EFFECTS OF DIFFERENT POSTHARVEST TREATMENTS AND PACKING ON QUALITY AND SHELF LIFE OF MANGO

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EFFECTS OF DIFFERENT POSTHARVEST TREATMENTS AND PACKING ON QUALITY AND SHELF LIFE OF MANGO

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Chairman
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Dedicated to
My
Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECTS OF DIFFERENT POSTHARVEST TREATMENTS AND PACKING ON QUALITY AND SHELF LIFE OF MANGO"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in HORTICULTURE****, embodies the results of a piece of bonafide research work carried out by* ***HAKIMUN NAHAR, Registration no. 09-03442*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2015
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The Author

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ABSTRACT

The experiment was carried out at the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in a Completely Randomized Design with three replications. The present research was conducted on the aspect of shelf life and quality of mango through two variety and eight postharvest treatments. Two important varieties of mango namely, V_1= Langra and V_2= Lakhanbhog were assigned to different post-harvest treatments, e.g. T_0= control, T_1= hot water dips, T_2= calcium chloride dips, T_3= sodium metabisulphite, T_4= citric acid dips, T_5= bamboo baskets, T_6= plastic crates having mango wrapped with tissue paper and T_7= plastic crates having mango without wrapping were used in the present study. Results revealed that the minimum changes in firmness (1.36, 2.48, 3.37, 4.01 and 5.01 at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of observation respectively), minimum TSS contents (12.45%, 17.59%, 21.66% and 23.59 at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of harvest, respectively) and the longest shelf life (15.67 days) was observed in V_1 treated with V_1T_1 treatment. The higher vitamin C contents (28.49, 26.42 and 23.47 mg/100g at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively) was found in V_1 treated with V_1T_4 treatment. The better performance was observed as Langra, treated with hot water dips, packaging materials as plastic crates, wrapping with tissue paper for long term storage quality control, transportation and marketing.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
^{0}C	=	Degree Centigrade
DAH	=	Days after harvest
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
CRD	=	Completely Randomized Design
LSD	=	Least Significant Difference
P^H	=	Hydrogen ion conc.
%	=	Percent
DMRT	=	Duncan's Multiple Range Test

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica*L.) belongs to the family Anacardiaceae, is an important and popular fruit of Bangladesh. It has a unique position in respect of nutritional quality, taste, consumer's preference etc., among the fifty kinds of fruits grown in Bangladesh (Ahmad and Sing, 2000). The fruit is believed to have originated in the Eastern India, Asam, Burma or in the Malayan region. It has been cultivated for more than 4000 years (Candole, 1984). It is commercially grown in more than 40 countries. Asia is the main producer with 76.9% of the world production, followed by USA with 13.38%, Africa with 9% & less than 1% for Europe (Jacobi *et al*. 2001).

Its food value is greatly dependent on its chemical composition, such as dry matter, titrable acidity, total sugar, total soluble solid and ascorbic acid which facilitates development of postharvest quality, intrinsic quality such as flavor and taste, transportability and processing. Carbohydrate content in ripe mango pulp is 16.9%. Besides, mango contains appreciable quantity of provitamin A, vitamin C and soluble sugar. The unripe fruits contain nearly 50% more vitamin C than the ripe ones and in mineral content, mango holds an average position among fruits and in containing iron, unripe mango is the first and ripe fruit, about the 16^{th} position among all major fruits (Salunkhe and Desai, 1984). The fruit has really of immense value in respect of money and prosperity.

The postharvest loss in terms of quality and quantity of fruits occur all stages in the postharvest system from harvesting to consumption. Mango showed highly prominent postharvest loss because of its high perishability and climacteric pattern of respiration. There are a number of fungi (*Colletotrium gloeosporoides. Botryodiplodia theobromae* etc.)attack mango fruits at maturity after collection

from tree. These fungi cause infection during storage and transfer, and losses sustained due to fungal infections during those periods are quite heavy. Srinivas *et al.,* (2002) reported that the total postharvest losses of mango to be 17.9% (3.5% Orchard field), 4:9% transportation, 4.1% storage and 5.4% retail level and 14.4% (1.9% Orchard 3.7% transportation, 3.7% storage and 5.3% retail level) respectively. Therefore, a critical area of examination would be how to reduce these postharvest losses in mango and other fresh fruits and to make a better situation of food balance in Bangladesh.

