ESTIMATION OF POSTHARVEST LOSSES AND INTEGRATED METHOD FOR MINIMIZING LOSSES AND ASSURING QUALITY OF TOMATO

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BY

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Dedicated to

My

Beloved Parents

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CERTIFICATE

*This is to certify that the thesis entitled "**ESTIMATION OF POST HARVEST LOSSES AND INTEGRATED METHOD FOR MINIMIZING LOSSES AND ASSURING QUALITY OF TOMATO**"submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **HORTICULTURE,** embodies the results of a piece of bona fide research work carried out by **Selina Akter,** Registration No.**12-04801** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

The experiment was carried out at the Postharvest laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207. The single factor experiment was laid out in a Completely Randomized Design (CRD) with three replication. The present research was conducted to evaluate the effect of different post harvest treatment on shelf life and quality of tomato. The postharvest treatments were (viz: W_o = Tap water dips, W_H= Hot water dips**,** I = With ice, I_o= Without ice**,** P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity and R_o= Relative humidity at room condition 60-65%. Results revealed that the lowest disease incidence (43.54%) and weight loss (7.62 %) were recorded from T_{13} (Hot water dips + With ice + Perforated Polybag + 80±5% RH) treatment where highest disease incidence (100%) and weight loss (16.17 %) were found in T_{12} (Tap water dips + Without ice + Control + RH at room condition 60-65%) treatment. The highest shelf life (17 days) and quality of tomato were obtained from T_{13} (Hot water dips + With ice + Perforated Polybag + 80±5% RH) treatment. The better performance was observed in tomatoes when treated with hot water, including ice and storage with perforated polybag and 80±5% relative humidity for longer shelf life and quality.

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CHEPTER I

INTRODUTION

Notwithstanding the apparent abundance of food, nearly 870 million people around the world suffer from hunger and malnutrition (FAO, 2013). A clear pathway to ensure the availability of food and alleviating poverty is to minimize the postharvest losses (PHL). One third of global food produced for human consumption is lost or wasted which amounts to about 1.3 billion tons per year (Gustavsson *et al*., 2011). Losses of fresh fruits and vegetables are of considerable interest due to their extremely high values reaching 55% in developed countries and 45% in developing countries (FAO, 2011). Several reasons are attributable for this situation such as the distance occurring between the producer and the consumer and improper postharvest practices including harvesting, handling, storage and processing of the produce. Fruits and vegetables are known to provide the necessary food to assure a balanced diet for a healthy population (FAO, 2002). It can play a crucial role in reducing the occurrence of chronic diseases caused by imbalanced diet. More significantly, whether in developed or developing countries, fruits and vegetables (Tiwari *et al*., 2013) are the main source of essential vitamins, minerals and dietary fiber feeding the world populations. There have been significant changes in food consumption habits in the last two decades, with a major shift towards the consumption of fresh fruits and vegetables due to health concerns. Consumer demand for high quality, fresh, nutritious and conveniently prepared food items has increased dramatically in recent years, and has led to the requirement of adequate technologies to preserve these food products. Tomato fruits are an excellent source of vitamins, minerals and Phyto-chemical compounds that is vital for health. They play a significant role in meeting the dietary requirements of these essential nutrients if they are consumed in adequate amounts along with other food types. On a similar note, Gustavsson *et al.* (2011) reported that postharvest losses of tomato in Latin America and the Caribbean (LAC) were estimated at 20% at the production level and up to 30% at the marketing level (including storage, distribution and retailing). Commonly existing methods to assess PHL in the Caribbean are mainly based on household surveys.

It is the fact that Bangladesh is blessed with rich farmlands and subsequent good harvest each year. The country is one of the leading producers of tomatoes, pepper, plantain, onions, okra and other vegetables that are grown in its diverse agro-ecological zones. Losses of horticultural produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. During the process of distribution and marketing, substantial losses are incurred which range from a slight loss of quality to total spoilage. Postharvest losses may occur at any point in the marketing process, from the initial harvest through assembly and distribution to the final consumer. The causes of losses are many: physical damage during handling and transport, physiological decay, water loss, or sometimes simply because there is a surplus in the market place and no buyer can be found. Not only are losses clearly a waste of food but also represent a similar waste of human efforts, farm inputs, livelihoods, investments and scarce resources such as water. However, there is need to store and preserve these farm produce to forestall the seemingly global food epidemics. It has also been pointed out that to achieve self sufficiency in food; there is an urgent need to match all efforts at increasing crop production with equal if not greater efforts of post harvest technology to save the crops that are produced from deterioration and wastages (Hall, 1968; Adeniyi, 1977; Agboola,1980).

Bangladesh is an agro based country. Agriculture plays a vital role in Bangladesh economy. Bangladesh ranked second in vegetable production. Vegetables are considered as commercially important agricultural product and nutritionally essential food commodities due to their provision of the major dietary sources of vitamin, sugar, organic acid and minerals and also other phytochemicals including dietary fiber and antioxidants. Government has set target to produce 143 M Mt of vegetable from 8.05 lakh ha cultivable land. Many types of vegetables are being cultivated in Bangladesh, but a huge amount of vegetables are losses due to improper postharvest management. It is estimated that a loss of the vegetables occur is nearly 25-40% due to packaging and improper postharvest handling, transportation and storage practices and the variation depends on types of vegetables (Gustavsson 2011). So we can minimizes the losses and increase the shelf life of vegetables by using appropriate packaging materials, proper handling, improved transport facilities, non-toxic chemicals and so on.

The proposed research will be undertaken with the following objectives;

OBJECTIVES:

1. To find out the physiological changes during postharvest handling and storage period of tomato.
2. To identify suitable postharvest treatment in extending the shelf life and quality of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most popular and widely grown vegetables of the world. It is a rich source of minerals and vitamins Since the consumers purchase fruits on the basis of quality, the quality of fruit is largely dependent on the stage of maturity of fruits and various ripening conditions. Changes in physiological characteristics during storage as well as ripening must be determining the fitness of tomato fruit for fresh consumption and marketing. The scientific literature does include a very few studies on physiological changes in fruits but they are neither adequate nor conclusive. However, available literature and their findings on tomato and some other fleshy fruits that are related to the present study have been reviewed in the following section.

In India, Mallik *et al*. (1996) reported that fruits of tomato (cv. Roma-VF) showed the lowest physiological weight loss of 7.7-9.7% after 6 days storage under ambient conditions.

Early Pear type and S-12 cultivars of tomato had 55 and 33 per cent loss in physiological weight, respectively harvested at red ripe stage after seven days of storage at room temperature. While, minimum loss of 23 and 46 per cent, respectively were observed when harvested at breaker stage observed that (Kaur *et al.*, 1977).

A minimum loss in weight was reported in tomatoes harvested at turning stage when compared to those harvested at red ripe stage after 12 days of storage (Gaur and Bajpai, 1982). Tomatoes stored at room temperature recorded a maximum weight loss as compared to those packed in polyethylene bags due to higher rate of transpiration and water loss (Lingaiah, 1982).

Changes in flesh texture (softening), flesh color; skin color, total soluble solids, and acidity have not proven to be useful, because they occur mostly after the proper harvest time for distant markets. Studies suggest that flesh color, starch content, and specific gravity might be useful indices for some cultivars (Kader, 2002).

Tigist *et al*. (2011) conducted an experiment to evaluate performances of four tomato varieties (Bishola, Eshet, Marglobe and Moneymaker) harvested at ripe stage from greenhouse and open field condition at Jimma for post-harvest quality characters (total soluble solid, weight loss, titratable acidity, sugar-acid ratio, and pH). Bishola and Eshet had better chemical quality characteristics maintained throughout the end of the storage period. Varieties grown under open field condition showed highest fruit weight loss. The total soluble solid (TSS) values in the open field grown tomatoes had highest than greenhouse grown tomatoes throughout storage period. The highest TSS was obtained at 14 days storage while the lowest was at harvest. Titratable acidity of tomatoes after harvest tended to decrease throughout the storage period. Bishola had highest titratable acidity when compared with Eshet. There was an increase in sugar/acid ratio throughout storage time for greenhouse growing condition, under open field condition there is a slight increment and rapid after harvest and then decrease at 14 days the storage period. This indicates that Greenhouse grown tomatoes have good flavor than open field grown. Tomato varieties grown under greenhouse condition were less weight loss, and higher sugar acid ratio and less prone to physical injuries than fruits of grown under open field condition. Variety Eshet and Bishola could be selected in maintaining better overall quality characteristics.

In Turkey, Kaynes and Surmeli (1995) observed that weight loss was more severe in fruits at an early stage of maturity and increased as storage temperature increased. They also stated that while green mature and breaker stages tomato were stored at 4 and 8°C then total weight loss over 35 days ranged from 3 to 8%, depending on cultivars, maturity and temperature.

