and kept. The fruits were first coated then left to absorb and/or dry out the coatings before being wrapped in newspapers.

3.7.2 Different postharvest treatments:

3.7.2.1 Control (R_0)

No treatment was used in R_0, and the fruits were left on white paper of the shelf, exposed to the ambient room temperature condition.

3.7.2.2 1- methylcyclopropene (1-MCP) (R_1)

Fruits were treated with 250 ppb 1-MCP (Smart Fresh, 0.14%) for 24 hours at 20±1˚C in sealed box. The required concentrations of 1-MCP were obtained by adding warm distilled water at 50˚C to the appropriate amounts of 1-MCP (Smart Fresh, 0.14%) powder, calculated according to the free space volume, in 100 ml flasks. After complete dissolution of 1-MCP powder, the flasks were placed and opened in the treatment chambers which were immediately sealed to avoid gas loss.

3.7.2.3 $CaCl_2$ (R_2)

40g of $CaCl_2$ salt was dissolved in 1000ml water to make 4 % $CaCl_2$ solution. The solution was manually swirled, and the fruits were then soaked for 10 minutes and then dried before being put to storage (Plate 1).

3.7.2.4 Aloe-vera gel (R_3)

Aloe vera pulp blending by using blender machine and filtered with a clean sterilized cloth. As a result, the aloe vera gel was created. The selected fingers were then submerged in the gel for 5 minutes, allowed to air dry for 10 minutes, and then placed on white paper for observation at room temperature (Plate 1).

3.7.2.5 Ginger extracts (R_4)

For obtaining required concentrated ginger extract, at first 500 gm ginger was made by blending fresh ginger and immersing it in 2.5 liters of water overnight before using as a therapy. Then a clean sterile cloth was used to filter the liquid. After that, the fruits were dipped into the solutions for 5 minutes to ensure that a

sufficient amount of extract was absorbed. After allowing the treated fruits to air dry for 10 minutes, they were placed on white paper to be observed (Plate 1).

3.7.2.6 Hot water treatment (45 ± 2°C for 5 minutes) (R_5)

For hot water treatment, the banana fingers were immersed into hot water (45±2°C) for 5 minutes before placing them on the white paper placed on the table in the laboratory at ambient condition (Plate 1).

3.8 Parameter studied

The following parameters were studied:

1. Physiological weight loss of banana (%)
2. Pulp to peel ratio
3. Moisture content (%)
4. Dry matter content (%)
5. Total soluble solid (%)
6. Total sugar content of pulp (%)
7. Reducing sugar content of pulp (%)
8. Non-reducing sugar content of pulp (%)
9. Titratable acidity of pulp (%)
10. Decay (%)
11. Shelf life (Days)

3.9 Methods of studying physico-chemical properties

Physico-chemical parameters were investigated over time to evaluate how they changed as a result of treatment for:

3.9.1 Total weight loss (%)

At 3-days intervals, the weight of each treatment's fruits was measured using an electric balance, and the percent weight reduction was computed using Ranganna's (1979) formula:

Total weight loss (%) = (IW-FW) /IW ×100

Here,

IW= Initial/Fresh weight

FW= Final weight

3.9.2 Pulp to peel ratio

The fruits were peeled at the end of the storage shelf life. Following the separation of the peel from the pulp, the weights of the peel and pulp were taken separately using an electric balance, and the pulp to peel ratio was computed.

3.9.3 Moisture content (%)

At the end of shelf life, each treatment and replication received 10g of fruit pulp, which was weighed and placed in an electric oven at 80°C for 72 hours until the weight did not change. After that, it was cooled down and the weight was taken once more.

Moisture content was measure by the following formula by Ranganna (1979)-

Moisture content (%) = (IW-FW)/ IW × 100

Here,

IW= Initial weight of fruit pulp

FW= Final weight of the fruit pulp

3.9.4 Dry matter content (%)

The dry matter content of the banana pulp was used to calculate the percent dry matter content using the following formula:

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

3.9.5 Total Soluble Solid (TSS)

At room temperature, the total soluble solids of well mixed banana fruit pulp were directly measured using a hand refractometer (Model BS Eclipse 3-45) at the end of shelf. A drop of fruit pulp was placed on the refractometer's prism, and the reading was taken. The percentage soluble solids (°Brix) were used to express the results.

3.9.6 Determination of total sugar content of banana pulp

The Anthrone method was used to determine the total sugar content of banana pulp (Jayaraman, 1981). To determine total sugar, the following reagents were used:

I. **Anthrone reagent:** The reagent was prepared by dissolving 2g of anthrone in 1 liter of concentrated H_2SO_4.
II. **Standard glucose solution:** A standard solution of glucose was prepared by dissolving 10 mg of glucose in 10 ml distilled water.

Estimation of sugar from banana pulp

The method of Loomis and Shull was used to extract sugar from banana pulp (1937). Banana pulps were chopped into little pieces and immediately immersed in boiling ethyl alcohol for ten minutes (10 ml of alcohol was used per g of pulp). The ground tissue was re-extracted for 3 minutes in hot 80 percent alcohols, using 2 to 3ml of alcohol per g of tissue, after the extract was filtered through two layers of cloths. After cooling, the extract was passed through two layers of cloths. Whatman No. 41 filter paper was used to filter both extracts. The extract was cooled after being evaporated to 25% of its original volume in a stem bath. This reduced volume of extract was transferred to a 100 ml volumetric flask, which was then filled with distilled water to the desired volume.

Procedure

1 ml pulp extract was pipette into test tubes, and 4 ml Anthrone reagent was added to each solution and thoroughly mixed. To avoid water loss due to evaporation, glass marbles were placed on top of each test tube. The tubes were then immersed in a boiling water bath for 10 minutes before being removed and chilled. A reagent blank was made by mixing 1 ml water with 4 ml Anthrone reagent in a tube and treating in the same way. In a colorimeter, the absorbance of blue-green solution was measured at 620 nm (Plate 2).

0.0, 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 ml of standard glucose solution were placed in test tubes containing 0.0, 10, 20, 40, 60, 80, and 100 g of glucose, respectively, and the volume was increased to 1 ml with distilled water. After that, 4ml of Anthrone reagent was used.

The amount of total sugar in the extract was estimated using a glucose standard curve. Finally, the percentage of total sugar was calculated using the formula below:

$$\text{Percent total sugar (g/100g)} = \frac{\text{Amount of sugar obtained (g)}}{\text{Weight of sample (g)}} \times 100$$

3.9.7 Determination of reducing sugar of banana pulp

The dinitrosalicylic acid technique was used to determine reducing sugar content of banana pulp (Miller, 1972).

Reagents:

I. **Dinitrosalicylic acid (DNS) reagent:** Simultaneously 1g of DNS, 200ml of crystalline Phenol and 50 mg of sodium sulphite were placed in a beaker and mixed with 100 ml of 1% NaOH by stirring. When it was needed tostore, then sodium sulphite was added just before use.

II. **40% solution of Rochelle salt:** It was prepared by dissolving 40 g of sodium potassium tartarate with 100 ml of distilled water in 100 volumetric flask.

Procedure

3ml aliquot of the extract was pipette into a test tube then 3ml of DNS reagent was added to each solution and thoroughly mixed. In a boiling water bath, the test tube was heated for 5 minutes. When the color had developed, 1ml of Rochelle salt (40%) was added to the tubes while they were still heated. After that, the test tubes were cooled by running water. Three milliliters of distilled water and three milliliters of DNS reagent were combined in a tube and handled similarly. In a colorimeter, the solution's absorbance was measured at 575 nm (Plate 2).

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

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

3.9.8 Estimation of non-reducing sugar content of pulp

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

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

3.9.9 Titratable acidity of pulp

To determine titratable acidity, the following reagents were employed. To determine titratable acidity, the following reagents were employed.

I. Standard NaOH solution (0.1 N)
II. 1% phenolphthalein solution

Extraction of banana pulp

In a 100 ml beaker, ten grams of fresh banana pulp was placed and homogenized with distilled water in a blender. The combined components were then filtered and transferred to a 100 ml volumetric flask, which was then filled with distilled water to the desired volume.

Procedure

In a conical flask, ten milliliters of pulp solution were taken. After adding two to three drops of phenolphthalein indicator, the conical flask was violently shaken. It was then promptly filtered through a burette with 0.1 N NaOH solution until a persistent pink color developed (Plate 2). Burette readings were used to calculate the amount of NaOH solution needed for titration. The following formula was used to compute percent titratable acidity:

$$\% \text{ Titratable acidity} = \frac{T \times N \times V_1 \times E}{V_2 \times W \times 1000} \times 100$$

Where,

T= Titre

N= Normality of NaOH

V_1= Volume made up

V_2= Volume of extract

E= Equivalent weight of acid

W= Weight of sample

3.9.10 Shelf life

The shelf life of banana fruits was estimated by counting the days from harvest to the last edible stage, by observing visual estimation of 15-20% surface spots appearance on banana as impacted by various post-harvest treatments (Mondal, 2000).

3.10 Statistical analysis

The collected data were statistically analyzed by STATISTIX 10 software. At the 1% level of probability, the significance of the difference between the pairs of means was examined using the least significant difference (LSD) test (Gomez and Gomez, 1984).

A. Collection of banana from field

B. Preparation of postharvest treatments

C. Banana treated by ginger extract

D. Banana treated by Aloe vera gel

E. Banana treated by $CaCl_2$ solution

F. Banana treated by hot water

Plate 1: Application of postharvest treatments

G. Titration for TA

H. Addition DNS reagent in sample

I. Estimation of total sugar, reducing sugar

J. Estimation of total sugar, reducing sugar

Plate 2: Chemical analysis of banana pulp

CHAPTER IV

RESULTS AND DISCUSSION

This chapter accounts for the presentation of the results acquired from the present study. The results of the study on quality and shelf life of banana during storage period of "BARI Kola 1" banana variety are represented and discussed from Table 1 to Table 11 and Figure 1 to Figure 22 in this chapter. These results are explained under the following headings:

4.1 Changes in physiological characteristics of banana during storage

4.1.1 Percent weight loss

There was a significant variation in percent weight loss between the three packaging treatments (Appendix II). However, increasing trend in percent weight loss was found from 3 DAS to 15 DAS. The maximum weight loss(3.52%, 7.26%, 11.19%, 15.39% and 19.60% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively), was found in P_3 (Newspaper wrapping fruits) and minimum (0.19%, 0.42%, 0.65%, 0.92% and 1.22% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was found in P_1 (non perforated poly bags stored fruits) (Fig. 1).

The percent weight loss demonstrated that there was a significant variation in postharvest banana treatments in relation to storage time (Appendix II). It was found that the maximum loss in weight (2.31%, 4.49%, 6.54%, 8.98% and 11.74% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was found in R_0 (non treated fruits) and the minimum (1.80%, 3.70%, 5.68%, 7.99% and 10.36% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day after harvest, respectively) was found in R_1 (1-MCP treated fruits) (Fig. 2).