The fruit may require 3–9 days to ripen and this short period seriously limits its commercialization in distant markets. A major and often neglected problem to greater volume of nutritious food is to prevent the losses between the time of harvesting and consumption. Mango fruit has poor storage qualities and technologies for long term storage such as controlled or modified atmosphere have not been applied successfully to this fruit.

The losses occur all along the value chain, beginning from the time of harvesting right up to packaging, storage, transportation, retailing and consumption. As a result of postharvest losses of fruits the nutritional status of the population and the economy of developing countries are deeply affected.

OBJECTIVES

The study conducted to achieve the following objectives:

1. To identify the impacts of different postharvest treatments on shelf life and quality of mango and
2. To identify the impacts of different packing system on shelf life and quality of mango

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh, The fruit begin to ripen in May and the peak ripening months are June and July. From the end of July the yield of the fruit decreases and at August the mango season ends. Producers incur losses of the fruit at harvesting and distribution is due to short shelf life of the fruit. To minimize the losses, it is important to find methods of preserving the fruit or postharvest treatment which can be a way to delay the ripening. The purpose of the present study was to find out the most suitable postharvest treatments for preservation of mango by using available resources.

The mango enjoys wide popularity among millions of people all over the world and has received much attention, to the researchers. A large number of research works on shelf life and quality as influenced by different postharvest treatments has been extensively investigated by a number of scientists in different parts of the world. Storage is essential for extending the consumption period of fruits, regulating their supply to the market and also for transportation to long distances. The mature green fruits can be kept at room temperature for about 4 to10 days depending upon the variety. Shelf life of fruits could be extended by pre-cooling, chemical treatments, low temperature, etc. The harvested fruits are pre-cooled to 10 to 12^{o}C and then stored at an appropriate temperature. The fruits could be stored for 3 to 4 weeks in good condition at low temperature. It is a general practice to harvest fruits early in the season (premature stage) to capture early market. Mature fruits can similarly be ripened with lower doses of ethrel for uniform color development. Green mangoes, harvested in India for commercial preparation of chutneys and pickles as well as for table use, are stored for as long as 40 days at 5.6 to 7.2^{o}C with relative humidity of 85 to 99 percent. Some of

these may be diverted for table use after 2 week ripening period at 16.7 to 18.1°C (Median, 2002).

The present study can be divided into two categories in case of post-harvest of mango storage operation viz. mechanical process and chemical process. Some of the available research findings pertaining to the present study have been reviewed and presented below under the following heads:

2.1 Non-chemical/mechanical treatment

2.1.1 Hot water treatment

Benitez *et al.* (2006) conducted an experiment on mango cv. Namdokmai' where fruits were treated in hot water at 55°C for 5 minutes. They observed that hot water treated fruits remarkably delayed the onset of disease infection, reduced the number of infected fruits and lowered the severity of infection. They reported that hot water treated fruits showed lower disease severity than untreated fruits during storage.

Hu *et al.* (2005) carried out an experiment on mango where fruits were kept in hot water at 52 *to*55°C for 10 minutes. They observed that hot water treated fruits made peel coloration uniform, improved quality and prolonged fruit storage, but could not inhibit fruit ripeness and reduce weight loss due to increased respiration.

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 p^H 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 colour.

Feng *et al.* (1991) conducted an experiment on mango cv. 'Kensington Pride' where mangoes were treated in hot water at 46-48^{0}C for 10 minutes. They observed that hot water treated fruits reliably increased respiration rate, ethylene production, physiological weight loss, total soluble solids during storage.

Manzano *et al.* (1997) experimented to find out an efficient handling method for mango cultivars 'Arumanis and Manalagi' by using different treatments viz. (i) fruits packed using carton boxes with Wit cells, (ii) fruits washed with 75 ppm chlorine, dipped in hot water (53°C) for 5 minutes, packed in boxes with fruit cells or fruit nets, (iii) fruits were washed with fruit cells or fruit nets: Results showed that there were no significant differences in physical and chemical characteristics among the three treatments but treatment (ii) showed longer storage life than other treatments.

Gofur *et al.* (1997) stated that the shelf life of mango fruit without applying any treatment was short because fruits exhibited a rapid rate of ripening. But the mango fruits treated with hot water at 52±2°C for 5 minutes containing 1% $CaCl_2$ delayed ripening by 5 to 8 days and their spoilage was reduced.