Yoltas *et al.* (1994) obtained that a 1.2% semper fresh (a fatty acid sucrose ester mixture) significantly reduced the weight loss in tomato fruit (cv. Galit-135) during storage at 21°C temperature in Turkey. Agnihotri and Ram (1970) observed that a 6% wax emulsion significantly reduced the weight loss in tomato fruit during storage at room temperatures in India.

Anju-Kumari *et al.* (1993) reported that the shelf life for all tomato cultivars were longest with harvesting at the mature green stage (10.9-13.5 days) but resulted in the lowest ascorbic acid content after storage and in patchy color develop on ripening.

Syamal (1981) conducted an experiment on effect of different environmental condition on the post harvest losses of tomato. He concluded that the highest weight loss was found in perforated polythene bag due to the rate of transpiration was lower in sealed polythene bags. He reported that the weight loss of tomatoes depends upon the transpiration and respiration of the tomato in storage condition, which are lower at sealed condition.

In a trial at Osaka in Japan, Hamauzu *et al*. (1998) reported that the color of mature tomato fruits changed from green to red during storage at 20°C. But changes to a mixed color or a speckled pattern of red, orange and yellow at 30°C and turned yellow at 35°C. The epidermis is more sensitive and lycopene was significantly inhibited in surface tissue.

Diaz *et al*. (1997) stored tomato fruits from 12 selections at 20°C and 65% RH. Fruit transpiration was determined as a rate of fruit weight loss. There was a gradual decline in the rate of transpiration during storage. After 14 days storage, transpiration was reduced to about 50% of its initial value. In another experiment, in fruits from 5 selections harvested at the mature-green (MG) or turning stages and stored at 20°C (65% RH) for 7 days, transpiration in MG fruits was about 28% lower compared with fruits at the turning stage, which suggests that skin permeance increases as fruit maturity progresses. It is suggested that these changes in water vaporpermeance as a result of both storage and stage of maturity may be associated with changes in skin permeance to other gases such as O_2, CO_2 and ethylene.

McDonald *et al.* (1999) was found to apply in this study with mature-green tomato fruit (*Lycopersicon esculentum* Mill. cv. Sunbeam) were treated in water for 1 h at 27 (ambient), 39, 42, 45, or 48°C, and then either ripened at 20°C (nonchilled) or stored at 2°C (chilled) for 14 days before ripening at 20°C. Treatment at 42°C reduced decay by 60%, whereas the other water temperatures were less effective. Heat treatment had no effect on time required to ripen the fruit, with 11 days required for nonchilled and 27 days required for chilled fruit (including storage time). Ripe, nonchilled tomatoes had higher respiration rates and evolved more ethylene than did chilled fruit. The 48°C treatment increased respiration and ethylene evolution compared with the other treatment temperatures. Red color development was enhanced by heat treatment, and inhibited by chilling. At red ripe, fruit were firmer as a result of storage at the chilling temperature, while heat treatment had no effect on firmness. With the exception of the 45°C treatment, chilled as well as nonchilled fruit previously treated at 39, 42, or 45°C were preferred in terms of taste and texture in informal taste tests over fruit treated at 27^0 or 48°C. Storage at 2°C led to an increase in electrolyte leakage, particularly in the 48°C treated fruit. Of the 15 flavor volatiles analyzed, the levels of five were decreased and two were increased with increasing temperature of heat treatment. Storage at the chilling temperature reduced the levels of five flavor volatiles. Heat treatments decreased sterols in the steryl ester fraction, several sterols in the free sterol, steryl glycoside, and acylated steryl glycoside fractions. Pre storage heat treatments, with the possible exception of the 48°C temperature, can reduce decay with only minimal adverse effects on tomato fruit quality. High temperature prevented the accumulation of phytoene more than that of lycopene. The content of P-carotene increased in the epidermis and the flesh (more so in the epidemic) during storage at 30°C, but decreased with extended storage (after about 15 days).

Thai *et al*. (1990) was found to apply in this study with a 2.6% prediction error for fruit under step-varying temperature storage. A new relationship between firmness and color development for tomato fruit was derived and found to yield about 2% prediction error under variable temperature conditions

According to Hakim *et al.* (1997). Mature green tomatoes were immersed in water at 38°C, 42°C, 46°C, 50°C or 54°C for 30, 60 or 90 min prior to storage at 2°C for 2, 4 or 6 weeks. Control fruits were immersed in water at 20°C. Hot-water-treated fruits showed less chilling injury, faster chlorophyll degradation and lycopene synthesis, lower titratable acidity, lower CO_2 and ethylene production, and less electrolyte leakage than control fruits. Among hot-water-treated fruits, the least chilling injury and lowest CO_2 production were detected in fruits that were treated at 46°C. Chlorophyll content and ethylene production were lowest in fruits treated at 54°C while electrolyte leakage was lowest in those treated at 42°C. Increased immersion time reduced chilling injury and ethylene production. Long periods of immersion at high temperatures increased CO_2 production and electrolyte leakage. Chilling injury increased with extended storage time.

Lana *et al.* (2005) was found to the tomato fruit (cultivar Belissimo) were harvested at three different stages of ripening, sliced and stored at 2, 5, 8, 12 and 16 °C. Firmness was measured as the force necessary to cause a deformation of 3 mm, in the outer and the radial pericarp, daily or every two days, depending on the combination of stage of ripening and temperature. For constructing a model, firmness was considered to be built up by a variable part (e.g. pectin based firmness) that changes according to a first order reaction mechanism and a fixed part (e.g. cellulose or structure based firmness) that is invariable under the circumstances under study.

Suparlan and Itoh, K (2003) studied the effects of hot water treatment (HWT) and modified atmosphere packaging (MAP) on quality of tomatoes were studied. Prior to packaging with low-density polyethylene (LDPE) film (0.02 mm in thickness), tomatoes were immersed in hot water (42.5°C) for 30 min. Control tomatoes were not treated and were stored for 2 weeks at 10°C and then for 3 days at 20°C without packaging. Steady states of O_2 and CO_2 concentrations inside the package were about 5 and 8%, respectively, and were reached after 6 and 4 days of storage, respectively. MAP reduced weight loss of tomatoes to about 41% of that of unpackaged fruit during a 2-week storage period. The use of a combination of HWT and MAP reduced weight loss and decay, inhibited color development and maintained firmness of tomatoes but had no effect on soluble solids content or titratable acidity. HWT slightly reduced mold growth of tomatoes stored in MAP. Packaging of control fruit in MAP resulted in stimulation of mold growth around the stem end of the fruit after about 1 week of storage and also resulted in cracking and decay. HWT could be used as disinfectant for tomatoes prior to storage in MAP in order to reduce microbial growth, cracking and decay that may be caused by excessive water vapor inside the package.

Mallik *et al*. (1996) harvested fruits of the tomato cultivars at mature green, breaker, half-ripe and red-ripe stages and analyzed for shelf-life and storage quality under ambient conditions during 1990 and 1991. Shelf-life was increased by earlier harvesting, being 10.9-13.5 days for mature green fruits and 3.1-5.1 days for red-ripe fruits. Fruits of Roma showed the lowest physiological weight loss (7.7-9.7% after 6 days) and longest shelf-life (13.5 days when harvested at the mature green stage). Ascorbic acid content was lowest in mature green fruits at harvest and after storage, during which it decreased. Color development in mature green fruits was poor (yellow or yellowish with red tinge). Fruits harvested at the breaker or half-ripe stage exhibited good shelf-life and keeping quality.

Jang *et al*. (1993) stated that, weight loss of Chinese cabbage was reduced of a greater extent when preserved in polyethylene bags. They also observed that, the use of polyethylene bags with 10 holes on the downward facing side resulted in the lowest trimming loss and best marketability as rated by sensory evaluation.

Cherono *et al*. (2018) investigate the effects of post-harvest handling practices prior to storage on the quality of tomatoes in South African supply chains. Pink mature tomatoes were harvested in the morning and afternoon, transported from two farms located 40 km apart to two central pack houses located near each of the farms in Limpopo, South Africa. The samples were transported using bins (468 kg capacity) and lugs (20 kg capacity). After harvesting, the samples were either immediately transported to the pack house and precooled within two hours, or left in the field and transported to the pack house to be pre-cooled after six hours, to simulate delays during transportation. On arrival at the pack houses, the fruit was sampled from the bottom 0.15 m of each lug or bin, precooled using forced air and washed. After precooling, the samples were stored either under ambient conditions or refrigerated storage (15±2 °C). The tomato color, firmness, weight loss, marketability and pH were monitored over a 24-day storage period. The rate of change of the fruit hue angle was significantly ($p \leq 0.05$) higher for samples handled using bins as compared to those handled using lugs. Handling conditions had no significant ($p > 0.05$) effect on the rate of loss of fruit flesh firmness. The bottom layer of fruit stored in bins showed 30% mechanical damage as compared to 2% in lugs. Harvesting in the morning and pre-cooling within two hours improved fruit marketability and weight-loss by up to 200 kg/ton and 75 kg/ton, respectively, as compared to harvesting in the afternoon and pre-cooling after six hours. As the best practices for industry, the study recommends minimizing the time to pre-cooling, harvesting in the morning and using lugs to handle the fresh tomatoes.