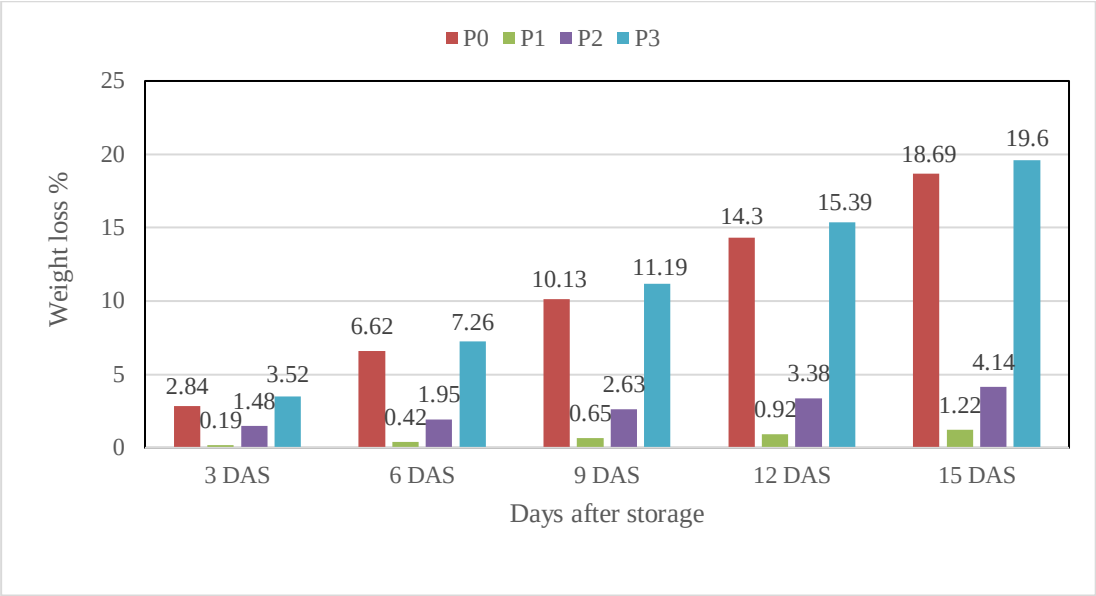

Figure 1: Effect of packaging materials on weight loss (%) of banana at different days after storage (DAS)

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

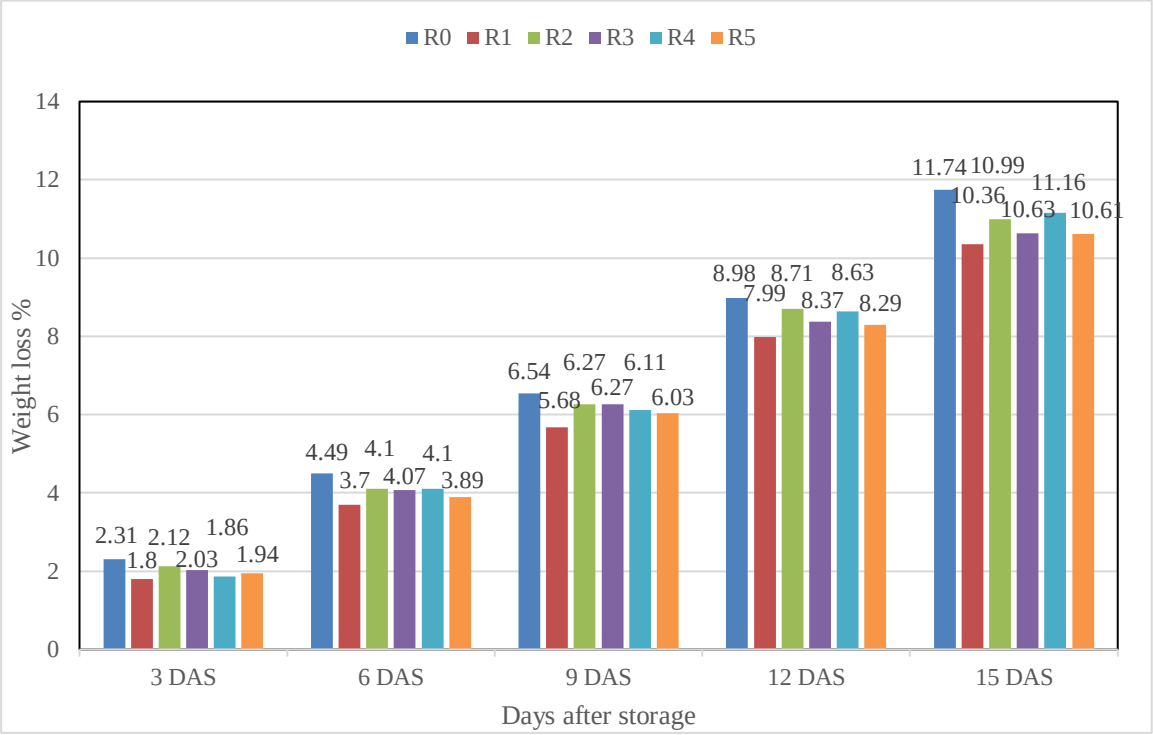

Figure 2: Effect of different postharvest treatments on weight loss (%) of banana at different days after storage (DAS)

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of packaging materials and postharvest treatments on total weight loss was statistically significant at 3rd, 6th, 9th, 12th and 15th days after storage (Appendix II). The highest rate of weight loss (3.87%, 8.63%, 12.36%, 17.37% and 23.28% at 3rd, 6th, 9th, 12th and 15th DAS) was observed in P_0R_0 (untreated fruits without packaging) combination and lowest (0.15%, 0.31%, 0.53%, 0.79% and 0.97% at 3rd, 6th, 9th, 12th and 15th DAS) rate was recorded in P_1R_0 (untreated fruits stored in non perforated poly bag) combination (Table 1).

The weight loss of bananas increased with the progress of storage duration. The combined effects of packaging materials and postharvest treatments were statistically significant at all days of observation. The highest weight loss was recorded in banana of control (P_0R_0), treatment during storage period and the lowest weight loss was recorded in untreated fruits stored in non perforated poly bag (P_1R_0) treatment during storage period. Sealed polythene bags may have inactivated the enzymes and slowed down other physiological processes that cause reduced weight loss. Jiang *et al*. (1999) reported that fruits ripening can be delayed by using 1-MCP in conjunction with polythene bags considerably.

Table 1: Combined effect of packaging materials and postharvest treatments on weight loss (%) of banana at different days after storage (DAS)

Treatments	Percent weight loss				
	3 DAS	**6 DAS**	**9 DAS**	**12 DAS**	**15 DAS**
P_0R_0	3.87 a	8.63 a	12.36 a	17.37 a	23.28 a
P_0R_1	1.86 g	5.04 f	7.99 f	12.01 f	15.88 e
P_0R_2	3.04 de	6.52 de	10.14 cd	14.18 d	18.21 d
P_0R_3	3.15 cd	7.27 bc	11.54 b	15.54 c	19.77 c
P_0R_4	2.40 f	6.10 e	9.26 e	13.41 de	17.41 d
P_0R_5	2.72 ef	6.14 e	9.49 de	13.28 e	17.58 d
P_1R_0	0.15 i	0.31 i	0.53 h	0.79 h	0.97 g
P_1R_1	0.15 i	0.40 i	0.65 h	0.90 h	1.27 g
P_1R_2	0.18 i	0.41 i	0.62 h	0.96 h	1.40 g
P_1R_3	0.23 i	0.44 i	0.66 h	0.88 h	1.09 g
P_1R_4	0.28 i	0.53 i	0.76 h	1.06 h	1.38 g
P_1R_5	0.18 i	0.43 i	0.67 h	0.92 h	1.24 g
P_2R_0	1.63 g	2.02 g	2.79 g	3.63 g	4.52 f
P_2R_1	1.45 gh	1.98 gh	2.53 g	3.25 g	3.99 f
P_2R_2	1.71 g	2.18 g	2.74 g	3.53 g	4.27 f
P_2R_3	1.48 gh	1.94 gh	2.50 g	3.17 g	3.86 f
P_2R_4	1.48 gh	2.08 g	2.81 g	3.56 g	4.35 f
P_2R_5	1.15 h	1.49 h	2.41 g	3.13 g	3.86 f
P_3R_0	3.59 ab	7.01 cd	10.48 c	14.12 de	18.19 d
P_3R_1	3.73 a	7.40 bc	11.53 b	15.79 bc	20.28 c
P_3R_2	3.55 a-c	7.29 bc	11.59 b	16.18 bc	20.08 c
P_3R_3	3.26 b-d	6.62 de	10.37 c	13.89 de	17.79 d
P_3R_4	3.27 b-d	7.70 b	11.61 b	16.51 ab	21.49 b
P_3R_5	3.72 a	7.51 bc	11.56 b	15.84 bc	19.74 c
CV%	9.17	5.91	5.56	4.82	4.48
$LSD_{0.01}$	0.404	0.526	0.749	0.897	1.071

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.1.2 Pulp to peel ratio

Significant variation was observed in respect of pulp to peel ratio of banana fingers between packaging materials and postharvest treatments of banana at the end of shelf life (Appendix III).

The maximum (3.65) pulp to peel ratio of banana was found in P_0 (non packaging fruits) and minimum (2.34) pulp to peel ratio was found in P_2 (perforated poly bags stored fruits) (Fig. 3).

It was recorded that the highest (3.01) pulp to peel ratio of banana was noticed in R_0 (untreated fruits) and the minimum (2.75) pulp to peel ratio was found in R_1 (1-MCP treated fruits) (Fig. 4).

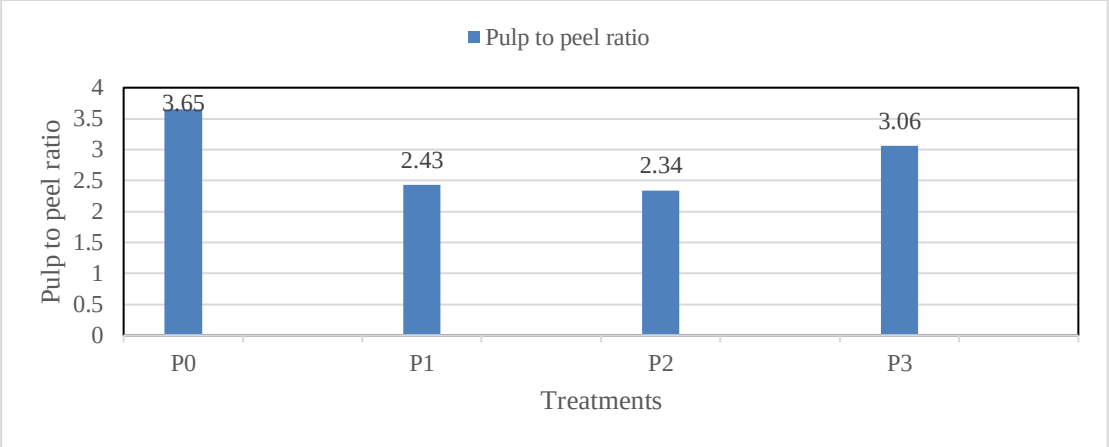

Figure 3: Effect of packaging materials on pulp to peel ratio of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated poly bag, P_2=Perforated poly bag, P_3= Newspaper wrapping

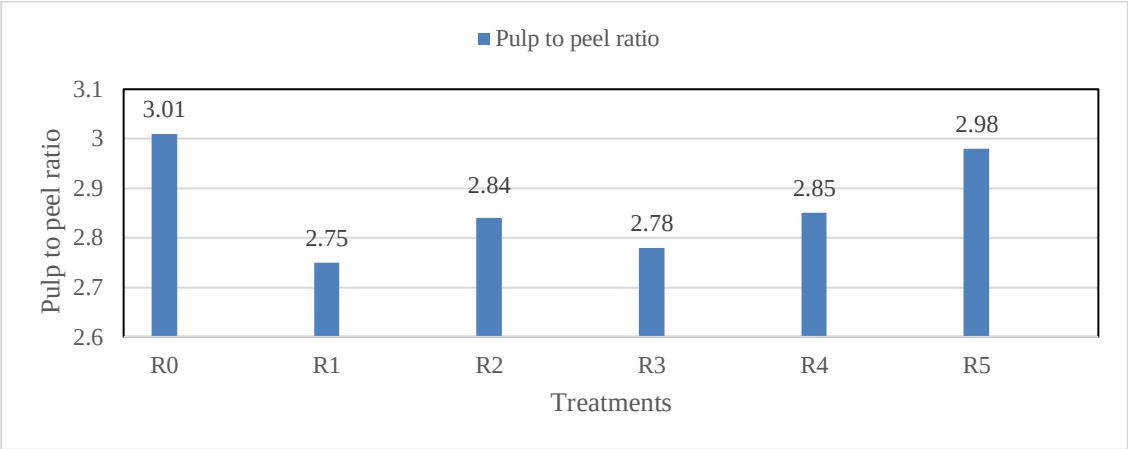

Figure 4: Effect of different postharvest treatments on pulp to peel ratio of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of pulp to peel ratio in banana fingers was found to be statistically significant at the end of shelf life (Appendix III). The maximum (4.33) pulp to peel ratio was found in P_0R_0 (untreated fruits without packaging) combination and minimum (2.12) pulp to peel ratio was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination (Table 2).

During storage, the ratio of pulp to peel increased day by day, as observed in this experiment. Because the increased ratio during storage could be due to a difference in sugar concentration in the pulp compared the peel, resulting in a distinct osmotic pressure shift. Both transpiration and osmosis release water from the banana peel. As a result, the peels weight decreases and the pulp to peel ratio increases. The interaction effects between packaging materials and postharvest treatments were statistically significant during storage period. The highest pulp to peel ratio was recorded in control treatment (P_0R_0) during storage period and the lowest pulp to peel ratio was recorded in 1-MCP treated fruits stored in perforated zip poly bags (P_2R_1) during storage period. Similar result was reported by Pathak and Sanwal (1999). He mentioned that pulp to peel ratio increased during ripening.