Johnson *et al.* (1994) suggested that heating of fruit at temperature of 52 °C for 5 minutes followed by benomyl dip or 30 second unheated overhead spray of prochloraze gave rise to best control of anthracnose disease in mango. Hot water treatment at 47°C temperature for 7.5 to 30 minutes shortened fruit softening and caused extensive external and internal injury as reported by Jacobi and Wang (1992). Joseph and Awrof (1992) observed that mature green mango fruits dipped in hot water at 55°C delayed ripening, controlled decay, minimized weight loss and extend shelf life of fruits without any adverse effects:

Feng *et al.* (1991) reported that hot water treatment of mature hard mango fruits at 52 to 54°C temperature for 8 to 10 minutes controlled mango anthracnose disease during storage and. prolonged shelf life. Jhonson *et al.* (1990) observed that

immersion of mango cv. 'Kingston Pride' in hot water at 52°C for 5 minutes provided good control of stem end rot of mangoes during storage for 14 days at 25 to 30°C temperature.

2.1.2 Other mechanical process

El and Ahmed (2001) showed the effect of wrapping and low temperature storage of mature green mango fruits cv. Tommy Atkins'. The fruits were wrapped in a commercial PVC (polyvinyl chloride) film (X-tend wrapping sheets) and stored at three different temperature (8, 10 or 13) °C and 85-90% RH. Wrapped mango fruits showed significantly lower percentage of fruit weight loss, decay and soluble solid contents and higher vitamin C content, total acidity and total phenol contents during storage period as compared with the control. The firmness of the wrapped fruits remained higher than those of non-wrapped one. Fruits stored at lower temperature (8°C) showed better storage ability and firmness than those stored at higher temperature (10 or 13°C). At the end of the storage period wrapped mango fruits held at 8°C temperature hewed better quality then all other treatments.

An experiment was carried out by Tefera *et al.* (2007) on mango where fruits were stored in a modified atmosphere obtained by packing the fruits in a low density polythene bag. They observed that low density polythene bag positively affected the quality of mangoes during storage. They also noticed that low density polythene bag reduced the weight loss and maintained better quality and marketability compared to the quality of unpackaged mangoes throughout the storage period.

Fawaz (2006) conducted an experiment on mango cv. `Bullock's heart' where fruits were individually wrapped in low density polyethylene film before packing them in one layer in carton boxes. They reported that individual wrapping of fruits

in low density, polyethylene film has the highest carotene content and the lowest weight loss.

A study on mango was carried out by Mortuza *et al*. (2002) where fruits were wrapped with polyethylene bag, newspaper or tissue paper and packed in wooden box, bamboo basket and hard paper carton. He observed that polyethylene bag wrapping caused maximum reduction in incidence of anthracnose (*Colletotrichum gloeosporioides*) which was followed by newspaper, arid tissue paper. Polyethylene wrapping delayed ripening considerably.

The storage performances of mango cv. 'Bangalora', 'Nelum' were studied by Reddy and Haripriya (2002) and analyzed physiochemical performance of the fruits treated with GA_3 and stored in polythene bag with ethylene absorbent. They noticed that this treatment significantly reduced the weight loss, rate of respiration, delayed color development and ripening and had longer shelf life.

The qualities of mango fruits were investigated by Srinivasa *et al*. (2002) on modified atmosphere packaging. On the other hand fruits stored in plastic film covered boxes showed an extension of shelf life up to 19 days and without any microbial growth and off flavor.

An experiment on mango cv. 'Amrapali' was carried out by Ahmed and Singh (2000) and showed that physiological loss in weight was progressively increased as the storage period advanced.

An experiment was carried out by Alves *et al.* (1998) on mango cv. `Tommy and Atkins' where fruits were stored in a modified atmosphere (MA) obtained by packing the fruits in a low density polythene bag. They observed that NIA stored fruits showed delayed ripening but these fruits developed off flavors, did not develop sweetness and remain more acid than control fruits when held under ambient conditions.