Nazar *et al*. (1996) studied the shelf life of carrots, turnips, tomatoes, okras and bitter gourds packed in polyethylene bags. It was found that, packaging eliminated moisture loss and also reduced the loss of vitamin c and chlorophyll compared with unpacked control samples.

Zhu *et al.* (2002) recommended hot water treatment as commercial postharvest technology of mango. They observed that hot water treatment made the color of both peel and pulp homogenous. The soluble solids content and pH values were very high in hot water treated fruits than those of non-hot treated fruits. Another experiment was carried out by Rosa (2002) on mangoes (cv. Keitt) where fruits were treated with hot water (50°C for 10 minutes). The results showed that hot water treatment had a bad effect on firmness and color.

Dennis *et al.* (1979) stated that it was possible to store green mature fruits cultivars (Sonato and Soatine) for up to 6 to 10 weeks at control atmosphere storage (3% O_2, 5% CO_2 and 92% N_2) at 13°C and 93-95% RH.

Gupta *et al.* (1988) stated that at room temperature the tomato fruits could be stored up to 12 days only with less than 10% weight loss compared to 20 days at 10°C and 28 days at 5°C and the respiration rate was higher in ethephon treated fruits than in those ripened on the plants.

The shelf life of a fresh market tomato cultivar (Money Maker) and a processing tomato cultivar (Cal-J) at 4.5°C, room temperature (18-25°C) and 30°C was studied by Nyalala *et al.* (1998). Weight loss was significantly higher at increased temperatures and there was an interaction between cultivar and temperature at room temperature and 30°C. Loss of fruit firmness was greatest at the 2 higher temperatures but there were no significant differences between the cultivars. The difference in shelf life was significant between temperature levels and cultivars. Money Maker had a longer shelf life than Cal-J under all conditions, but storage temperature rather than cultivar was the major factor determining shelf life.

Ping *et al.* (1996) studied the quality, degree of chilling injury and physiological changes occurring in tomato fruits heated at 33 or 38°C for 2, 5 or 8 days after cold storage (2+1°C, 85-90% RH) were investigated. Heat-treatment was able to lower respiration rate, cell membrane permeability and malondialdehyde (MDA) content, increase free proline content and decrease chilling injury. The best treatments were 33°C for 5 days or 38°C for 2 days; 33°C for 2 days had less effect, and treatment for 8 days resulted in fruit injury, increased MDA content, cell membrane permeability and off-flavor, and decreased fruit firmness. There was a positive correlation between the chilling injury index and cell membrane permeability (r = 0.9744).

Kim *et al.* (1996) studied the effect of storage temperature (0-3 5°C) on the quality of tomato and strawberry fruits, stored for 21 and 8 days, respectively, were investigated. In tomatoes, the respiration rate of fruits increased at higher storage temperatures, but decreased with storage period. Ethylene production was suppressed at 0, 5, 10, 30 or 35°C, but was high for fruits stored at 20°C due to a mould infection; mould infection was also observed on fruits stored at 15 or 25°C. Fruit firmness was maintained following storage at 0, 5, 10, 30 or 35°C, but at 15, 20 or 25°C softening occurred. The a/b values of fruit skin color were lower for fruits stored at 0,10, 30 or 35°C than for fruits stored at 15, 20 or 25°C

Naik *et al* (1993) studied the tomatoes are highly perishable and postharvest losses vary greatly among production areas and seasons of production. This study was conducted to evaluate the effects of open or protected cultivation system and postharvest modified atmosphere packaging (MAP) on the physical and chemical changes of tomatoes during ambient storage with temperatures ranging from 20 to 35 °C and relative humidity (RH) of 80% to 90%. The cultivation system had no significant effect on the physicochemical constituents. In contrast, MAP storage significantly influenced some of the storage parameters evaluated. Use of paper bags and 0.02 mm thick low-density polyethylene bags with diffusion holes slightly delayed ripening, effectively reduced weight loss, minimized decay incidence and maintained better visual quality throughout the 12-day storage period relative to fruits stored in the open.

Ben-Yehshua *et al*. (1980) wrapped brinjal fruits in height density polyethylene (10 um thick) or in polyethylene (20 or 30 ums thick), which was sealed of left unsealed. The rate of loss of weight of sealed vegetable was 10 to 30-fold less than that of non sealed packages, and the firmness and quality were maintained for a longer period.

Perez *et al* (2003) reported the effect of storage temperature on the shelf life, weight loss, and respiration rate and ethylene production of Hass avocado (Perseaamericana Mill) was studied. Two batches of green mature avocado fruits, classified as ‘‘super extra’’ were stored at 10 and 20 °C (first batch) and at 7 and 25 °C (second batch). The avocado shelf lives were 22, 8, 32 and 6 days at 10, 20, 7 and 25 °C, respectively. Based on the data of the first assay Q10 was calculated as 2.75, with this value the predicted shelf life at 7 and 25 C were 29.8 and 4.8 days, respectively. That mean shelf life was underestimated 7 and 20% at 7 and 25 °C, respectively. Weight loss was linear at both the storage temperatures, it was 4.3% in fruits at 20 °C for 8 days and 3.0% at 10 °C for 22 days. The maximum CO_2 production at 20 °C was reached during the second day of storage, while at 10 C it was reached at the 17th day (176.17 15.98 and 74.73 7.32 ml/kg/ h, respectively). The maximum ethylene production at 20 °C was reached the second day of storage, and at 10 °C the 6th day (239.06 54.55 and 28.00 8.12 ml/kg/h, respectively).

Padmanaban *et al.* (1994) studied on fresh vegetables of carrots, bitter gourds, lab-lab bean, brinjal, okra, beet roots, tomatoes, chilies and peas stored in polyethylene bags together with relative humidity and vials containing fused $CaCl_2$ or $CaCo_3$ at 15 g/kg with perforated lids or loosed under ambient conditions (25-31 0C and 70-85 % RH). Storage in poly bags increased shelf life in all cases.

Frezza *et al.* (1998) stated that polyolefin film gave the best results as measured by weight loss and firmness of tomatoes at 10^0c and 80% RH, and could be stored up to 5 weeks. They also reported that, PVC- film wrapped tomatoes developed color at a lower rate than control and polyolefin-wrapped tomatoes. Decay (caused by Alternaria sp.) was observed form after 4 weeks of storage for non wrapped and wrapped tomatoes.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from February to March 2018 on estimation of post harvest losses of tomato and integrated method for minimizing losses and assuring quality. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Location of the experimental site

The experiment was conducted at postharvest laboratory of Sher-e-Bangla Agricultural University, Dhaka. It was located in 24.09^{o} N latitude and 90.26^{o} E longitudes. The altitude of the location was 8 m above from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.2 Experimental materials

The experimental materials were mature green, uniform size and shape tomato. Fresh tomato was obtained from farmer field of Raipura upazilla of Narsinghdi District. After harvesting, the samples were labeled and separated into experimental units of similar quantity for further analysis.

3.3 Treatment of the experiment

W_o = Tap water dips, W_H= Hot water dips

I = With ice, I_o= Without ice

P= Perforated Polybag, P_o = Non-Perforated Polybag

R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%

Treatment combination

T_1= Wo + I + P + R_H

T_2= Wo + I + P + R_o

T_3= Wo + I + P_o + R_H

T_4= Wo + I + P_o + R_o

T_5= Wo + I + Control + R_H

T_6= Wo + I + Control + R_o

T_7= Wo + I_o + P + R_H

T_8= Wo + I_o + P + R_o

T_9= Wo + I_o + P_o + R_H

T_{10}= Wo + I_o + P_o + R_o

T_{11}= Wo + I_o + Control + R_H

T_{12}= Wo + I_o + Control + R_o

T_{13}= W_H + I + P + R_H

T_{14}= W_H + I + P + R_o

$T_{15}= W_H + I + P_o + R_H$

$T_{16}= W_H + I + P_o + R_o$

$T_{17}= W_H + I + \text{Control} + R_H$

$T_{18}= W_H + I + \text{Control} + R_o$

$T_{19}= W_H + I_o + P + R_H$

$T_{20}= W_H + I_o + P + R_o$

$T_{21}= W_H + I_o + P_o + R_H$

$T_{22}= W_H + I + P_o + R_o$

$T_{23}= W_H + I + \text{Control} + R_H$

$T_{24}= W_H + I + \text{Control}+ R_o$

3.4 Design and layout of the experiment

The single factor experiment was laid out in the Completely Randomized Design (CRD) with three replications. A total of 288 tomato with more or less similar size and shape and free of visible disease symptoms were harvested. The skin adherences, dots and latex were cleaned by gently wiping the fruits with moist and clean towel. There were 4×24×3 treatments combinations.