Table 2: Combined effect of packaging materials and postharvest treatments on pulp to peel ratio of banana at different days after storage (DAS)

Treatments	Pulp to peel ratio
P_0R_0	4.33 a
P_0R_1	3.36 b-d
P_0R_2	3.39 bc
P_0R_3	3.29 b-e
P_0R_4	3.49 b
P_0R_5	4.04 a
P_1R_0	2.41 i-k
P_1R_1	2.29 jk
P_1R_2	2.76 f-i
P_1R_3	2.51 h-k
P_1R_4	2.25 jk
P_1R_5	2.36 i-k
P_2R_0	2.27 jk
P_2R_1	2.12 k
P_2R_2	2.32 jk
P_2R_3	2.29 jk
P_2R_4	2.44 i-k
P_2R_5	2.59 g-j
P_3R_0	3.04 c-f
P_3R_1	3.23 b-e
P_3R_2	2.90 e-h
P_3R_3	3.05 b-f
P_3R_4	3.21 b-e
P_3R_5	2.95 d-g
CV%	6.97
$LSD_{0.01}$	0.438

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.1.3 Percent moisture content

Significant variation was observed in respect of moisture content (%) of banana pulp between packaging materials and postharvest treatments of banana at the end of shelf life (Appendix III).

The maximum (81.62%) moisture content of banana was found in P_1 (non perforated poly bags stored fruits) and the minimum (80.17%) moisture was found in P_3 (Newspaper wrapping fruits) (Fig. 5).

It was recorded that the highest moisture (81.10%) content was noticed in R_0 (untreated fruits) and the minimum (80.53%) moisture content was found in R_4 (ginger extract treated fruits) treated banana (Fig. 6).

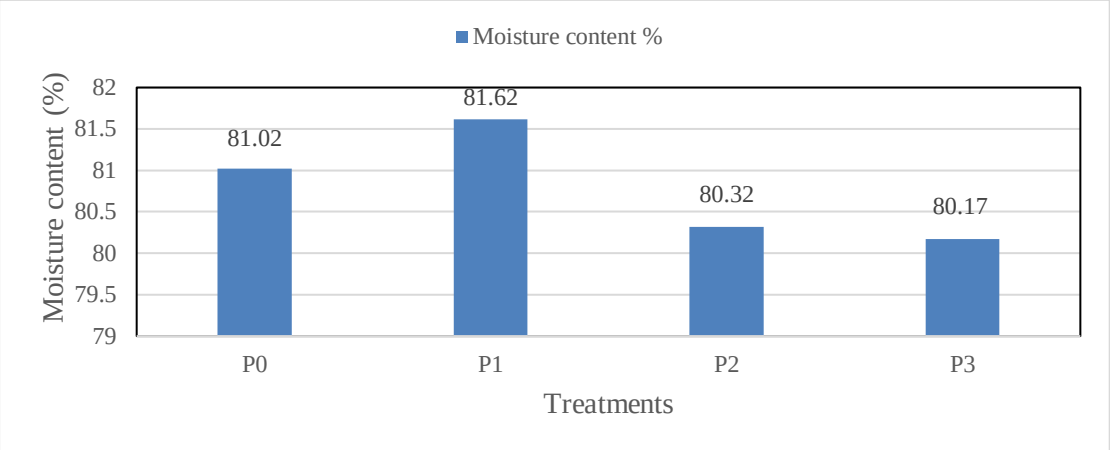

Figure 5: Effect of packaging materials on percent moisture content of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated poly bag, P_2=Perforated poly bag, P_3= Newspaper wrapping

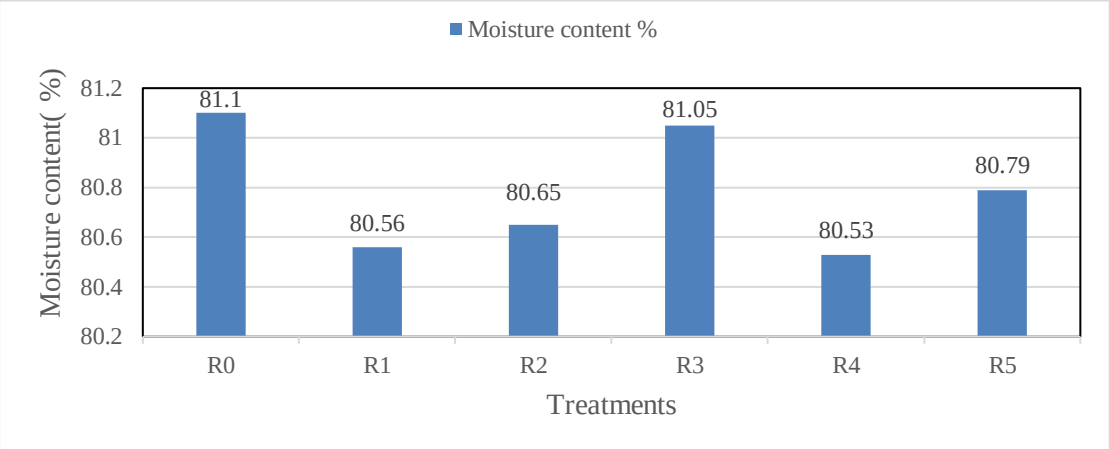

Figure 6: Effect of different postharvest treatments on percent moisture content of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of moisture content in banana pulp was found to be statistically significant at the end of shelf life (Appendix III). The maximum moisture content (82.50%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum moisture content (79.23%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination (Table 3).

From the experiment it was observed that moisture content gradually increased with the advance of period. Among the treatments, the minimum moisture content was observed in 1-MCP treated fruits stored in perforated poly bags (P_2R_1) treatment. For this reason, this is the best treatment to control the increasing rate of moisture content. The combined effects of packaging materials and postharvest treatments were statistically significant at all days of observation. The highest moisture content was recorded in control treatment (P_0R_0) during storage period and the lowest weight loss was recorded in 1-MCP treated fruits stored in perforated poly bags (P_2R_1) treatment during storage period. These results are supported by the findings of Krishnamurthy (1993). He found that moisture content of the pulp of banana fruits increased from 69-75% and dry matter 25-31% and that of peel decreased during ripening.

Table 3: Combined effect of packaging materials and postharvest treatments on moisture content of banana pulp at the end of shelf life

Treatments	Moisture content %
P_0R_0	82.50 a
P_0R_1	81.30 b-d
P_0R_2	80.63 c-g
P_0R_3	80.50 d-g
P_0R_4	80.04 g-i
P_0R_5	81.13 b-f
P_1R_0	81.79 ab
P_1R_1	81.22 b-e
P_1R_2	81.81 ab
P_1R_3	81.94 ab
P_1R_4	81.57 a-c
P_1R_5	81.41 b-d
P_2R_0	79.82 g-i
P_2R_1	79.23 i
P_2R_2	80.22 f-h
P_2R_3	81.52 bc
P_2R_4	79.86 g-i
P_2R_5	81.26 b-e
P_3R_0	80.30 e-h
P_3R_1	80.48 d-g
P_3R_2	79.95 g-i
P_3R_3	80.25 f-h
P_3R_4	80.67 c-g
P_3R_5	79.37 hi
CV%	0.54
$LSD_{0.01}$	0.961

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.1.4 Percent dry matter content

The dry matter content (%) of banana pulp varied significantly between packaging materials and postharvest banana treatments at the end of shelf life (Appendix III).

The maximum (19.83%) dry matter content of banana was found in P_3 (newspaper wrapping stored fruits) and minimum (18.38%) dry matter content was found in P_1 (non perforated poly bags fruits) (Fig. 7).

It was recorded that the highest dry matter (19.47%) content was noticed in R_4 (ginger extract treated fruits) and the minimum (18.90%) dry matter content was found in R_0 (untreated fruits) treated banana (Fig. 8).

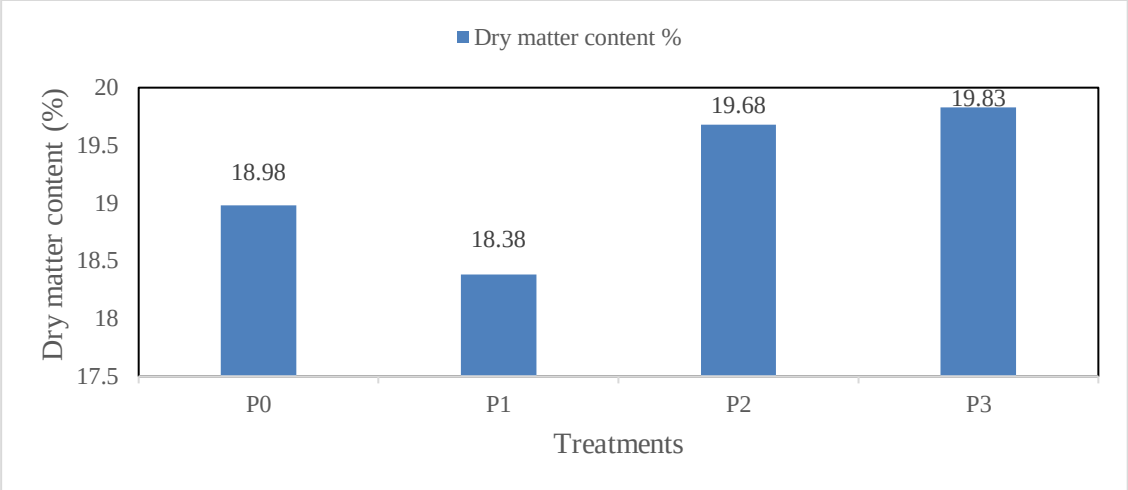

Figure 7: Effect of packaging materials on percent dry matter content of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated poly bag, P_2=Perforated poly bag, P_3= Newspaper wrapping

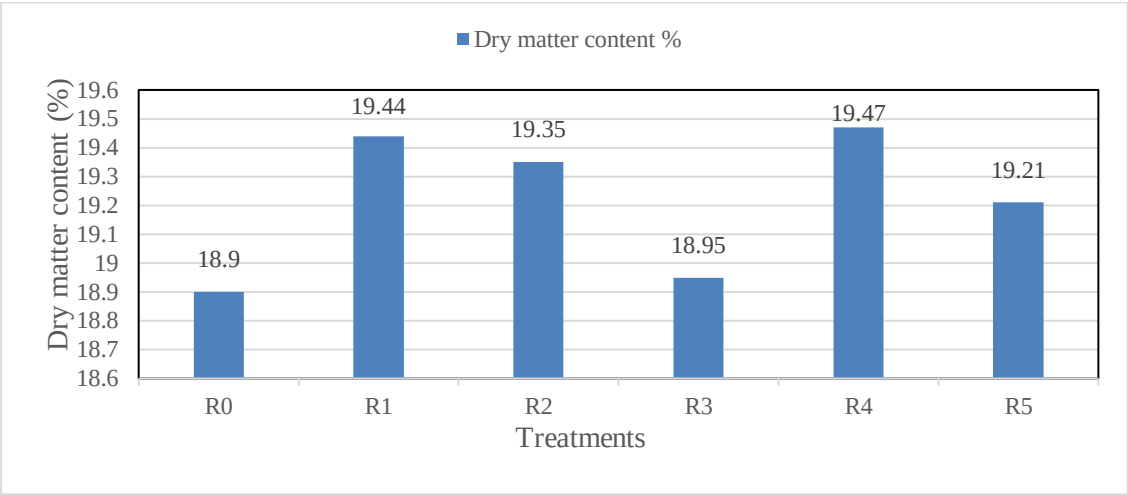

Figure 8: Effect of different postharvest treatments on percent dry matter content of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of dry matter content in banana pulp was found to be statistically significant at the end of shelf life (Appendix III). The maximum dry matter content (20.77%) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and minimum dry matter content (17.50%) was recorded in P_0R_0 (untreated fruits without packaging) combination (Table 4).

Dry matter content is always reverse with the moisture content. So, here dry matter content gradually decreased with the advance of period. The fastest decreasing rate of dry matter content was observed in control bananas (P_0R_0) and the slowest decreasing rate of dry matter content was observed in 1-MCP treated fruits stored in perforated poly bags (P_2R_1) treatment. So, 1- MCP treated fruits stored in perforated poly bags (P_2R_1) is the best treatment to control the decreasing rate of dry matter content. Combination effects of packaging materials and postharvest treatments were statistically significant during storage period. The highest dry matter content was recorded in 1-MCP treated fruits stored in perforated zip poly bags (P_2R_1) treatment and the lowest dry matter content was recorded in bananas of control (P_0R_0) treatment during storage period.