Fruits stored in polythene bags resulted in increased respiration and earlier fruits rotten worked with mango fruit cv. `Keitt' and found lower loss of fruit packed in both heat shrinkable polythene film (D-955) arid a low density polythene film (LDPF) for 0 to 5 weeks at 20°C temperature' Bagging reduced postharvest diseases of mango and increased skin color at the ripe stage. The intensity of red colour decreased with the increasing duration of bagging (Hofinan *et al.*; 1997).

Noomhom and Tiasuwan (1995) reported that ripening of `Red' mangoes was delayed by using controlled atmosphere for two weeks compared to untreated mangoes. Mondal *et al.* (1995) noticed that shelf life of mango was 21 days by keeping mango fruits in poly bag.

Jagdish and Pathak (1992) conducted an experiment on mango and observed that postharvest disease severity can be reduced by using wrapping materials. They reported that rot significantly reduced 5 to 8 days after inoculation with *Botryodiplodia theobromadae*, *Aspergillus niger*, *Rhizopus arrhizus* and *Colletotrochiurn gloeosporioides* as a result of wrapping the fruits in 0.002 cm thin plastic film. Initially the mango fruits were surface sterilized, inoculated and incubated for 10 hours at 30±2°C then wrapped with film and further incubated at 30±2°C temperature and 75 to 90% relative humidity.

Fruits were evaluated objectively and subjectively for quality change. Modified atmosphere packaging (MAP) delayed fruits ripening, reduced weight losses, and did not result any off flavor (Gonzalez, *et al.*; 1990). Similar experiment was also conducted by Feng *et al.* (1991) and observed that controlled or modified atmosphere storage delayed ripening and also controlled post-harvest diseases.

Shrivarma and Thimmaraju (1989) conducted an experiment with mango cv. ‘Alphonso’ and reported that fruits stored in perforated polythene bags had the lowest weight loss and spoilage during storage and ripening. Another experiment was conducted on mango cv. ‘Alphonso’ and observed that fruits stored in

perforated polythene bags had the lowest weight loss and spoilage during storage and ripening.

Different types of wrapper materials such as polythene, tissue paper, cellophane, thin film etc. could be used to prolong storage life of mangoes (Singh, 1960). They also reported that among the selected wrapper materials, polythene was found to be superior and cellophane bag caused a greater retention of total soluble solids.

An experiment conducted by Miller and Risse (1988) to explore the benefits of wrapping fresh produce in plastic film as a technique for maximizing fresh quality during postharvest storage and transport. They found that film wrapping reduced moisture loss, retarded softening and maintained characteristic freshness with reduced color development during extended periods of storage and marketing.

Jagdish and Pathak (1992) found that postharvest disease severity can be reduced by using wrapping materials. They showed that rot severity could be significantly reduced 5 and 8 days after inoculation with *Botryodiplodia theobromae*, *Aspergillus niger*, *Rhizopus arrhizus and Colletotrichum gloeosporioides* as a result of wrapping the fruits in 0.002 cm thin plastic film.

Working on 'Nam Dork Mai' mango, Koolpluksee *et al*. (1993) found that storage treatments (Polythylene or Polypropylene bags, perforated or not perforated and with or without ethylene absorbent) reduced off flavors, chilling injury and delayed ripening compared with control fruits. Fruits kept in perforated polypropylene bags with or without ethylene absorbent had the longest storage life of 21 and 23 days respectively while the control fruits had the storage life of less than 5 days.

Mango stored inside the refrigerator throughout the storage period had significantly the longest storage life of 28.33 days as reported by Dipasupil (1984).

Thangaraj and Irulappan (1988) reported that the evaporative cooling maintained the temperature between 14.33°C and 19.26°C and the relative humidity between 70.15% and 82.4% during the storage period. The shelf life of mangoes kept in the evaporative cooling unit was increased from 3 to 28 days, compared to storage at ambient conditions. The storage temperature greatly affected all postharvest quality parameters tested in mangoes during storage. Higher temperatures rapidly deteriorated the physiological and chemical quality of mangoes. Similarly, modified atmosphere packaging positively affected the physiological and chemical quality of mangoes during storage. It also reduced the PWL and maintained better quality in terms of pH, AA_1, and marketability, compared to the quality of unpackaged mangoes throughout the storage period.