3.5 Methods

The postharvest treatments were randomly assigned to the experimental unit. The tomato fruits were treated with hot water, ice, perforated polybag, non-perforated polybag, relative humidity etc. This experiment placed on laboratory table and rack at ambient condition.

3.5.1 Control (Tomato treated with tap water)

After harvesting half of total tomato fruits were washed with normal tap water. After washing tomato were kept in a shady place for air drying and used for next treatments.

3.5.2 Tomato treated with hot water

Normal tap water was heated in plastic jar at a temperature of 52°C. A thermometer was used to measure the temperature. Rest amount of tomato were dipped into hot water for 2 minutes.

3.5.3 Packaging with polybag

Tomato is bagging with no polybag, perforated and non-perforated polybag. Then half portion of all bagging and non bagging tomatoes are kept into plastic cerates with ice bottle and rest half packaging with a plastic cerates with no ice bottle.

3.5.4 Treated with ice

Ice bottle are used along with produce for first cooling. However, as the ice comes in contact with the produce, it melts and the cooling rate slows considerably. The ice keeps a high relative humidity around the product.

3.5.5 Treated with relative humidity (RH)

For making relative humidity condition a steel rack was used in laboratory which was covered with a wetted sack. These sacks were always kept in wetted condition. As a result, relative humidity was 98% during storage.

3.6 Collection of data

To assess the effect of different types of treatment and relative humidity on postharvest losses and shelf life of tomato data on different parameters were collected at 3 days interval during the storage period. The shelf life (days), weight loss (%), time for color development (days), Disease incidence (%), pH, Vitamin-C, TSS (%) and TA (Titratable acidity) of marketable tomato were studied the entire storage period.

3.7 Parameters studied:

3.7.1 Changes in physical characteristics of tomato fruit:

i. Shelf life
ii. Weight loss (%)
iii. Vitamin-c
iv. TSS (%)
v. TA (Titratable acidity)
vi. Color change
vii. Disease incidence (%)

3.8 Method of studying different parameters

3.8.1 Shelf life

The shelf life was calculated by counting the days required to attain the beginning of rotting of fruits.

3.8.2 Weight loss (%)

The fruits of each treatment were individually weighted by using electric balance and kept for storage. Percent total weight loss was calculated by using the following formula.

$$\% \text{ Weight loss} = \frac{\text{Initial weight stored} - \text{Final weight}}{\text{Total weight stored}} \times 100$$

3.8.3 Vitamin C content

Ascorbic acid content was determined according to the method of Ranganna (1979).The procedure of lab test for vitamin C content was done and obtained results were recorded.

3.8.4 Estimation of total soluble solids content (TSS %)

Total soluble solids content of vegetable pulp was estimated by using Abbes, Refractometer. A drop of mango juice squeezed from the fruit pulp on the prism of the refractometer. Percent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna (1979).

3.8.5 Titratable Acidity (TA)

Titratable acidity was estimated chemical analysis process by using tomato pulp stored in control and high relative humidity condition. Titratable acidity was declined slowly when stored in low temperature. The titratable acidity of tomato pulp was determined by titration.

3.8.6 Color change

The peel color of fruit was recorded by matching with a standard color chart. Thirteen days required of color during storage and ripening were measured by using numerical rating scale of 1-7, where 1 = green, 2 =Greenish yellow, 3 = Yellowish (< 25%), 4 = Light red (<50%), 5 = Uniform red colour (<75%), 6 = Deep red (75-100%) and 7 = Mashy not edible.

3.8.7 Assessment of disease incidence

The tomato fruits were critically examined one day later for the appearance of rot. The incidence of fruit rot was recorded after one day. The first count was made at the 3 days after storage. Diseases incidence means percentage of fruits infected with disease. This is measured by calculating the percentage of fruits infected in each replication of each treatment. The diseased fruits were identified symptomatically.

The disease incidence was calculated as follow:

$$\text{\% Disease incidence} = \frac{\text{Number of infected fruits in each replication}}{\text{Total number of fruits in each replication}} \times 100$$

3.9 Statistical analysis

The data recorded on different parameters were statistically analyzed using MSTAT software to find out the significance of variation resulting from the experimental treatments. The mean for the treatments were calculated and analysis of variance for each of the characters was performed by F (variance ratio) test. The differences between the treatment means were evaluated by LSD test at 1% or 5% level of probability whenever applicable.

CHAPTER IV

RESULTS AND DISCUSSION

A laboratory experiment was conducted to investigate the influence of various post harvest treatments and the storage conditions in tomato. This chapter includes the findings of the results and discussion with appropriate interpretation. The experiment consisted of 24 treatment combinations. Observations on various physio-chemical, physiological and biochemical changes during storage were recorded. The results have been presented under the following headings.

4.1 Shelf life (days)

The maximum shelf life was observed in T_{11}, T_{13}, T_{15}, T_{17}, T_{19}, T_{21} T_{23} and T_1 (17 days), followed by T_8 (15days) in the fruits treated with hot water, packed in perforated polyethylene bag and kept in ice. On the other hand, tomato treated with control without packaging showed the minimum T_{12} (7days) shelf life. It was statistically similar to T_6, T_7, T_4, T_2, $T_{10,}$ T_{22} and T_{14} (9 days) respectively (Figure 1). A major problem with the storage and marketing of fresh tomatoes is their relatively fast deterioration in quality and short shelf life. Hence, different post-harvest technologies are employed in reducing the losses and extending the shelf life. High temperature and relative humidity favor growth of microorganisms which cause extensive damage to the produce. Humid tropical climate conditions favors decay of bruised yam tubers and also encourages the proliferation of harmful organisms.

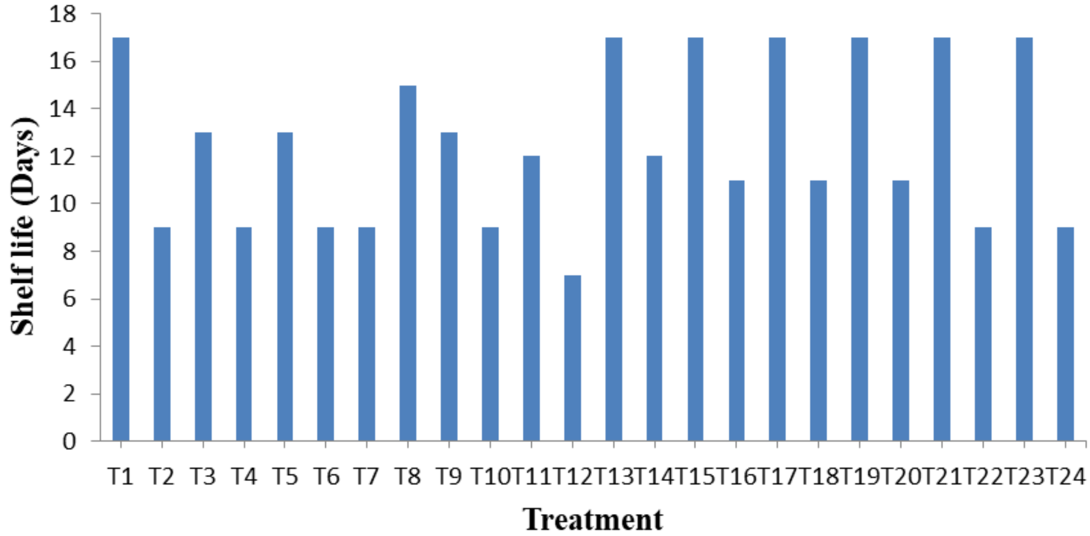

Fig. 1. Effect of postharvest treatments on shelf life of tomato

W_o = Tap water dips, W_H= Hot water dips, I = With ice, I_o= Without ice, P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%

T_1= Wo + I + P + R_H, T_2= Wo + I + P + R_o, T_3= Wo + I + P_o + R_H, T_4= Wo + I + P_o + R_o, T_5= Wo + I + Control + R_H, T_6= Wo + I + Control + R_o,T_7= Wo + I_o + P + R_H, T_8= Wo + I_o + P + R_o, T_9= Wo + I_o + P_o + R_H, T_{10}= Wo + I_o + P_o + R_o, T_{11}= Wo + I_o + Control + R_H, T_{12}= Wo + I_o + Control + R_o, T_{13}= W_H + I + P + R_H, T_{14}= W_H + I + P + R_o, T_{15}= W_H + I + P_o + R_H, T_{16}= W_H + I + P_o + R_o, T_{17}= W_H + I + Control + R_H, T_{18}= W_H + I + Control + R_o, T_{19}= W_H + I_o + P + R_H, T_{20}= W_H + I_o + P + R_o, T_{21}= W_H + I_o + P_o + R_H , T_{22}= W_H + I + P_o + R_o, T_{23}= W_H + I + Control + R_H ,T_{24}= W_H + I + Control+ R_o.