Table 4: Combined effect of packaging materials and postharvest treatments on dry matter content of banana pulp at the end of shelf life

Treatments	Dry matter content %
P_0R_0	17.50 k
P_0R_1	18.70 e-j
P_0R_2	19.37 c-h
P_0R_3	19.50 c-g
P_0R_4	19.96 a-c
P_0R_5	18.87 d-i
P_1R_0	17.54 k
P_1R_1	18.78 d-j
P_1R_2	18.19 i-k
P_1R_3	17.77 jk
P_1R_4	18.43 h-k
P_1R_5	18.59 f-j
P_2R_0	20.18 a-c
P_2R_1	20.77 a
P_2R_2	19.78 a-d
P_2R_3	18.48 g-k
P_2R_4	20.14 a-c
P_2R_5	18.74 e-j
P_3R_0	19.70 b-e
P_3R_1	19.52 c-f
P_3R_2	20.05 a-c
P_3R_3	19.75 a-d
P_3R_4	19.33 c-h
P_3R_5	20.63 ab
CV%	2.44
$LSD_{0.01}$	1.027

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.2 Changes in chemical characteristics of banana during storage

4.2.1 Percent total soluble solid

Significant variation in TSS concentration (%) of banana pulp was found between packaging materials and postharvest banana treatments towards the end of shelf life (Appendix IV).

The maximum (20.04%) TSS content of banana was found in P_3 (No packaging fruits) and minimum (18.10%) TSS content was found in P_1 (non perforated poly bags fruits) (Fig. 9).

It was recorded that the highest TSS (19.29%) content was found in R_4 (Ginger extract treated fruits) and the minimum (17.92%) TSS content was found in R_1 (1-MCP treated fruits) treated banana (Fig.10).

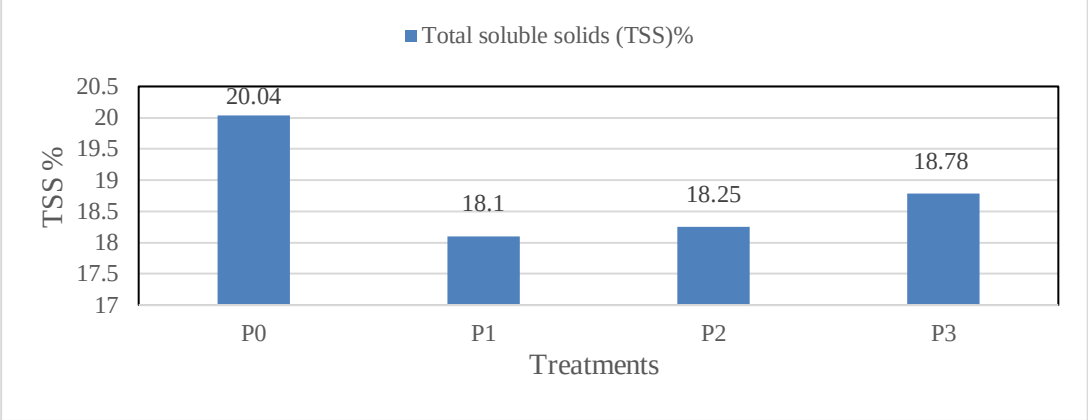

Figure 9: Effect of packaging materials on percent total soluble solids of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated poly bag, P_2=Perforated poly bag, P_3= Newspaper wrapping

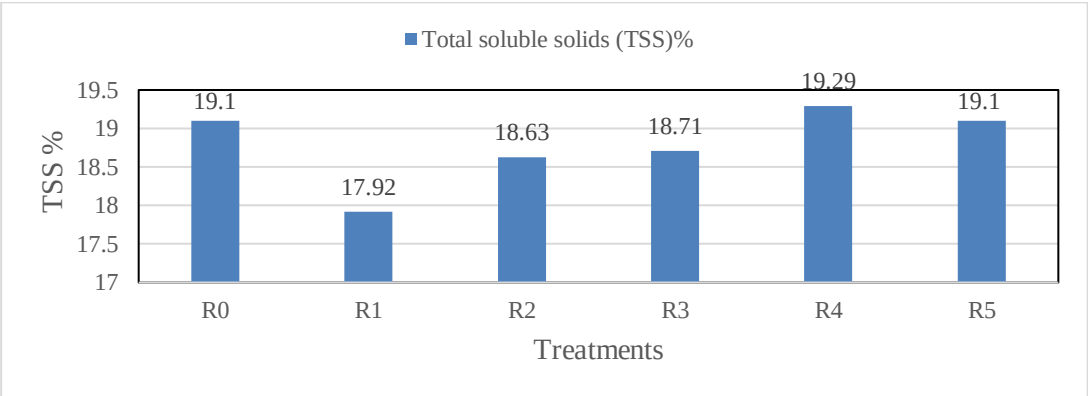

Figure 10: Effect of different postharvest treatments on percent total soluble solids of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of TSS content in banana pulp was found to be statistically non-significant at the end of shelf life (Appendix IV). The maximum TSS content (21.00%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum TSS content (17.17%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) (Table 5).

From the experiment it was observed that TSS value increased with the advance of time in all the treatments. But control showed the highest value than the other. The degree of increase in TSS value for different postharvest treatments might be due to the modified internal atmosphere and physiological aspects of banana fruits, suppressed respiration and metabolic processes, which involve in increasing TSS at different magnitudes. The combined effects of packaging materials and postharvest treatments were statistically significant during storage period.

The highest TSS was recorded in control treatment during storage period and the lowest TSS was recorded in 1-MCP treated fruits stored in perforated zip poly bags treatment during storage period. Munasque and Mandoza (1990) stated that total soluble solids increased during ripening which is similar to the findings of the present study.

Table 5: Combined effect of packaging materials and postharvest treatments on total soluble solids (TSS) of banana pulp at the end of shelf life

Treatments	Total soluble solids (TSS)
P_0R_0	21.00 a
P_0R_1	18.92 c-f
P_0R_2	20.00 a-c
P_0R_3	20.00 a-c
P_0R_4	20.17 ab
P_0R_5	20.17 ab
P_1R_0	17.83 f-h
P_1R_1	17.67 gh
P_1R_2	18.00 e-h
P_1R_3	18.33 d-h
P_1R_4	18.42 d-g
P_1R_5	18.33 d-h
P_2R_0	18.58 d-g
P_2R_1	17.17 h
P_2R_2	18.08 e-h
P_2R_3	18.00 e-h
P_2R_4	19.17 b-e
P_2R_5	18.50 d-g
P_3R_0	19.00 b-f
P_3R_1	17.92 f-h
P_3R_2	18.42 d-g
P_3R_3	18.50 d-g
P_3R_4	19.42 b-d
P_3R_5	19.42 b-d
CV%	2.90
$LSD_{0.01}$	1.195

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.2.2 Percent total sugar content

The total sugar content (%) of banana pulp varied significantly between packaging materials and postharvest banana treatments at the end of shelf life (Appendix IV).

The maximum (20.61%) total sugar content of banana was found in P_2 (perforated poly bags stored fruits) and minimum (19.98%) total sugar content was found in P_1 (non perforated poly bags stored fruits) (Fig. 11).

It was recorded that the highest total sugar (21.01%) content was obtained in R_0 (untreated fruits) and the minimum (19.81%) total sugar content was found in R_1 (1-MCP treated fruits) treated banana (Fig. 12).

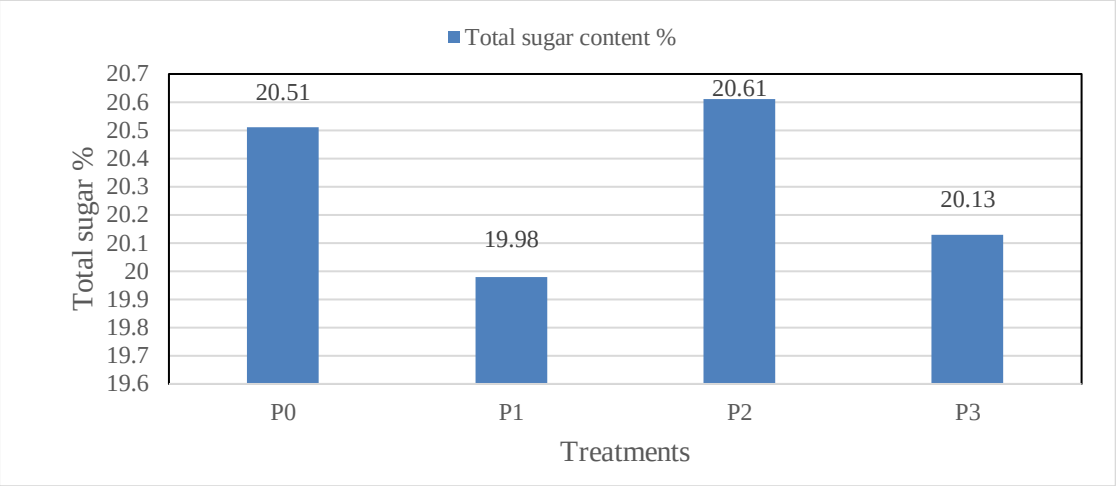

Figure 11: Effect of packaging materials on percent total sugar content of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

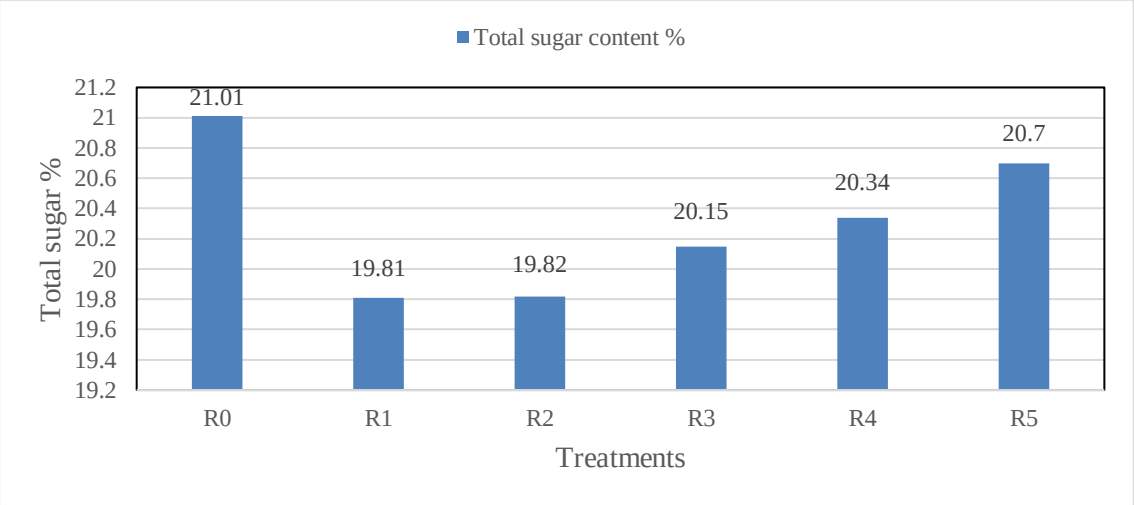

Figure 12: Effect of different postharvest treatments on percent total sugar of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of total sugar content in banana pulp was found to be statistically significant at the end of shelf life (Appendix IV). The maximum total sugar content (22.43%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum total sugar content (18.52%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination (Table 6).

Total sugar content increased gradually during storage period which was observed in this experiment. During ripening, banana fruits undergo physiological changes. The most striking chemical changes which occur during the postharvest ripening of banana fruits were hydrolysis of starch and accumulation of sugars. The interaction effects of packaging materials and postharvest treatments were statistically significant during storage period. The highest total sugar content was recorded control treatment during storage period and the lowest total sugar content was recorded in 1-MCP treated fruits stored in perforated poly bags treatment during storage period. These results are supported by the findings of Bhardra and Sen (1999). They conducted an experiment and mentioned that total sugar contents of banana pulps increased as storage period progressed.

Table 6: Combined effect of packaging materials and postharvest treatments on total sugar content of banana pulp at the end of shelf life

Treatments	Total sugar content %
P_0R_0	22.43 a
P_0R_1	21.11 bc
P_0R_2	19.28 g-i
P_0R_3	19.42 f-i
P_0R_4	19.72 e-h
P_0R_5	21.11 bc
P_1R_0	20.90 b-d
P_1R_1	20.59 c-e
P_1R_2	18.89 hi
P_1R_3	19.42 f-i
P_1R_4	20.53 c-e
P_1R_5	19.56 f-h
P_2R_0	21.07 bc
P_2R_1	18.52 i
P_2R_2	20.75 b-d
P_2R_3	21.69 ab
P_2R_4	20.60 c-e
P_2R_5	21.04 bc
P_3R_0	19.65 e-h
P_3R_1	19.04 hi
P_3R_2	20.37 c-f
P_3R_3	20.07 d-g
P_3R_4	20.53 c-e
P_3R_5	21.09 bc
CV%	2.16
$LSD_{0.01}$	0.959

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.2.3 Percent reducing sugar content

Significant variation in reducing sugar content (%) of banana pulp was identified across packaging materials and postharvest banana treatments towards the end of shelf life (Appendix IV).