Bender *et al*. (2000) worked with CA storage of mangoes suggested to use lower temperature for storage riper fruits. Mature-green Tommy Atkins, Haden, Keitt and Kent mangoes can tolerate and benefit from 3-4% O_2 plus 25% CO_2 for 3 weeks at 12°C, while tree-ripe fruits tolerated and benefited from the same levels of O_2 and CO_2 for 3 weeks at 5°C or 5% O_2 plus 10% CO_2 for 3 weeks at 5°C with an evidence of chilling injury.

Lertpuk *et al.* (1988) observed that great variations in postharvest characteristics of mangoes were only obtained when the conditions in storage were modified. Storage at, 10°C for 3 weeks prior to ambient storage (32°C) significantly extended the postharvest' the effect of two commercial wax coating on' the shelf life of the two varieties. The fruits were dipped fully in 1% aqueous suspension of Prolong or Primafresh C (original concentration) and then the fruits were placed in 20 litre plastic containers followed by storing at 15^{o}C temperature with 85-95% relative humidity. They found that both the commercial grades were highly effective to reduce weight loss as compared with uncoated fruits during storage.

2.2 Chemical treatment

2.2.1 Calcium chloride

In recent years, significant advances have been made in fruit storage by the use of Calcium Chloride dipping alone or combined with other treatments. Therefore, in present study different concentrations of Calcium chloride salts were used to ascertain their effects on delaying the ripening and eating quality of mango fruits.

Due to perishability, farmers are losing a bulk of produce each year. Calcium is relatively divalent action that readily enters the apoplast and is bound in exchangeable from to cell wall and exterior surface of plasma membrane. Nontoxic even at high concentrations it serves as a detoxifying agent. In the cell walls calcium serves as a binding agent in the form of calcium pectates. Calcium has received considerable attention in recent years due to its desirable effects; particularly it can delay ripening and senescence, reduce respiration, extend shelf life and reduce the physiological disorders (Sharma *et al.* 1996).

Postharvest quality of a product after harvest can be improved; it is possible to reduce the rate of quality loss. Surface treatments delay physiological decay in fruit tissues, stabilize the fruit surface and prevent degradation that affect the (Ca_2^+) has been extensively reviewed as both an essential element and its potential role in maintaining postharvest quality of fruit and vegetable crops. The role of calcium in stabilizing cellular membranes and delaying senescence in horticultural crops is well known (Poovaiah *et. al*., 1988).

Dhillon and Sukhjit Kaur (2013) conducted an experiment to assess the effect of postharvest application of Calcium Chloride on the storage life of mango (*Mangifera indica* L.) var. Dushehari fruits. The fully mature mango fruits were harvested and treated with different concentrations of $CaCl_2$ viz. 0%, 2%, 4%, 6% and 8% and stored for different days viz. 3, 6, 9, and 12 days at room temperature. The results showed that postharvest application of Calcium Chloride (6%) had

proved quite effective in enhancing the shelf life of Dushehari mango fruits up to 12 days at room temperature.

The role of calcium in the physiology of plant tissue is well established (Chaplin and Scott, 1980). In addition to its involvement in cell wall membrane and chromosome, metabolism it contributes to the maintenance of configuration of specific enzymes (Jones and Lunt, 1967). Addition of calcium improves rigidity of cell walls and obstruct enzymes such as polygalcturonase from reaching their active sites (John, 1987), thereby retarding tissue softening and delaying ripening. Calcium inhibits the ripening of tomato and pineapples (Goncalves *et al*., 2000 and Wills *et al*., 1977). Its role in physiological disorders is related to shelf life, ripening and fruit quality (Wilnwright and Burbage, 1989).

Calcium as postharvest treatment has been used as firming agents to extend postharvest shelf life in whole and fresh cut fruits. Rosen and Kader (1989) found that $CaCl_2$ treated strawberries by dipping resulted in higher calcium content and were firmer than water dipped. Agar *et al*. (1999) also found $CaCl_2$ maintained the firmness throughout storage for kiwifruits dipped in 0.5 or 1% $CaCl_2$. It was also reported that the rate of fruit softening depends on fruit calcium status.

Postharvest treatments of fruits with low concentrations of calcium salts have been found to reduce physiological disorders and delay senescence (Conway, 1982). Postharvest calcium dips can increase calcium content considerably compared to pre-harvest sprays, without causing fruit injury, depending on salt type and calcium concentration. Postharvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus extending storage life of fresh fruits (Chaplin and Scott, 1980 and Picchion *et al*., 1998).