4.2 Weight loss (%)

The treatments were found to have significant effect on weight loss of tomato (Appendix I). The highest weight loss (16.17 %) was found in T_{12} treatment while the second highest (14.52%) was in T_6 treatment and the lowest (7.62 %) in the treatment T_{13} (Table 1). This might be due to the rate of transpiration was lower in sealed polythene bag. This might be due to the rate of transpiration was lower in sealed polythene bag. This finding agrees with the report of Syamal (1981). There had also a significant variation due to the combined effect of different method and hot water treatment at room temperature (28°C) in respect of percent weight loss of tomatoes. This means that the difference between the ambient and evaporative was highly significant and therefore the use of treatment for preserving and improving the shelf life of tomatoes cannot be avoided. FAO (1989) as reported that water is an important constituent of most fruits and vegetables and its adds up to the total weight and losses of water will definitely reduce the weight.

The difference was also due to the reason that the fruits were stored for different storage duration (Hobson, 1981). Znidarcic and Pozrl (2006) reported similar result that tomato stored for longer period had greater weight loss. A minimum loss in weight was reported in tomatoes harvested at turning stage when compared to those harvested at red ripe stage after 12 days of storage (Gaur and Bajpai, 1982). Tomatoes stored at room temperature recorded a maximum weight loss as compared to those packed in polyethylene bags due to higher rate of transpiration and water loss (Lingaiah, 1982).

4.3 Vitamin-C (mg/100 g)

Initially tomato contained Vitamin-C but at the last day of storage period it was reduced significantly (Appendix II). The maximum values were found to be T_{13} (6.61mg/100g) and minimum values T_{12} (4.38 mg/100) respectively (Table-1). Vitamin-C was reduced in small amount when fruits were packed in perforated polyethylene bag, hot water and kept in ice. These chemical compositions and changing behavior of its after storage and the vitamin C and titrable acidity content of tomato juice was increased with maturity stages and reached the peak and thereafter started to decreased (Sinaga, 1986).

Table 1. Effect of different postharvest treatments on Weight loss (%) and Vitamin-C (mg/100g) of tomato at the end of shelf life

Treatment	Weight loss (%)	Vitamin-C (mg/100g)
T_1	10.17 j	5.91 e
T_2	13.65 d	4.86 j
T_3	10.69 hi	5.57 f
T_4	14.52 c	4.56 kl
T_5	11.73 g	5.34 fg
T_6	14.95 b	4.56 kl
T_7	13.21 e	4.80 jk
T_8	10.56 i	5.94 de
T_9	10.95 h	5.55 f
T_{10}	14.60 c	4.55 kl
T_{11}	11.65 g	5.39 fg
T_{12}	16.17 a	4.38 l
T_{13}	7.63 n	6.61 a
T_{14}	12.95 ef	5.31 fgh
T_{15}	8.47 m	6.52 ab
T_{16}	13.76 d	5.05 hij
T_{17}	9.62 k	6.33 bc
T_{18}	12.85 f	6.16 cde
T_{19}	8.45 m	6.51 ab
T_{20}	12.99 ef	5.13 ghi
T_{21}	8.99 l	6.36 abc
T_{22}	13.92 d	5.13 ghi
T_{23}	9.70 k	6.21 cd
T_{24}	13.95 d	5.01 ij
LSD%	0.32	0.27
CV	1.62	2.92

W_o = Tap water dips, W_H= Hot water dips, I = With ice, I_o= Without ice, P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%,
T_1= Wo + I + P + R_H, T_2= Wo + I + P + R_o, T_3= Wo + I + P_o + R_H, T_4= Wo + I + P_o + R_o, T_5= Wo + I + Control + R_H, T_6= Wo + I + Control + R_o,T_7= Wo + I_o + P + R_H, T_8= Wo + I_o + P + R_o, T_9= Wo + I_o + P_o + R_H, T_{10}= Wo + I_o + P_o + R_o, T_{11}= Wo + I_o + Control + R_H, T_{12}= Wo + I_o + Control + R_o, T_{13}= W_H + I + P + R_H, T_{14}= W_H + I + P + R_o, T_{15}= W_H + I + P_o + R_H, T_{16}= W_H + I + P_o + R_o, T_{17}= W_H + I + Control + R_H, T_{18}= W_H + I + Control + R_o, T_{19}= W_H + I_o + P + R_H, T_{20}= W_H + I_o + P + R_o, T_{21}= W_H + I_o + P_o + R_H , T_{22}= W_H + I + P_o + R_o, T_{23}= W_H + I + Control + R_H ,T_{24}= W_H + I + Control+ R_o.

4.4 Total Soluble Solids (TSS)

There was a significant difference in TSS for all the tomatoes from the different treatment on the day of purchasing (Appendix III). Total TSS ranged from 3.13– 4.16% and was highest for tomatoes from T_{19} (4.16%) followed by T_{13} (4.15 %) and lowest from T_{12} (3.13%) (Table 2). The hot water tank would have had sweeter flavor at full ripe stage than other treatment and after storage it was reduced which was also lower in fruits packed in perforated polyethylene bag than others. There was a gradual decrease in TSS for produce from the over time. This phenomenon can probably be attributed to the normal senescing causing carbohydrate respiratory losses (Nunes, 2008). Changes in tomato TSS were also significantly different between the storage conditions. Ripening contributes to the breakdown of pectin substances into more simple sugars thereby increasing the total TSS (Wills & Ku, 2002).The total soluble solids increased during the ripening due to degradation of polysaccharides to simple sugars thereby causing a rise in TSS (Naik *et al.*, 1993). Excess moisture promotes the growth of fungi and other spoilage micro-organisms. This increases susceptibility of improved varieties of produce to moulds and insect pests (Akinbode, 1983; Perez *et al*., 2003; Nunes, 2008). For instance, TSS of heat treated tomatoes was unaffected when tomatoes ripened at ambient temperatures (McDonald *et al.,* 1999*)* or when they ripened in a modified atmosphere storage system (Suparlan and Itoh, 2003)

4.5 Titratable Acidity (%)

There was a significant reduction in tomato acidity with storage time (Appendix III). The TA ranged from 0.244– 0.595% and was significantly higher for tomatoes from T_{13} (0.594) compared to T_{19} (0.560) and T_{15} (0.522) which was statistically similar. Tomatoes kept in ambient condition had lower value from T_{12} (0.244%) compared to that T_{10} (0.334) and T_4 (0.333%) respectively, (Table 2). Increased storage temperature has been reported to enhance fruit ripening which is inversely related to the acidity of fresh produce, as organic acids decline with continued ripening (Kader, 2002). The major acid constituents of tomatoes are malic and citric acid. Malic acid decreases quickly as produce start to turn red while the citric acid is rather stable throughout the ripening period (Hobson & Grierson, 1993). For this reason TA was determined using citric acid measurements.

Varieties with higher titratable acidity could have lower incidence of fungal infection and suitable processing (Tigist *et al.,* 2011). The environmental effect on fruit acidity is complex. Organic acids can be produced in the fruit itself from stored carbohydrates (Sakiyamaand Stevens, 1976), while some of these acids may be trans located from the leaves and roots to the fruits (Bertin *et al.*, 2000).

Table 2. Effect of different postharvest treatments on total soluble solids (TSS) (%) and titratable acidity of tomato

Treatment	Total soluble solids (TSS)%		Titratable acidity (TA)%	
T_1	4.09	abc	0.452	defgh
T_2	3.74	ghi	0.357	kl
T_3	4.01	abcdef	0.467	defg
T_4	3.79	fgh	0.333	l
T_5	3.94	abcdefg	0.392	ijk
T_6	3.52	I	0.271	m
T_7	3.75	ghi	0.348	kl
T_8	4.05	abcde	0.439	efghi
T_9	3.93	abcdefg	0.430	ghi
T_{10}	3.84	defgh	0.334	l
T_{11}	3.17	J	0.445	defgh
T_{12}	3.13	J	0.244	m
T_{13}	4.15	A	0.595	a
T_{14}	3.88	bcdefg	0.415	hij
T_{15}	4.12	ab	0.522	bc
T_{16}	3.86	cdefg	0.434	fghi
T_{17}	4.07	abcde	0.488	cde
T_{18}	3.93	abcdefg	0.425	ghi
T_{19}	4.16	A	0.560	ab
T_{20}	3.85	cdefg	0.393	ijk
T_{21}	4.07	abcde	0.494	cd
T_{22}	4.08	abcd	0.373	jkl
T_{23}	3.61	hi	0.485	cdef
T_{24}	3.83	efgh	0.369	jkl
LSD%	0.24		0.052	
CV	3.86		4.640	

W_o = Tap water dips, W_H= Hot water dips, I = With ice, I_o= Without ice, P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%,
T_1= Wo + I + P + R_H, T_2= Wo + I + P + R_o, T_3= Wo + I + P_o + R_H, T_4= Wo + I + P_o + R_o, T_5= Wo + I + Control + R_H, T_6= Wo + I + Control + R_o,T_7= Wo + I_o + P + R_H, T_8= Wo + I_o + P + R_o, T_9= Wo + I_o + P_o + R_H, T_{10}= Wo + I_o + P_o + R_o, T_{11}= Wo + I_o + Control + R_H, T_{12}= Wo + I_o + Control + R_o, T_{13}= W_H + I + P + R_H, T_{14}= W_H + I + P + R_o, T_{15}= W_H + I + P_o + R_H, T_{16}= W_H + I + P_o + R_o, T_{17}= W_H + I + Control + R_H, T_{18}= W_H + I + Control + R_o, T_{19}= W_H + I_o + P + R_H, T_{20}= W_H + I_o + P + R_o, T_{21}= W_H + I_o + P_o + R_H , T_{22}= W_H + I + P_o + R_o, T_{23}= W_H + I + Control + R_H ,T_{24}= W_H + I + Control+ R_o.