The maximum (14.29%) reducing sugar content of banana was found in P_0 (non packaging fruits) and minimum (13.77%) reducing sugar content was found in P_1 (non perforated poly bags stored fruits) ((Fig. 13).

It was recorded that the highest reducing sugar (14.97%) content was obtained in R_0 (untreated fruits) and the minimum (13.34%) reducing sugar content was found in R_1 (1-MCP treated fruits) treated banana (Fig. 14).

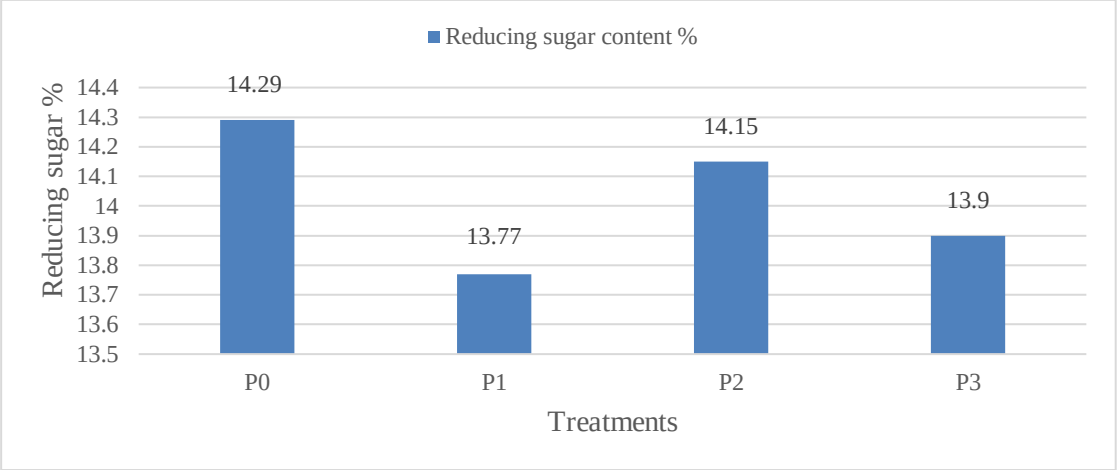

Figure 13: Effect of packaging materials on percent reducing sugar content of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

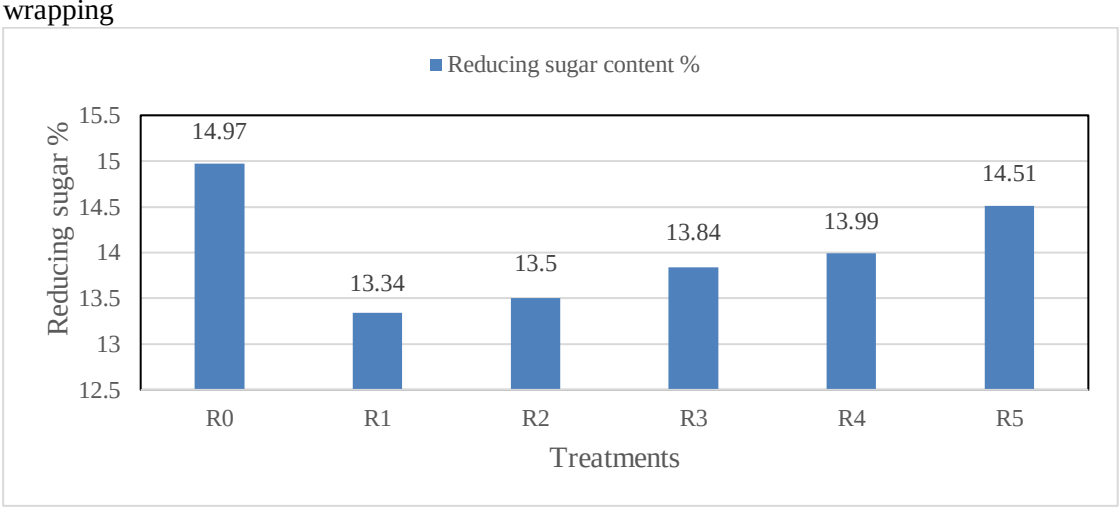

Figure 14: Effect of different postharvest treatments on percent reducing sugar of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of reducing sugar content in banana pulp was found to be statistically significant at the end of shelf life (Appendix IV). The maximum reducing sugar content (16.96%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum reducing sugar content (11.56%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags (Table 7).

Reducing sugar also increased gradually during storage period which was observed in this experiment. The increase of reducing sugar contents in banana pulp is resulted from the degradation of starch to glucose and fructose by the activities of amylase and maltase and also by conversion of some non-reducing sugar to reducing sugar. The combined effects of packaging materials and postharvest treatments were statistically significant during storage period. The highest reducing sugar content was recorded in control treatment during storage period and the lowest reducing sugar content was recorded in 1-MCP treated fruits stored in perforated poly bags treatment during storage period. Similar result was reported by Tandon *et al*. (1985). He mentioned that fructose content of banana pulp was increased during ripening.

Table 7: Combined effect of packaging materials and postharvest treatments on reducing sugar content of banana pulp at the end of shelf life

Treatments	Reducing sugar content %
P_0R_0	16.96 a
P_0R_1	14.79 bc
P_0R_2	13.02 gh
P_0R_3	13.08 gh
P_0R_4	13.09 gh
P_0R_5	14.79 bc
P_1R_0	14.59 b-d
P_1R_1	14.38 b-e
P_1R_2	12.60 h
P_1R_3	13.41 f-h
P_1R_4	14.35 b-e
P_1R_5	13.26 f-h
P_2R_0	14.41 b-e
P_2R_1	11.56 i
P_2R_2	14.74 bc
P_2R_3	15.06 b
P_2R_4	14.17 b-f
P_2R_5	14.96 b
P_3R_0	13.93 c-g
P_3R_1	12.62 h
P_3R_2	13.62 e-g
P_3R_3	13.82 d-g
P_3R_4	14.35 b-e
P_3R_5	15.04 b
CV%	2.98
$LSD_{0.01}$	0.915

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.2.4 Percent non-reducing sugar content

The non-reducing sugar content (%) of banana pulp varied non significant between packaging materials and postharvest banana treatments at the end of shelf life (Appendix IV).

The maximum (6.46%) non- reducing sugar content of banana was found in P_2 (perforated poly bags stored fruits) and minimum (6.17%) non- reducing sugar was found in P_3 (newspaper wrapping fruits) (Fig. 15).

It was recorded that the highest non- reducing sugar (6.47%) content was obtained in R_1 (1-MCP treated fruits) and the minimum (6.04%) non- reducing sugar content was found in R_0 (untreated fruits) treated banana (Fig. 16).

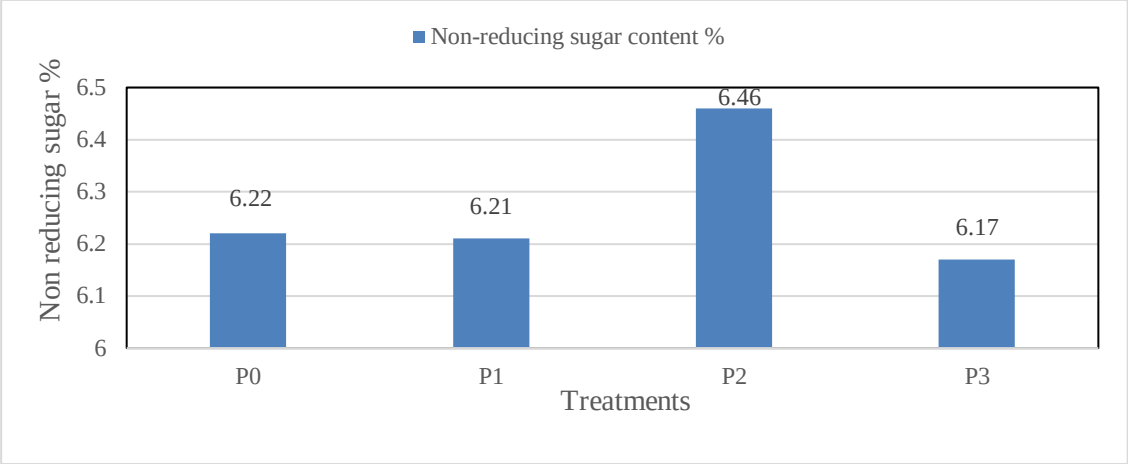

Figure 15: Effect of packaging materials on percent non reducing sugar content of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

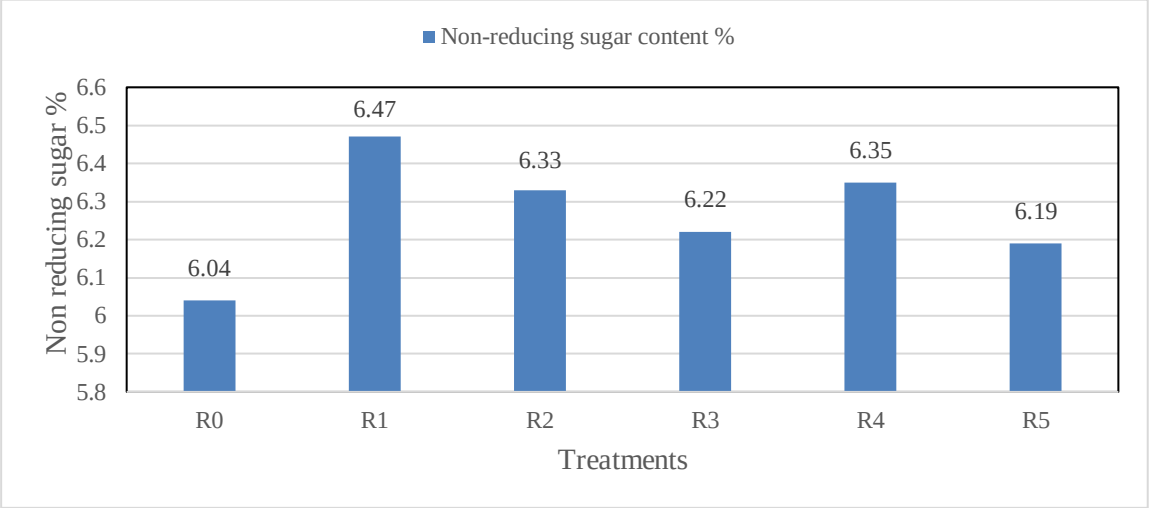

Figure 16: Effect of different postharvest treatments on percent non reducing sugar of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of non- reducing sugar content in banana pulp was found to be statistically significant at the end of shelf life (Appendix IV). The maximum non- reducing sugar content (6.96%) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and minimum non reducing sugar content (5.47%) was recorded in P_0R_0 (untreated fruits without packaging) combination (Table 8).

Non-reducing sugar contents decreased gradually at all the day of observation in this experiment. The combined effect of packaging materials and postharvest treatments were statistically significant at all days of observation. The highest level of non-reducing sugar content was recorded in 1-MCP treated fruits stored in perforated poly bags treatment of storage period and the minimum value was recorded in control treatment at of storage period. These results are similar by the findings of Joshi and Roy (1988). They estimated that after attaining a peak non reducing sugar remains more or less constant.

Table 8: Combined effect of packaging materials and postharvest treatments on non-reducing sugar content of banana pulp at the end of shelf life

Treatments	Non-reducing sugar content %
P_0R_0	5.47 e
P_0R_1	6.31 a-d
P_0R_2	6.25 a-e
P_0R_3	6.34 a-d
P_0R_4	6.62 a-c
P_0R_5	6.31 a-d
P_1R_0	6.30 a-d
P_1R_1	6.21 a-e
P_1R_2	6.30 a-d
P_1R_3	6.01 b-e
P_1R_4	6.18 a-e
P_1R_5	6.30 a-d
P_2R_0	6.65 a-c
P_2R_1	6.96 a
P_2R_2	6.01 b-e
P_2R_3	6.63 a-c
P_2R_4	6.43 a-d
P_2R_5	6.09 b-e
P_3R_0	5.72 de
P_3R_1	6.41 a-d
P_3R_2	6.75 ab
P_3R_3	5.92 c-e
P_3R_4	6.18 a-e
P_3R_5	6.05 b-e
CV%	5.81
$LSD_{0.01}$	0.798

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.2.5 Percent titratable acidity (% TA)

Significant variation in TA content (%) of banana pulp was found between packaging materials and postharvest banana treatments at the end of shelf life (Appendix IV).