Most early workers applied calcium by dipping fruits in solutions of calcium salts, but more recent works have shown that vacuum infiltration of these solutions may

be a more effective method of getting calcium into the fruits (Lara *et al*., 2004 and Saftner *et al*., 1998). Infiltrated solutions also retain much of their effectiveness when the fruits are rinsed with water following treatment to reduce the possibility of injury to the fruit or damage (Scott and Wills, 1979). Although most efforts in treating fruit with calcium solutions have been directed towards reducing losses due to physiological disorders, it has been reported that increased calcium content of fruit may also reduce losses due to decay causing organisms (Lara *et al*., 2004).

In India, few researches have been done on papaya using calcium dip application on storage life and some aspects of quality. There was positive effects on prolonging storage life and maintained the quality aspects using dip treatment (Krishna and Purushotham, 2005 and Rajkumar and Manivannan, 2005).

Mahmud *et al*. (2008) conducted an experiment with papaya (*Carica Papaya* L.) fruits index 2 were treated with 1.5%, 2.5% and 3.5% solutions of calcium chloride by dipping and vacuum infiltration (-33 Kpa) or untreated (0%) as control. Effects of these treatments were evaluated on storage life and postharvest quality characteristics of papaya. After 21 days of storage at 13±1°C, the fruits were removed from storage for physicochemical analysis. Following additional five days holding in the storage condition for fruits used for evaluation of the rate of disease incidence and storage life. Postharvest dip treatments at different concentrations of calcium prolonged storage life, slowed down the ripening processes and maintained the quality of papaya. Whereas, it was effectively greater with calcium infiltration treatments than that of dip treatments. Calcium infiltration extended the storage life and retained the quality as calcium concentrations increased up to 2.5% and then declined. The desired effect was obtained at 2.5% infiltration compared with other treatments. The least disease incidence was found in those fruits infiltrated with 2.5% calcium. Hence, it can be concluded that postharvest infiltration of calcium at 2.5% has the potential to control disease incidence, prolong the storage life and preserve valuable attributes

of postharvest papaya, presumably because of its effects on inhibition of ripening and senescence process and loss of the fruit firmness of papaya.

Calcium carbide has been frequently used since long times to enhance ripening process of mango fruits (Paj, 1998), however, some other calcium salts especially calcium chloride and calcium nitrate have been reported in literature to delay the ripening and senescence in fruits by lowering the respiration rate (Kumar and Singh 1993). The calcium salts in different concentrations have either been used as pre-harvest sprays or infiltrated into harvested fruits, while some workers treated the harvested fruits by immersing in calcium solution for varying times. Three fortnightly sprays of 1% calcium nitrate, commencing 6-8 weeks before harvesting, delayed colour change and ripening in storage (Sive and Resnizky 1985).

Wills *et al*. (1988) dipped mature fruits of 3 mango cultivars in 4% (w/v) Ca solution under sub-atmospheric pressure ranging from 20 – 80 kpa (cv. Cengkir) or 20–100 kpa (cvs. Arumanis and Gedong) for 4.5 min. and stored at 23^{o}C. Colour changes were delayed by 1 – 2 days in fruits dipped in Ca at 20 and 40 kpa. In another study, mature green mango cv. Kensington Pride fruits were infiltrated with 2%, 4%, 6% and 8% calcium chloride solution under a positive pressure of 115 kpa for 2 min or in an artificial vacuum of 32 kpa. After treatment, fruits were stored at 20^{o}C in boxes lined and covered with polyethylene film. Pressure and vacuum infiltration with $CaCl_2$ delayed fruit ripening by approximately 12 and 8 days respectively, compared with fruits infiltrated with water. Few differences in the effects of different $CaCl_2$ concentrations on ripening were also observed (Yuen *et al*. 1993).

Mango (cvs. Manila and Tommy Atkins) fruits were stored at 4 or 8^{o}C, 85% RH for 7 or 25 days. Half of the fruits were dipped in 5% $CaCl_2$ for 10 min. prior to storage. The fruits were ripened at ambient temperature (20^{o}C) after storage.