4.6. Colour development (13 Days)

The number of days required for color development after harvest of tomato significantly influenced at 13 days due to different post harvest treatment (Appendix II). It was found that the highest colour score (7) was observed in T_{12}, T_2, T_6, T_7, T_{22}, and T_{24} and the lowest treatment colour score T_{13}, and T_{23}, was found in Uniform red colour (Score <6) in hot water, perforated polythene, ice and relative humidity (Fig. 2.) (Plate 2). This might be due to higher concentration of CO_2 and lower concentration of O_2 inside the sealed polythene bag. There had a significant variation due to the combined effect of different color and types of polythene bag at relative humidity in respect of time required for color development or ripening of tomato. Thai *et al.* (1990) found the similar result in their work.

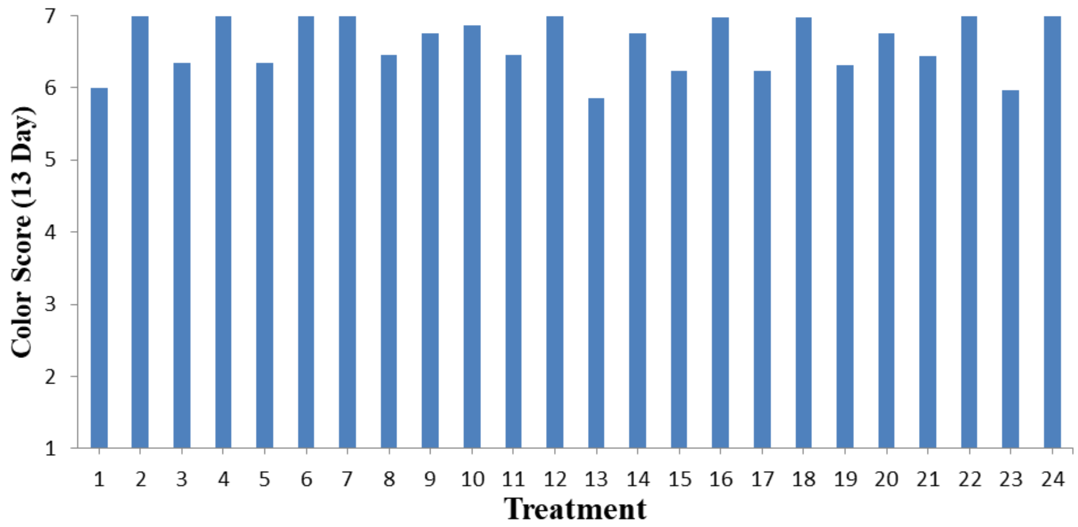

Fig. 2. Effect of postharvest treatments on color of tomato at 13 days

W_o = Tap water dips, W_H= Hot water dips, I = With ice, I_o= Without ice, P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%

T_1= Wo + I + P + R_H, T_2= Wo + I + P + R_o, T_3= Wo + I + P_o + R_H, T_4= Wo + I + P_o + R_o, T_5= Wo + I + Control + R_H, T_6= Wo + I + Control + R_o,T_7= Wo + I_o + P + R_H, T_8= Wo + I_o + P + R_o, T_9= Wo + I_o + P_o + R_H, T_{10}= Wo + I_o + P_o + R_o, T_{11}= Wo + I_o + Control + R_H, T_{12}= Wo + I_o + Control + R_o, T_{13}= W_H + I + P + R_H, T_{14}= W_H + I + P + R_o, T_{15}= W_H + I + P_o + R_H, T_{16}= W_H + I + P_o + R_o, T_{17}= W_H + I + Control + R_H, T_{18}= W_H + I + Control + R_o, T_{19}= W_H + I_o + P + R_H, T_{20}= W_H + I_o + P + R_o, T_{21}= W_H + I_o + P_o + R_H , T_{22}= W_H + I + P_o + R_o, T_{23}= W_H + I + Control + R_H ,T_{24}= W_H + I + Control+ R_o.

4.7 Disease incidence (%)

Significant variation was observed in respect of disease incidence among postharvest treatments (Appendix IV). It was observed that the disease incidence trended to increase with the advancement of storage period in both control and hot water treatment. The present investigation showed that the postharvest treatments of tomato harvest had significant effects on disease incidence.

Here, it was also observed a gradual increase in disease incidence with the advancement of storage duration. Disease incidence was found to be the highest (15.59% 42.47% 67.62 and 100% at 7^{th}, 10^{th} and 13^{th} and 16^{th} days of harvest respectively) at all stages in case of control (T_{12}) where the hot water, ice, perforated polybag and relative humidity (T_{13}) represented the lowest disease incidence (0.0%, 2.76% 19.68% and 43.54% at 7^{th}, 10^{th} and 13^{th} and 16^{th} days of harvest respectively) (Table 3).

Table 3. Effect of postharvest treatments on Disease incidence (%) of tomato at different days of storage

Treatment	Disease incidence (%)							
	7th		10th		13th		16th	
T_1	0.00	E	6.92	q	26.53	p	45.80	p
T_2	10.50	Bc	33.82	e	54.76	f	100.00	a
T_3	0.00	E	14.85	l	28.54	no	80.72	g
T_4	11.07	B	38.55	c	60.71	d	95.52	b
T_5	0.00	E	13.87	m	22.62	r	60.60	j
T_6	11.68	B	40.30	b	63.50	c	100.00	a
T_7	0.00	E	7.85	pq	25.96	pq	46.66	o
T_8	10.52	Bc	35.42	d	58.55	e	94.58	c
T_9	0.00	E	19.73	j	29.00	n	65.51	i
T_{10}	14.05	A	41.78	a	64.49	b	100.00	a
T_{11}	0.00	E	16.57	k	25.64	q	58.80	k
T_{12}	15.59	A	42.47	a	67.62	a	100.00	a
T_{13}	0.00	E	2.76	t	19.68	t	43.54	q
T_{14}	0.00	E	22.53	i	35.46	k	72.52	h
T_{15}	0.00	E	9.58	o	29.87	m	50.64	m
T_{16}	4.41	D	25.59	h	49.61	i	87.66	f
T_{17}	0.00	E	5.72	r	27.98	o	49.76	n
T_{18}	5.36	D	26.68	g	50.44	h	90.65	e
T_{19}	0.00	E	3.95	s	20.49	s	45.50	p
T_{20}	0.00	E	16.72	k	44.71	j	80.81	g
T_{21}	0.00	E	10.65	n	30.89	l	55.82	l
T_{22}	5.27	D	20.65	j	52.50	g	92.73	d
T_{23}	0.00	E	8.78	op	29.94	m	45.74	p
T_{24}	8.81	C	30.94	f	53.18	g	93.44	d
LSD%	1.85		0.95		0.73		0.84	
CV	27.72		2.78		1.09		0.69	

W_o = Tap water dips, W_H= Hot water dips, I = With ice, I_o= Without ice, P= Perforated Polybag, P_o = Non-Perforated Polybag, R_H= 80±5% Relative Humidity (RH), R_o= Relative humidity (RH) at room condition 60-65%,

T_1= Wo + I + P + R_H, T_2= Wo + I + P + R_o, T_3= Wo + I + P_o + R_H, T_4= Wo + I + P_o + R_o, T_5= Wo + I + Control + R_H, T_6= Wo + I + Control + R_o,T_7= Wo + I_o + P + R_H, T_8= Wo + I_o + P + R_o, T_9= Wo + I_o + P_o + R_H, T_{10}= Wo + I_o + P_o + R_o, T_{11}= Wo + I_o + Control + R_H, T_{12}= Wo + I_o + Control + R_o, T_{13}= W_H + I + P + R_H, T_{14}= W_H + I + P + R_o, T_{15}= W_H + I + P_o + R_H, T_{16}= W_H + I + P_o + R_o, T_{17}= W_H + I + Control + R_H, T_{18}= W_H + I + Control + R_o, T_{19}= W_H + I_o + P + R_H, T_{20}= W_H + I_o + P + R_o, T_{21}= W_H + I_o + P_o + R_H , T_{22}= W_H + I + P_o + R_o, T_{23}= W_H + I + Control + R_H ,T_{24}= W_H + I + Control+ R_o.