The maximum (0.39%) TA content of banana was found in P_3 (Newspaper wrapping fruits) and minimum (0.33%) TA was found in P_2 (perforated poly bags stored fruits) (Fig. 17).

It was recorded that the highest TA (0.39%) content was obtained in R_0 (untreated fruits) and the minimum (0.34%) TA content was found in R_1 (1-MCP treated fruits) treated banana (Fig. 18).

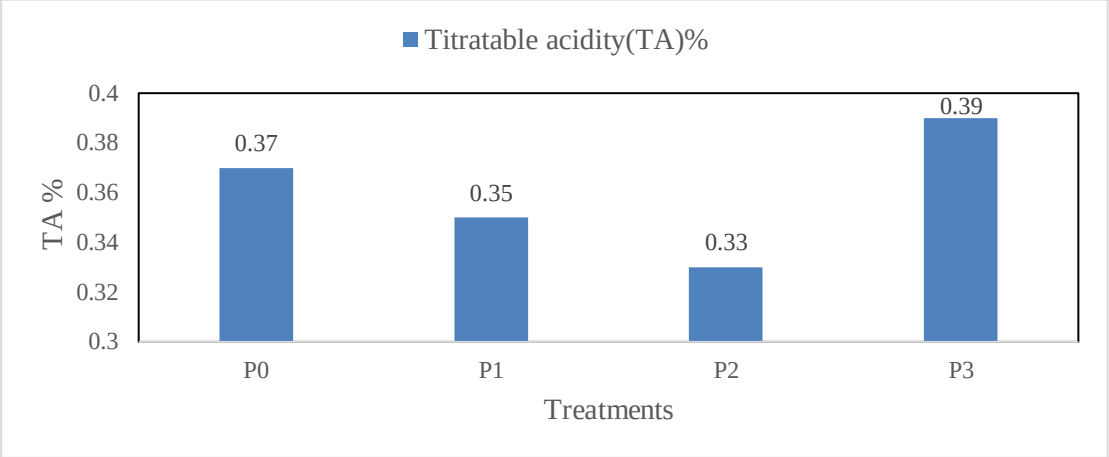

Figure 17: Effect of packaging materials on percent titratable acidity of banana at the end of shelf life

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

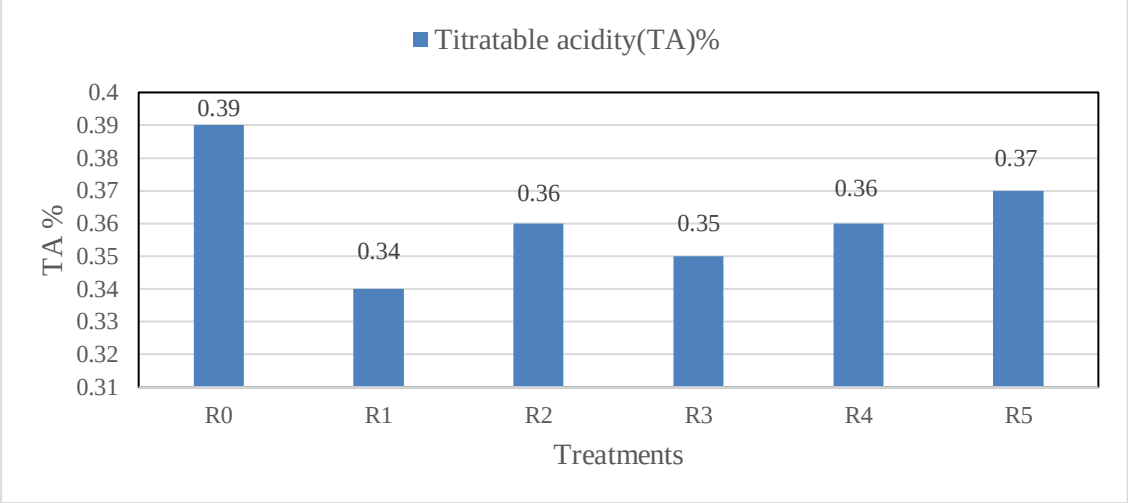

Figure 18: Effect of different postharvest treatments on percent titratable acidity of banana at the end of shelf life

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of TA content in banana pulp was found to be statistically significant at the end of shelf life (Appendix IV). The maximum TA content (0.45%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum TA content (0.29%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination (Table 9).

From this experiment it was observed that, titratable acidity gradually decreased during storage period. The interaction effects of packaging materials and postharvest treatments were statistically significant at all days of observation. The highest titratable acidity was recorded in control treatment and the minimum value was recorded in 1-MCP treated fruits stored in perforated poly bags treatment during storage period. These results are supported by the findings of Resis *et al*. (2004). He reported that the effect of chemical dip, calcium chloride + ascorbic acid and modified atmosphere storage loss the titratable acidity.

Table 9: Combined effect of packaging materials and postharvest treatments on titratable acidity (TA) of banana pulp at the end of shelf life

Treatments	Titratable acidity (TA)%
P_0R_0	0.45 a
P_0R_1	0.34 f-i
P_0R_2	0.40 bc
P_0R_3	0.33 f-j
P_0R_4	0.35 d-h
P_0R_5	0.32 g-j
P_1R_0	0.33 f-j
P_1R_1	0.35 e-h
P_1R_2	0.30 ij
P_1R_3	0.36 c-g
P_1R_4	0.36 c-g
P_1R_5	0.39 b-d
P_2R_0	0.36 c-g
P_2R_1	0.29 j
P_2R_2	0.32 h-j
P_2R_3	0.33 f-j
P_2R_4	0.31 h-j
P_2R_5	0.38 b-e
P_3R_0	0.40 bc
P_3R_1	0.37 c-f
P_3R_2	0.41 ab
P_3R_3	0.37 c-f
P_3R_4	0.40 bc
P_3R_5	0.38 b-e
CV%	5.46
$LSD_{0.01}$	0.0430

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

4.3 Percent Decay

The data on decay (%) of banana (at 6th, 9th, 12th and 15th DAS) significantly influenced by packaging materials and postharvest treatments and their interaction (Appendix V).

The maximum decay (10.17%, 16.39%, 26.22%, and 42.67% at 6th, 9th, 12th and 15th DAS) value of banana was recorded from P_0 (non packaging fruits). On the contrary, minimum decay (6.83%, 12.67%, 18.17% and 30.33% at 6th, 9th, 12th and 15th DAS) value was obtained from P_1 (non-perforated poly stored fruits) (Fig. 19).

It was seen that the highest decay (9.17%, 15.83%, 26.27% and 42.08% at 6th , 9th, 12th and 15th DAS) value were obtained from R_0 (untreated fruits), while the lowest value (6.75%, 11.08%, 16.83% and 27.67% at 6th, 9th, 12th and 15th DAS) was recorded when banana treated with 1-MCP (R_1) (Fig. 20).

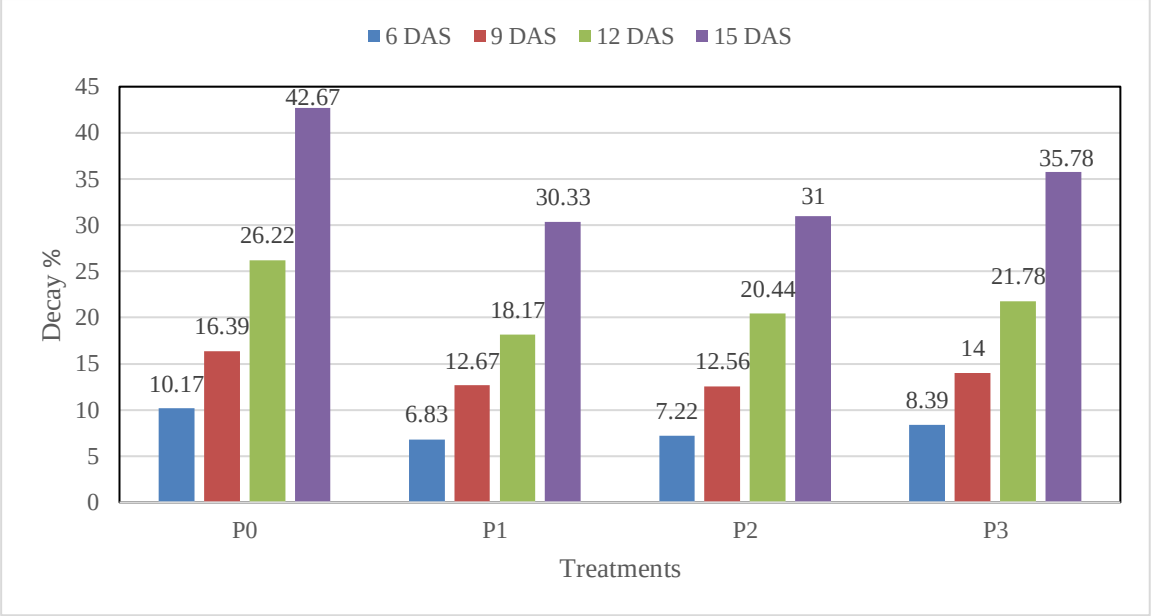

Figure 19: Effect of packaging materials on percent decay of banana at different days after storage (DAS)

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

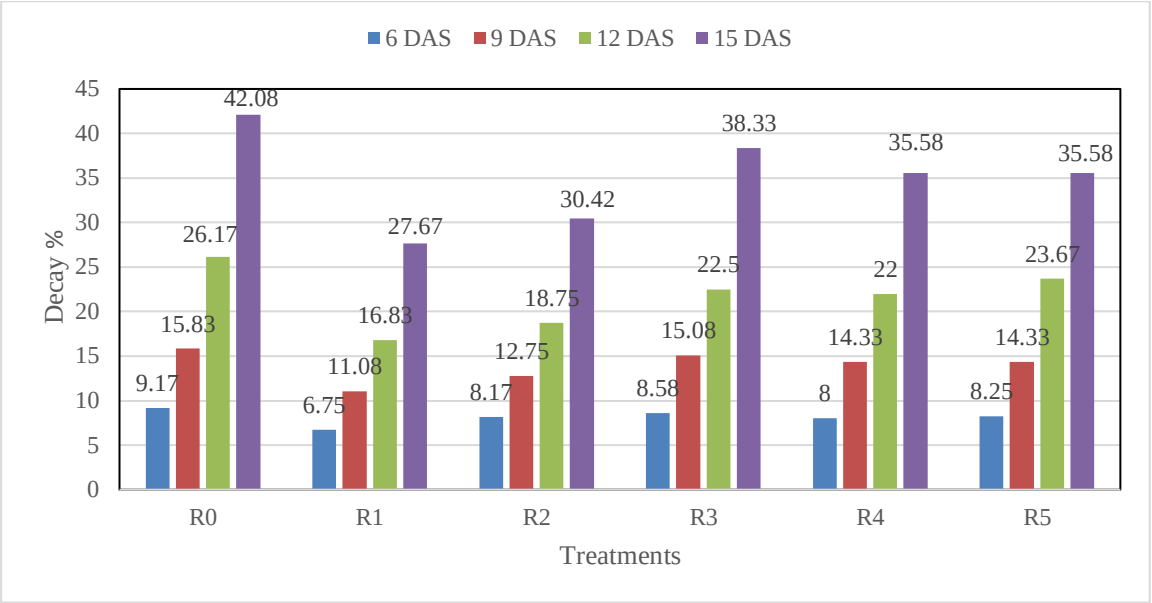

Figure 20: Effect of different postharvest treatments on percent decay of banana at different days after storage (DAS)

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effects of packaging materials and postharvest treatments on decay (%) were statistically significant (Appendix V). The maximum value of decay (%) (12.00%, 19.33%, 35.00% and 50.00% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value of banana were obtained from P_0R_0 (untreated fruits without packaging) and lowest value (4.00%, 6.67%, 12.67%, and 20.00% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination (Table 10).