Calcium treatment delayed softening in Tommy Atkins fruits but not in Manila fruits (Corrales-Garcia and Lakshminarayana 1991). $CaCl_2$ at 2% in the fungicide dip raised the Ca level and delayed ripening (Sive and Resnizky 1985). Hot water treatment containing 1% $CaCl_2$ has been found the most effective treatment to retard ripening and spoilage of mango fruits (cvs. Fazli and Ashwina). Ripening was delayed by 5 – 8 days (Gofure *et al*. 1997).

Calcium ammonium nitrate application did not increase shelf-life of mango fruits when immersed for 90 min in 0.2 or 4% solution. However, the external appearance of the fruits was better at a concentration of 4% but this did not guarantee export quality (Freire and Chitarra 1999). These results seem to be quite confusing. Therefore, in the present study different concentration of various calcium salts (i.e. calcium chloride, calcium sulphate and calcium ammonium nitrate) were used to ascertain their effects on delaying the ripening and eating quality of mango fruits.

Anjum and Ali (2004) conducted an experiment with green mature fruits of mango cv. SS-1 (Kala Chaunsa) were immersed for 10 minutes in 2.5%, 5.0% or 7.5% calcium chloride ($CaCl_2.2H_2O$), calcium sulphate ($CaSO_4.2H_2O$) or calcium ammonium nitrate $\{Ca(NH_4NO_3)_2\}$ solutions. A control was also included in which fruits were dipped in fresh water for 10 minutes. The fruits were ripened at ambient temperature (25 ± 3^oC) in boxes lined and covered with newspaper. Calcium chloride delayed the fruit ripening about 3 days as compared to control and resulted in better aroma of the fruits, however, it induced skin shrivelling. Calcium sulphate treatments resulted in improved pulp colour. The increase in concentration of calcium salts resulted in delayed ripening but had negative effect on fruit quality by increasing skin shriveling and lowering flavour and taste of the fruits. Calcium chloride at 5.0% delayed the ripening for 4 days and resulted in better skin and pulp colour but with increased skin shriveling and poor flavour and taste, indicating poor eating quality.

The method of Esguerra and Bautista (1984) is often applied where the mangoes are submersed in a cold calcium chloride solution for 2 hours after harvest. In studies of 'Julie' (Mootoo, 1991) and 'Willard' (Suntharalingam, 1996) mangoes, treatments of 4% to 6% calcium chloride extended the shelf-life of the fruit by 5 to 7 days. Both Tirmazi and Wills (1981) and Suntharalingam (1996)observed skin injury to 'Kensington Pride' and 'Willard' mangoes, respectively, when treated with 8% calcium chloride solutions.

2.2.2 Potassium permanganate ($KMnO_4$)

An experiment was carried out by Silva *et al.* (2009) on mangoes (cv. Keitt and Palmer) where fruits were stored for 18 days at 10 ^{o}C or 15^{o}C (85 to 90% RH) in bags containing vermiculite or silica gel impregnated with saturated aqueous $KMnO_4$ for ethylene absorption. Total soluble solids, alcohol insoluble solids and starch contents after storage were significantly higher in Keitt fruits than in Palmer fruits. Fruit chemical quality after storage was the best in fruits stored at 10°C with vermiculite saturated aqueous $KMnO_4$.

The effect of different methods of ripening retardation of mangoes (cv. Arumanis) during transportation in order to minimize postharvest losses was studied. Mangoes were harvested at optimal packing maturity and treated with (i) wrapping in perforated polythene bags containing $KMn0_4$ as an ethylene absorbent (2.5, 5.0, 7.5 or 10.0 %) and (ii) wrapping in sealed polythene bags with $KMn0_4$ as in . Fruits were then placed in perforated cartons to analyze and inspect for weight loss, soluble solid content, texture, days taken to reach optimal ripeness at room temperature, or the over-ripe condition. These treatments showed considerable effect in regarding ripening (Mootoo, 1991).

Wavhal and Athale (1989) reported that inclusion of a bag of vermiculite (30 g), saturated with $KMnO_4$ in the polythene bag gave a reduction of weight loss and storage disorders. Chattopadhay (1989) carried out an experiment on mango cv.

'Himsagar'. The fruits were stored in tined wooden boxes for up to 14 days after treatment with tap water, cold water or an aminoethoxyvinyl glycine (10 ppm) solution. For each treatment, half of the fruits were kept in boxes with $KMn0_4$ soaked paper savings. Physiological weight loss and decay loss were the minimum in cold water with $KMnO_4$ treatment.