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was carried out at the postharvest laboratory of Sher-e-Bangla Agricultural University, Dhaka during February to March 2018. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The present research was conducted on the aspect of physiological changes and shelf life of tomato through pre-harvest condition, various postharvest treatments. It is a fact that Bangladesh is blessed with rich farmlands and subsequent good harvest each year. The country is one of the leading producers of tomatoes, pepper, plantain, onions, okra and other vegetables that are grown in its diverse agro-ecological zones. Losses of horticultural produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. During the process of distribution and marketing, substantial losses are incurred which range from a slight loss of quality to total spoilage. Postharvest losses may occur at any point in the marketing process, from the initial harvest through assembly and distribution to the final consumer.

In this study observations were made on external and internal fruit attributes, physiochemical properties such as shelf life, total weight loss, vitamin C, total soluble solids content, titratable acidity and disease incidence. External fruit attributes were evaluated by unaided eye, and standard color chart was used for the determination of skin color. In this experiment tomato of each treatment from three replications were collected randomly at 1, 3, 6, 9, 12, 15 and 17 days after harvest for physiochemical studies. The data were statistically analyzed and interpreted. Marked variations were observed in relation to various fruit characters. The results of the experiment showed that almost all the parameters studied were significantly influenced by the different post harvest treatments.

The maximum shelf life was observed in T_{11}, T_{13}, T_{15}, T_{17}, T_{19}, T_{21} and T_{23} (17 days), followed by T_8 (15days) in the fruits treated with hot water, packed in perforated polyethylene bag and kept in ice. On the other hand, tomato treated with control without packaging showed the minimum T_{12} (7days) shelf life. It was statistically similar to T_6, T_7, T_4, T_2, T_{10} T_{22}, T_{14} (9 days) respectively.

The treatments were found to have significant effect on weight loss of tomato. The highest weight loss (16.17 %) was found in treatment T_{12} the second highest (14.52%) was in treatment T_6 and the lowest (7.62 %) in the treatment T_{13}. Initially tomato contained Vitamin-C but at the last day of storage period it was reduced significantly. The maximum values were found to be T_{13} (6.61mg/100g) and minimum values T_{12} (4.38 mg/100) respectively. Vitamin-C reduced in small amount when fruits were packed in perforated polyethylene bag, hot water and kept in ice.

Total TSS ranged from 3.13– 4.16% and the highest was found from T_{19} (4.16%) followed by T_{13} (4.15 %) and lowest from T_{12} (3.13%). The hot water would have had sweeter flavor at full ripe stage than other treatment and after storage it was reduced which was also lower in fruits packed in perforated polyethylene bag than others. There was a gradual decrease in TSS for produce from the over time. There was a significant reduction in tomato acidity TA with storage time. The TA ranged from 0.244 – 0.595% and was significantly higher for tomatoes from T_{13} (0.594) compared to T_{19} (0.560) and T_{15} (0.522) which was statically similar. Tomatoes kept in ambient condition had lower from T_{12} (0.244%) compared to that T_{10} (0.334) and T_4 (0.333%) respectively.

The number of days required for color development after harvest of tomato day was significantly influenced at 13 days due to different post harvest treatment. It was found that the highest deferent treatment color score $T_{12,}$

T_2, T_6, T_7, T_{22}, and T_{24} (Score 7) and the lowest treatment colour score T_{13}, and T_{23}, was found in Uniform red colour (Score <6) in hot water, perforated polythene, ice and relative humidity.

Significant variation was observed in respect of disease incidence among postharvest treatments. It was observed that the disease incidence trended to increase with the advancement of storage period in both control and hot water treatment. The present investigation showed that the postharvest treatments of tomato harvest had significant effects on disease incidence.

Here, it was also observed a gradual increase in disease incidence with the advancement of storage duration. Disease incidence was found to be the highest (15.59% 42.47% 67.62 and 100% at 7th, 10th and 13th and 16th days of harvest respectively) at all stages in case of control (T_{12}) where the hot water, ice, perforated polybag and 80±5% relative humidity (T_{13}) represented the lowest disease incidence (0.0%, 2.76% 19.68% and 43.54% at 7th, 10th and 13th and 16thdays of harvest respectively).

Conclusion: To minimize postharvest losses and keeping maximum quality in storage, hot water treatment is needed than other treatment. Without the postharvest treatment tomato was attacked by fungi and color deterioration occurred that led to shorter shelf life and lower quality. In these experiments found that T_{13} was the best treatment that reduce weight loss (%), diseases incidence (%) color development higher vitamin C, TSS and TA (%) content than others. So it is proved that the tomato fruit treated with hot water, ice and storage with perforated polybag and 80±5% relative humidity that increase shelf life and quality of tomato.

REFERENCE

Adeniyi, M. O. (1977). Status of plant protection in the operation feed the nation programmers, presidential address delivered at its 7th Annual *Conference at Institute of Agriculture Research and Technology (IAR&T), Moore plantation in Ibadan* Page 10-17.

Agboola, S. D. (1980). The role of the Nigerian Stored Products Research Institute in Nigeria March towards self sufficiency in food. *NSPRI occasional paper series* No. 117 page 25-29.

Akinbode, I. A. (1983). A comparative analysis of the adaptation of post- harvest loss prevention practices by farmers and traders in Oyo state of Nigeria. *Agricultural Wastes*, **5**: 179-188.

Anju-Kumari, Bhardwaj, M. K., Guleria S.P.S. and Kumari, A. (1993). Influence of stage of harvest on shelf life and quality of tomato. *Horticulture., J*. **6**(2) : 89-92.

Ben- Yehoshua, S., Kobiler, I. and Shapiro, B. (1980). Effects of individual seal-packing of fruit in film of high density polyethylene (HDPE) on various post harvest blemishes of citrus and tomatoes. *Hort. Science*, **15** (3) 93p.

Bertin, N., S., Guichard, C., Leonardi, J.J., Longenesse, D., Langlois and Navez, B. (2000). Seasonal evolution of the quality of fresh greenhouse tomatoes under Mediterranean con dictions, affected by air vapor pressure deficit and plant fruit load. *Ann. Bot*. **85**:741–750.

Charles, A. (2009). Reducing Postharvest Losses of Horticultural Commodities in Nigeria through Improved Packaging cited from the world of Food Science article Page.

Cherono, M., Jamil, M., Anwar N. and Kapse, A. F. M. (2018). Color atlas of postharvest quality fruits and vegetables. *Blackwell Publishing*, Pp. 145-148.

Desai, B. B. and Salunkhe, D. K. (1991). Fruits and Vegetables. In: Salunkhe DK, Deshpande SS (Eds) Foods of Plant Origin. Production, Technology and Human Nutrition, *AVI, New York*, pp 301-355.

Dennis, N., Mulekar, V. G., and Soto-Valdez, H. (1979). Effect of maturity stage on quality of tomato cv. *Bulletin Penelitian Horticulture* **11** (4): 22-36.

Diaz, P. and Saltveit, M. E. (1997). Changes in transpiration rates and skin permeance as affected by storage and stage of tomato fruit ripeness. *Postharvest-Hort. Series Dept. of Pomology, Univ. of California.* **18**, 34- 38; 4.

FAO, (1989). Prevention of Post-Harvest Losses Fruits, Vegetables and Root Crops: A Training Manual (Smith, K.ed.). Food and Agricultural Organization of the United Nations, Rome. Series: no 17/2.

FAO. (2002). Fruits and vegetables: an overview on socio-economical and technical issues. Agriculture and consumer Protection.

FAO. (2011). Food loss reduction strategy: Rural infrastructure and agro industries division. p. 8-12.

FAO. (2013). Abundance of Food and available of fruits and vegetables. Food and Agricultural Organization of the United Nations, Rome. Series: no 12/3.

Frezza, D., Moccia, S., Trinchero, G., Chuesa, A. and Ben Yehoshua, S. (1998). Polyolefin and PVC films on the quality and shelf life and tomatoes. 14^{th} International congress on Plastics in Agriculture. *Tel Aviv, Israel,*.pp 513-520.

Gaur, G. S. and Bajpai, P. N. (1982). Effect of storage on tomato harvested at different stages of maturity. *Progressive Horticulture*, **14** (1) : 47-49.

Gupta.O. P. N., Methan and Pandita, M. L. (1988). Effect of ethrel on the storage behaviour of tomato fruits at various storage conditions. Hariana J. *Horticulture , Sci.* **17** (3-4) : 265-272.