Table 10: Combined effect of packaging materials and postharvest treatments on decay (%) of banana at the end of shelf life

Treatments	Decay percent			
	6 DAS	9 DAS	12 DAS	15 DAS
P_0R_0	12.00 a	19.33 a	35.00 a	50.00 a
P_0R_1	8.67 a-f	14.33 c-e	23.33 c-f	37.33 b
P_0R_2	11.00 a-c	17.67 a-c	25.67 b-e	46.00 a
P_0R_3	11.33 ab	18.33 ab	26.67 b-d	47.67 a
P_0R_4	8.67 a-f	14.33 c-e	23.33 c-f	37.33 b
P_0R_5	9.33 a-e	14.33 c-e	23.33 c-f	37.67 b
P_1R_0	6.67 e-h	12.33 d-f	20.00 f-h	33.33 b
P_1R_1	6.67 e-h	11.67 d-f	14.67 ij	27.67 cd
P_1R_2	7.67 c-g	12.67 d-f	17.33 g-i	27.67 cd
P_1R_3	5.00 gh	10.67 ef	14.00 ij	26.67 d
P_1R_4	8.33 b-g	14.67 b-d	22.33 ef	34.33 b
P_1R_5	6.67 e-h	14.00 c-e	20.67 fg	32.33 bc
P_2R_0	8.67 a-f	15.00 b-d	22.67 d-f	36.67 b
P_2R_1	4.00 i	6.67 g	12.67 j	20.00 e
P_2R_2	7.00 e-h	10.67 ef	15.67 ij	24.67 de
P_2R_3	7.33 d-h	14.00 c-e	21.67 ef	32.33 bc
P_2R_4	5.00 gh	10.67 ef	16.67 g-j	25.67 d
P_2R_5	11.33 ab	18.33 ab	33.33 a	46.67 a
P_3R_0	9.33 a-e	16.67 a-c	27.00 bc	48.33 a
P_3R_1	7.67 c-g	11.67 d-f	16.67 g-j	25.67 d
P_3R_2	7.00 e-h	10.00 fg	16.33 h-j	23.33 de
P_3R_3	10.67a-d	17.33 a-c	27.67 b	46.67 a
P_3R_4	10.00 a-e	17.67 a-c	25.67 b-e	45.00 a
P_3R_5	5.67 f-h	10.67 ef	17.33 g-i	25.67 d
CV%	2.67	2.69	2.69	2.69
$LSD_{0.01}$	3.38	3.75	4.23	5.62

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

From the experiment it was observed that decay value increased with the advance of time in all the treatments. The degree of increase in decay value for different postharvest treatments might be due to bananas are typical climacteric fruits, which ripen with increasing rate of respiration coupled with ethylene production. The perishability of the fruit is attributed to the adverse physiological changes, loss of weight due to respiration and transpiration, softening of flesh and loss of resistance to microbial attack. The combined effects of packaging materials and postharvest treatments were statistically significant during storage period. The highest decay value was recorded in control treatment during storage period and the lowest decay value was recorded in 1-MCP treated fruits stored in perforated poly bags treatment during storage period. Golding *et al.* (1998) stated that it has been well demonstrated that 1-MCP can postpone the ripening of mature-green, pre-climacteric bananas which is similar to the findings of the present study.

4.4 Shelf life

Significant variation was observed in respect of shelf life of banana between packaging materials and postharvest treatments of banana at the end of shelf life (Appendix VI).

The maximum (14.44 days) shelf life of banana was found in P_1 (non perforated poly fruits) and minimum (9.06 days) shelf life was found in P_0 (non packaging fruits) (Fig. 21).

It was recorded that the highest shelf life (14.42 days) shelf life was noticed in R_1 (1-MCP treated fruits) and the minimum (9.33 days) shelf life was found in R_0 (untreated fruits) treated banana (Fig 22).

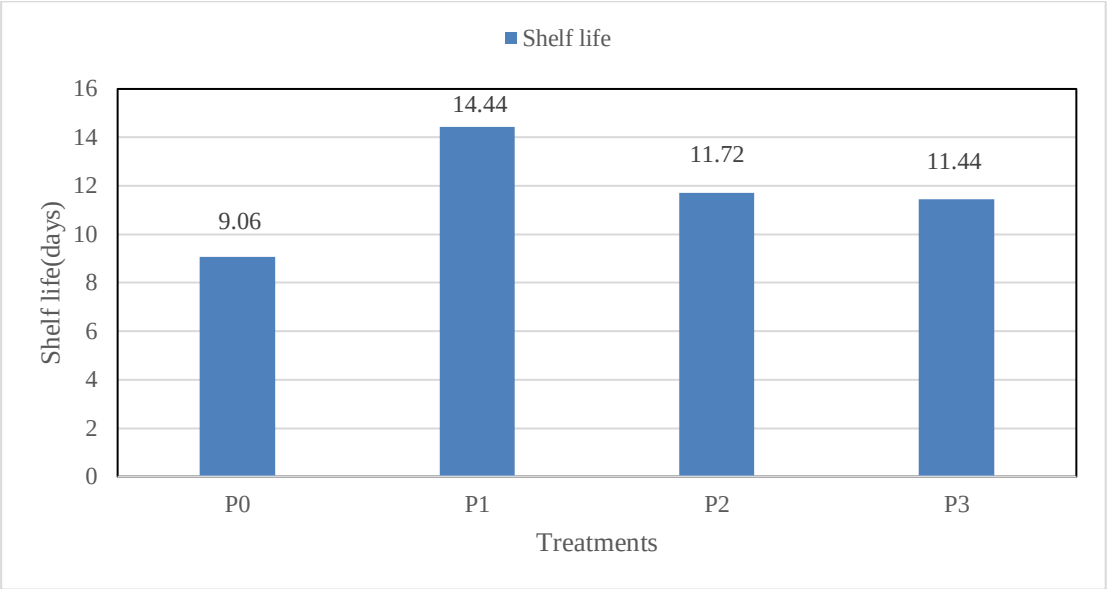

Figure 21: Effect of packaging materials on shelf life of banana

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping

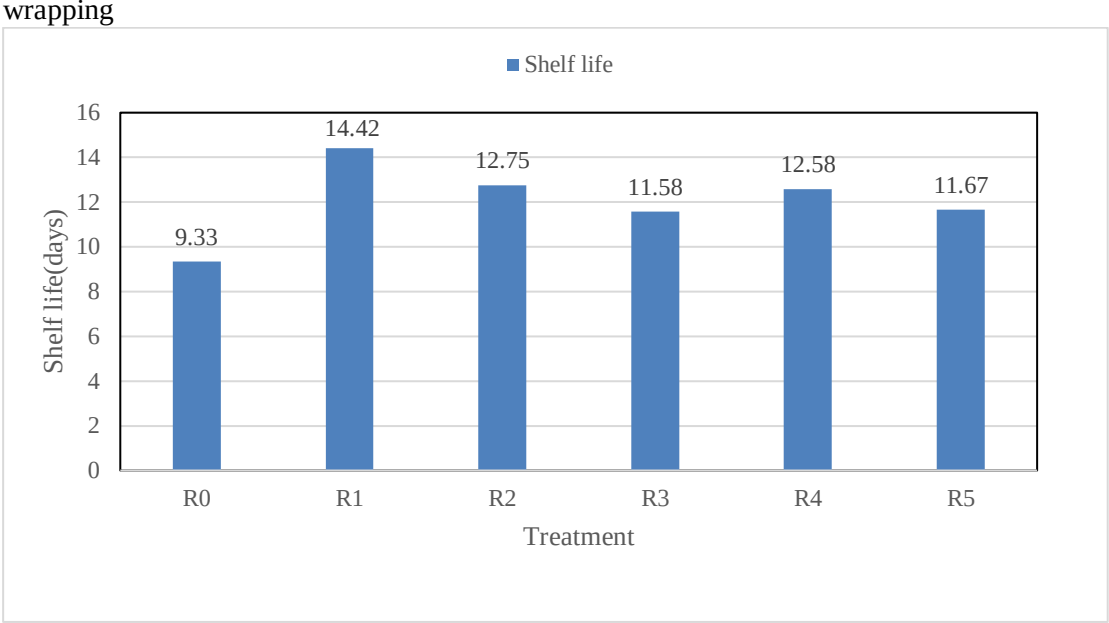

Figure 22: Effect of different postharvest treatments on shelf life of banana

R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

The combined effect of these treatments in respect of shelf life in banana was found to be statistically significant at the end of shelf life (Appendix VI). The highest shelf life (15 days) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and lowest shelf life (9 days) was recorded in P_0R_0 (untreated fruits without packaging) combination (Table 11).

Table 11: Combined effect of packaging materials and postharvest treatments on shelf life of banana

Treatments	Shelf life
P_0R_0	9.00 j
P_0R_1	10.67 g-i
P_0R_2	9.67 ij
P_0R_3	9.33 ij
P_0R_4	10.67 g-i
P_0R_5	10.67 g-i
P_1R_0	12.67 c-f
P_1R_1	14.00 a-c
P_1R_2	13.00 b-e
P_1R_3	14.33 ab
P_1R_4	11.67 e-g
P_1R_5	12.67 c-f
P_2R_0	11.33 f-h
P_2R_1	15.00 a
P_2R_2	14.00 a-c
P_2R_3	12.67 c-f
P_2R_4	13.67 a-d
P_2R_5	9.67 ij
P_3R_0	12.33 d-f
P_3R_1	14.00 a-c
P_3R_2	14.33 ab
P_3R_3	10.00 h-j
P_3R_4	10.33 g-j
P_3R_5	13.67 a-d
CV%	5.26
$LSD_{0.01}$	1.390

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=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

Shelf life is the period of time which start from the time of harvesting and extend up to the start of rotting of fruit (Mondal, 2000) and it is the basic quality of fruit as well as it is the most important parameter in loss of biochemical reaction of fruit. The combined effects of packaging materials and postharvest treatments were statistically significant at all days of observation. The highest shelf life was recorded in 1-MCP treated fruits stored in perforated poly bags treatment and the lower value in control treatment. Jiang *et al*. (1999) reported that using 1-MCP in conjunction with polythene bags can considerably extend banana postharvest shelf life.

P_0R_0 P_0R_1 P_0R_2 P_0R_3

P_0R_4 P_0R_5 P_1R_0 P_1R_1

P_1R_2 P_1R_3 P_1R_4 P_1R_5

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

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

P_2R_0 P_2R_1 P_2R_2 P_2R_3

P_2R_4 P_2R_5 P_3R_0 P_3R_1

P_3R_2 P_3R_3 P_3R_4 P_3R_5

Plate 3: Cont'd

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

P_0R_0 P_0R_1 P_0R_2 P_0R_3

P_0R_4 P_0R_5 P_1R_0 P_1R_1

P_1R_2 P_1R_3 P_1R_4 P_1R_5

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

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

P_2R_0 P_2R_1 P_2R_2 P_2R_3

P_2R_4 P_2R_5 P_3R_0 P_3R_1

P_3R_2 P_3R_3 P_3R_4 P_3R_5

Plate 4: Cont'd

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

P_0R_0 P_0R_1 P_0R_2 P_0R_3

P_0R_4 P_0R_5 P_1R_0 P_1R_1

P_1R_2 P_1R_3 P_1R_4 P_1R_5

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

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

P_2R_0 P_2R_1 P_2R_2 P_2R_3

P_2R_4 P_2R_5 P_3R_0 P_3R_1

P_3R_2 P_3R_3 P_3R_4 P_3R_5

Plate 5: Cont'd

P_0=Non packaging, P_1=Non Perforated polythene, P_2=Perforated polythene, P_3= Newspaper wrapping, R_0=Control, R_1=1-MCP, R_2=4% $CaCl_2$, R_3=Aloe vera gel, R_4=Ginger extract, R_5=Hot water (45^0C @ 5 mins)

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the Postharvest Laboratory of Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during the period from October to November, 2020. The objectives of the present study were to investigate the effect of packaging materials and postharvest treatments on shelf life and quality attributes of banana cv. "BARI Kola 1" after storage. In this two factorial experiment packaging materials were denoted as Factor A and postharvest treatments were denoted as Factor B. Packaging materials i.e. P_0: Without packaging, P_1: Non perforated poly bags, P_2: Perforated poly bags, P_3: Newspaper wrapping and postharvest treatments i.e. R_0: Control, R_1: 250ppb 1-methylcyclopropene (1-MCP), R_2: 4% $CaCl_2$, R_3: Aloe vera gel, R_4: Ginger extract and R_5: Hot water (45^0 C for 5 min) were used in this experiment. In this study observations were made on fruits physiochemical properties such as total weight loss, pulp to peel ratio, moisture content, dry matter content, total soluble solids, total sugar content, reducing sugar content, non-reducing sugar, titratable acidity, and shelf life. The data were statistically analyzed and evaluated. The results of the experiment expressed that almost all the parameters studied were significantly influenced by the above factors.

Total three packaging materials were applied in this experiment along with non packaging fruit marked as control. Among all those treatments the maximum weight loss (3.52%, 7.26%, 11.19%, 15.39% and 19.60% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively), was found in P_3 (Newspaper wrapping fruits) and minimum (0.19%, 0.42%, 0.65%, 0.92% and 1.22% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was found in P_1 (non perforated poly bags stored fruits). The maximum (3.65) pulp to peel ratio was found in P_0 (non packaging fruits) and minimum (2.34) pulp to peel ratio was found in P_2 (perforated poly bags stored fruits). The highest (81.62%) moisture content was found in P_1 (non perforated poly bags stored fruits) and lowest (80.17%) moisture was found in P_3 (Newspaper wrapping fruits). The highest (19.68%) dry matter content was found in P_2 (perforated poly bags stored fruits) and lowest (18.38%) dry matter content was found in P_1 (non perforated poly bags fruits). TSS value which was an important quality parameter of banana, the maximum (20.04%) TSS content was found in P_3 (No packaging fruits) and minimum (18.10%) TSS content was found in P_1 (non perforated poly bags fruits). The maximum (20.61%) total sugar content was found in P_2 (perforated poly bags stored fruits) and minimum (19.98%) total sugar content was found in P_1 (non perforated poly bags stored fruits). The maximum (14.19%) reducing sugar content was found in P_0 (non packaging fruits) and minimum (13.77%) reducing sugar content was found in P_1 (non perforated poly bags stored fruits).

The maximum (6.46%) non- reducing sugar content was found in P_2 (perforated poly bags stored fruits) and minimum (6.17%) non- reducing sugar was found in P_3 (newspaper wrapping fruits). The maximum (0.39%) TA content was found in P_3 (Newspaper wrapping fruits) and minimum (0.33%) TA was found in P_2 (perforated poly bags stored fruits). The maximum decay (10.17%, 16.39%, 26.22%, and 42.67% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value was recorded from P_0 (non packaging fruits). On the contrary, minimum (6.83%, 12.67%, 18.17% and 30.33% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value was obtained from P_1 (non perforated poly stored fruits). In case of shelf life affected by different packaging materials, the highest shelf life (14.44 days) was found in P_1 (non perforated poly fruits) and lowest shelf life (9.06 days) was found in P_0 (non packaging fruits).

Regarding application of different postharvest treatments, the maximum loss in weight (2.31%, 4.49%, 6.54%, 8.98% and 11.74% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was found in R_0 (non treated fruits) and the minimum (1.80%, 3.70%, 5.68%, 7.99% and 10.36% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days after harvest, respectively) was found in R_1 (1-MCP treated fruits). The highest (3.01) Pulp to peel ratio was noticed in R_0 (untreated fruits) and lowest (2.75) Pulp to peel ratio was found in R_1 (1-MCP treated fruits). The highest moisture (81.62%) content was noticed in R_0 (untreated fruits) and minimum (80.53%) moisture content was found in R_4 (ginger extract treated fruits). The highest dry matter (19.44%) content was noticed in R_1 (1-MCP treated fruits) and minimum (18.90%) dry matter content was found in R_0 (untreated fruits). The highest TSS (19.29%) content was noticed in R_4 (Ginger extract treated fruits) and minimum (17.92%) TSS content was found in R_1 (1-MCP treated fruits). The highest total sugar (21.01%) content was noticed in R_0 (untreated fruits) and minimum (19.81%) total sugar content was found in R_1 (1-MCP treated fruits). The highest reducing sugar (14.97%) content was noticed in R_0 (untreated fruits) and minimum (13.34%) reducing sugar content was found in R_1 (1-MCP treated fruits). The highest non- reducing sugar (6.47%) content was noticed in R_1 (1-MCP treated fruits) and minimum (6.04%) non- reducing sugar content was found in R_0 (untreated fruits). The highest TA (0.39%) content was noticed in R_0 (untreated fruits) and minimum (0.34%) TA content was found in R_1 (1-MCP treated fruits). The highest decay (9.17%, 15.83%, 26.27%, 42.08% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value were obtained from R_0 (untreated fruits), while the lowest value (6.75%, 11.08%, 16.83% and 27.67% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) was recorded when fruits treated with 1-MCP (R_1). In case of shelf life affected by different postharvest treatments, the highest shelf life (14.42 days) shelf life was noticed in R_1 (1-MCP treated fruits) and minimum (9.33 days) shelf life was found in R_0 (untreated fruits).

In case of combined effect of packaging materials and different postharvest treatments, The highest rate of weight loss (3.87%, 8.63%, 12.36%, 17.37% and 23.28% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) was observed in P_0R_0 (untreated fruits

without packaging) combination and lowest (0.15%, 0.31%, 0.53%, 0.79% and 0.97% at 3rd, 6th, 9th, 12th and 15th DAS) rate was recorded in P_1R_0 (untreated fruits stored in non perforated poly bag) combination. The maximum (4.33) pulp to peel ratio was found in P_0R_0 (untreated fruits without packaging) combination and minimum (2.12) pulp to peel ratio was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. The maximum moisture content (82.50%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum moisture content (79.23%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. The maximum dry matter content (20.77%) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and minimum dry matter content (17.50%) was recorded in P_0R_0 (untreated fruits without packaging) combination. The maximum TSS content (21.00%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum TSS content (17.17%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags). The maximum total sugar content (22.43%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum total sugar content (18.52%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. The maximum reducing sugar content (16.96%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum reducing sugar content (11.56%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. The maximum non- reducing sugar content (6.96%) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and minimum non- reducing sugar content (5.47%) was recorded in P_0R_0 (untreated fruits without packaging) combination. The maximum TA content (0.45%) was found in P_0R_0 (untreated fruits without packaging) combination and minimum TA content (0.29%) was recorded in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. The maximum (%) value of decay (12.00%, 19.33%, 35.00% and 50.00% at 6th, 9th, 12th and 15th DAS) value obtained from P_0R_0 (untreated fruits without packaging) and lowest value (4.00%, 6.67%, 12.67%, and 20.00% at 6th, 9th, 12th and 15th DAS) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination. In case of shelf life affected by different affect by combined effect of packaging materials and postharvest treatments, the highest shelf life (15 days) was found in P_2R_1 (1-MCP treated fruits stored in perforated poly bags) combination and lowest shelf life (9 days) was recorded in P_0R_0 (untreated fruits without packaging) combination.

So, it can be concluded that to increase the shelf life & maintained better quality of banana need to be treated with 1-MCP (250ppb) and stored in perforated polythene.

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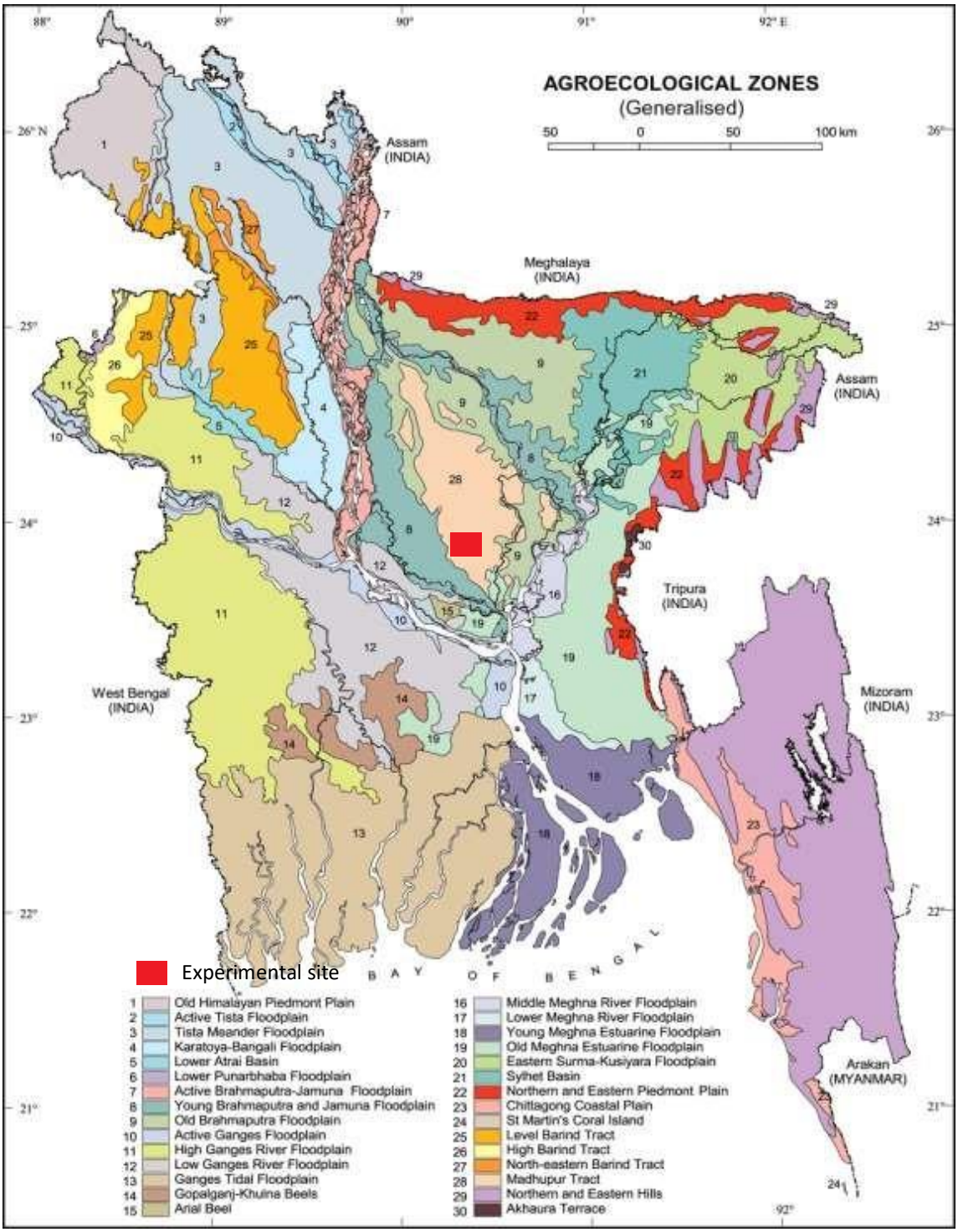
APPENDICES

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



Appendix II: Effect of packaging materials and postharvest treatments on percent weight loss of banana at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent weight loss				
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS
Factor A	3	39.272**	206.616**	503.331**	988.965**	1653.54**
Factor B	5	0.417**	0.824**	1.016**	1.480**	2.96**
AB	15	0.418**	1.429**	2.583**	4.396**	7.67**
Error	48	0.034	0.058	0.117	0.168	0.24

** = Significant at 1% level

Appendix III: Effect of packaging materials and postharvest treatments on pulp to peel ratio, percent moisture content, percent dry matter content of banana at the end of shelf life

Sources of variation	Degrees of freedom	Mean square at the end of shelf life		
		Pulp to peel ratio	Moisture content (%)	Dry matter content (%)
Factor A	3	6.740**	8.119**	9.783**
Factor B	5	0.136**	0.737**	1.144**
AB	15	0.218**	1.569**	1.617**
Error	48	0.04	0.192	0.220

** = Significant at 1% level

Appendix IV: Effect of packaging materials and postharvest treatments on TSS, Total sugar (%), Reducing sugar (%), Non reducing sugar (%), TA (%) of banana at the end of shelf life

Sources of variation	Degrees of freedom	Mean square at the end of shelf life				
		TSS	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	TA (%)
Factor A	3	14.03**	1.637**	1.013**	0.311^{NS}	0.01**
Factor B	5	2.90**	2.770**	4.618**	$O.274^{NS}$	0.004**
AB	15	0.361^{NS}	2.967**	3.884**	0.338**	0.004**
Error	48	0.30	0.191	0.175	0.133	0.0004

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

Appendix V: Effect of packaging materials and postharvest treatments on percent decay of banana at different days after storage (DAS)

Sources of variation	Degrees of freedom	Mean square percent decay			
		6 DAS	9 DAS	12 DAS	15 DAS
Factor A	3	40.310**	57.199**	207.051**	582.889**
Factor B	5	7.714**	35.447**	136.614**	328.156**
AB	15	11.410**	25.210**	70.984**	174.200**
Error	48	2.374	2.923	3.720	6.561

** = Significant at 1% level

Appendix VI: Effect of packaging materials and postharvest treatments on shelf life of banana

Sources of variation	Degrees of freedom	Mean square shelf life (days)
Factor A	3	34.926**
Factor B	5	8.289**
AB	15	6.148**
Error	48	0.403

** = Significant at 1% level

Appendix VII: Different physical and chemical data of mature green banana

Initial weight (gm)	**Pulp-peel ratio**	**Moisture content (%)**	**Dry matter content (%)**	**TA (%)**	**TSS (%)**	**Total sugar (%)**	**Reducing sugar (%)**	**Non-reducing sugar (%)**
101.57	1.49	71.51	28.49	0.17	4	11.90	6.74	5.16
106.32	1.62	71.82	28.18	0.23	4	11.91	6.83	5.08
107.31	1.65	75.11	24.89	0.20	4	11.80	6.99	4.81