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R., and Meybeck, (2011). Global Food Losses and Food Waste. *Food and agriculture organization of the United Nations.*

Hakim, A., Kaukovirta, E., Pehu, E., and Voipi, I. (1997). Effect of hot water, immersion time, and length of storage on chilling injury of tomato fruit. *J. of Vegitables Crop Production*., **3**: 2, 17-27; 17.

Hall, F. W. (1968). Prevention of waste of agricultural produce during handling, storage and transportation. *Topical Stored Institute* pp. 15– 23.

Hamauzu, Y., Chachin, K., and Ueda, Y. (1998). Effect of postharvest storage temperature on the conversion of 14C-mevalonic acid to carotenes in tomato fruit. *J. of the Japanese Society for Horticulture Sci*. **67**: 4, 549- 555; 30.

Hobson, G. E. (1981). The short-term storage of tomato fruit. *J. Hort. Sci.* **56**:363-368.

Hobson, G. and Grieson, D. (1993). Tomato. In: G. Seymour, J. Taylor, and G. Tucker (Eds). *Biochemistry of Fruit Ripening*. Chapman and Hall, London UK. Pp. 405- 442.

Jang, Y. j., Jeong, J. C., Chang, T. J., Lee, S. Y. and Pek, U. H. (1993). Marketability affected by cultivars and packaging methods during the long term storage of Chinese cabbage grown in autumn. *J. kotean Society Hort. Sci.* **6**(4-6): 1545. 1995.

Kader, A. A. (2002). Postharvest technology of horticultural crops. Third edition. Publ.3311.Univ. Calif., Div. Agr. Natural Resources, Oakland. CA. USA.

Kaur, G., Kanwar, J. S. and Nandpuri, K. S., (1977). Effect of maturity stages on the storage of tomato. *The Punjab Horticultural Journal*, **17** : 70-74.

Kaynes, K. and Surmeli, N. (1995). Characteristic changes at various ripening stages of tomato fruits stored at different temperatures. *Turkis J. Agric Forestry,* **19** (4) : 277-285.

Kim, Y., Kubo, Y., Inaba, A., Nakamura, R. and Kim, Y. B. (1996). Effect of storage temperature on keeping quality of tomato and strawberry fruits. *J of the Korean Society for Horticulture.Sci.* 1996, **37**: 4, 526-532; 20.

Kipchumba, C., Milindi, S. and Tilahun, S. W. (2018). Effect of infield handling conditions and time to pre-cooling on the shelf-life and quality of tomatoes. *Braz. J. Food Technol.* **21**: 1981- 6723.

Lana, M. M., Tijskens, L. M. M., and van Kooten, O. (2005). Effects of storage temperature andfruit ripening on firmness of fresh cut tomatoes. *Postharvest Biology and Technology*, **35**(1), 87-95.

Lin gaiah, H. B., (1982). Effect of pre-cooling, waxing and prepackaging of field bean, bell pepper, carrot and tomato on their shelf life and quality. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

Li Ping, K., Mercado, J. and Brennan, A. S. (1996). Effect of storage temperature on the shelf life of tomato cv. *Food Science and Technology International* **14**: 65-68.

Mallik, S. E., Biswajit, B. and Bhattacharja, B. (1996). Effect of stage of harvest on storage life and quality of tomato Environ. Ecol., **14** (2) : 301- 303.

Naik, D. M., Mulekar, V. G., Chandel, C. G. and Kapse, B. M., (1993). Effect of prepackaging on physico-chemical changes in tomato (*Lycopersicon esculentum* Mill.) during storage. *Indian Food Packer, July-August*, pp. 9-13.

Nazar, M., Jamil, M., Anwar, M. and Ehtashamuddin, A. F. M. (1996). Film packaging of fresh vegetable. *Sarhad J. Agric*. **12**(2): 185-192.

Nunes, M. C. N. (2008). Color atlas of postharvest quality fruits and vegetables. *Blackwell Publishing*, Pp. 240-243.

Nyalala, S. P. O. and Wainwright, H. (1998). The shelf life of tomato cultivars at different storage temperatures. *TropicalSci.* **38**: 3, 151-154;11.

Padmanaban, M., Misuke, S., and Jesukuma, W. (1994). Study of quality changes of fruits and vegetables during storage. *Postharvest Biology and Technology*, vol.**17** (2): 122-137.

Perez, K., Mercado, J. and Soto-Valdez, H. (2003). Effect of storage temperature on the shelf life of Hass avocado (*Persea Americana*). *Food Science and Technology International* **10**: 73-77.

Ranganna, M. A. (1979). Vitamin C content of postharvest quality of fruits and vegetables. *Biochemistry of Fruit Ripening*. Chapman and Hall, London UK. Pp. 302-313.

McDonald, R. E., McCollum, T. G. and Baldwin, E. A. (1999). “Temperature of water heat treatments influences tomato fruit quality following low-temperature storage,” Postharvest Biology and Technology, vol. **16** (2): 147–15.

Sakiyama, R. and Stevens, M. A. (1976). Organic acid accumulation in attached and detached tomato fruits. *J. Am. Soc. Hort. Sci*. **101**:394-396.

Sinaga, R. M. (1986). Effect of maturity stages on quality of tomato cv. Money maker. *Bulletin Penelitian Horticulture* **13** (2): 43-53.

Suparlan, R. E. and Itoh, K. (2003). “Combined Effects of Hot Water Treatment (HWT) and Modified Atmosphere Packaging (MAP) on quality of tomatoes,” *Packaging Technolog y and Science*. **16** (4): 171– 178.

Syamal, M. M. (1981). Biochemical composition of tomato fruits during storage. *Acta Horticulture*., **287** : 369-374.

Thai, C. N; Shewfelt, R. L; Garner, J. C. (1990). Tomato color and firmness changes under different storage temperatures. No. 89-6596, **26** pp.; 25.

Tigist, M., Tilahun, S., and Kebede, W. (2011). Effects of variety on the quality of tomato stored under ambient conditions. *J. Food Sci. Technol*. Pp. 1- 10.

Tiwari, B. K., Brunton, N. P., and Brennan, C. S. (2013). Handbook of plant food phytochemicals: sources, stability and extraction. Oxford, UK: Wiley-Blackwell.

Wills, R. B. H and Ku, V. (2002). Use of 1-MCP to extend the time to ripen green tomatoes ad postharvest life of ripe tomatoes. *Postharvest Biology and Technology*, **26,** 85-90.

Yoltas, T., Tuzel, Y., Gul, A., Cockshull, K. E., Tuzel, Y. and Gul, A. (1994). Effects of Semperfresh application on ripening of romato harvested at mature stage. *ActaHorticultue*., **366** : 469-474.

Zhu, M. M., Chen, M., Deng, Z. Z., Yu, Y. J. and Yin, P. (2002). Effect of mango hot water treatment and artificial ripening of its quality.Transactions Chinese Soc. Agril.Engg. **18**(3): 139-141.

Znidarcic, D. and Pozrl, T. (2006). Comparative study of quality changes in tomato. *Acta Agric*. Slov. **87** (2):24

APPENDICES

Appendix I. Analysis of variance of the data on days of weight loss and shelf life of postharvest tomato

Source of Variation	Degrees of freedom	Mean Square of	
		Weight loss	Shelf life
Factor A	22	16.828*	27.250*
Error	46	0.037	3.780

***: Significant at 0.05 level of probability**

Appendix II. Analysis of variance of the data on days of vitamin-c, and color of postharvest tomato

Source of Variation	Degrees of freedom	Mean Square of	
		Vitamin-c	Color
Factor A	23	1.516*	48.250*
Error	46	0.026	0.414

***: Significant at 0.05 level of probability**

Appendix III. Analysis of variance of the data on days of TSS% and TA of postharvest tomato

Source of Variation	Degrees of freedom	Mean Square of	
		TSS%	TA
Factor A	23	0.226*	0.021*
Error	45	0.022	0.002
***: Significant at 0.05 level of probability**			

Appendix IV. Analysis of variance of the data on days of Disease incidence of different days of postharvest tomato

Source of Variation	Degrees of freedom	Mean Square for plant height			
		7thDAT	10thDAT	13thDAT	16thDAT
Factor A	23	88.658*	500.978*	761.320*	1420.339*
Error	45	1.262	0.331	0.196	0.258
***: Significant at 0.05 level of probability**					

A

B

C

D

Plate 1. Pictorial presentation A. Harvesting of fruit, B. Fruit treated with hot water, C. Fruit treated with ice, D. Fruit treated with relative humidity.

1

2

3

4

5

6

7

Plate 2. Color development of tomato during storage.
where 1 = green, 2 =Greenish yellow, 3 = Yellowish (< 25%), 4 = Light red (<50%), 5 = Uniform red colour (<75%), 6 = Deep red (75-100%) and 7 = Mashy not edible.