2.2.3 Sodium metabisulphite

Decadence fruit product could be attributed to non- enzymatic browning and it can be treated enzymatically by adding suitable additives such as sodium metabisulphite or sulphur dioxide (Vijayanand *et al*., 2000). Sodium metabisulfite ($Na_2S_2O_5$)is a compound that gradually releases SO_2 and in mostcases it packed as a sheet in a wrapper bag or box thatenables the gradual release of SO_2 to restrain the growthof pathogens and SO_2 treatments have also been used forcontrolling postharvest decay of litchi, figs andblueberries (Cantin *et al.,* 2012). In addition, Sodium metabisulphite isalso widely used to keeping quality grapes and driedmango slices (Abdelgader and Ismail, 2011). Different fresh cut fruits can bestore at recommended temperature from 7 to 20 days andWonderful pomegranate arils reached 16 days at 5°C with20% gas composition of CO_2, while the arils withmechanical damage presented more susceptibility to themoulds after 12 days (Watada and Qi, 1999).

2.2.4 Citric acid

Hossain *et al.* (2014) carried out a study to investigate the effectiveness of chemical (0.2% and 0.3% citric acid and potassium sorbate) and radiation (0.5 and 1.0 kgy) at room and low temperature (4°C) in extending the post-harvest life in relation to delay ripening of mango (*Mangifera indica* L.) during storage to reduce the postharvest losses which will have direct significant impact on local economy. During this study, Potassium sorbate (0.3%) and irradiated sample (0.5KGy and 1.0KGy) took 7 days to ripe fully at room temperature without any decay. At 4°C

temperature, 0.3% potassium sorbate and 1.0 kgy treated samples took 28 days to fully ripe. Reduced rate of moisture and weight loss were found in irradiated sample (1.0 kgy) at both temperature comparing with the other treatments during the storage. A reversible result was attributed between Titratable acidity (TA) and pH. Increasing TSS and significant decline in ascorbic acid were found in all treatments under both temperatures during the storage. At room temperature, reduction in ascorbic acid was low in 1.0 kgy irradiated sample followed by 0.3% citric acid and 0.3% potassium sorbate treated samples from 0 day to 7th day. At 4°C temperature the lowest ascorbic acid loss 1.18 mg was attributed for 0.5 kgy radiation treated followed by 0.3% potassium sorbate (1.22mg) and 1.0 kgy irradiated sample (1.52mg). Total phenol content was increased in all treatments during preservation at both temperatures and the highest total phenol content was found in control sample compare to the other treatments. Total flavonoids content was increased with increasing storage period in all treatments at both temperatures. The present study revealed that postharvest treatment of 0.3% potassium sorbate and 1.0 kgy radiation was most effective to delay ripening that resulted in extending shelf life of mango.

2.3 Different changes during storage

2.3.1 Color development and ripening of fruit

Color is an important mango quality characteristic. For the consumer color development is an important indicator for ripening of mango for edible purpose. Some more information on change in color is cited below.

Jayawickrama *et al.* (2006) conducted an experiment to find out the effect of ethrel on papaya ripening. They observed that fruits at ambient temperature (28±1°C) took 7 days to ripe, but on the other hand when the fruits were treated with ethrel solution (250 ppm) under similar condition it was found to ripen in 4 days.

Kumar and Dhawan (1995) conducted an experiment with different concentrations of ethrel solution (250, 500, 1000 ppm) on mango fruit ripening. They found that the ripening rate progressively increased with increase in concentration. Kumar and Dhawan (1995)

Murray and Hartz (2001) reported that the application of ethylene in the form of ethaphone in tomato hastened uniform ripening keeping the quality of fruit unaffected when proper concentration was used. They further mentioned that a solution of 1000-1500 ppm influenced significantly tomato ripening. However, higher rates caused additional maturity advances, but resulted with unacceptable crop phytotoxicity when air temperature exceeded 35°C for extended period. Furthermore, there were variable cultivar responses to similar ethaphone rates.

Gonzalez *et al.* (1990) performed an experiment with hot water treatment at 46°C for 0, 60 and 90 minutes and evaluated after 7, 14 and 21 days. They observed that hot water treatment increased the speed of ripening but did not cause injuries in keitt mangoes.

In Sydney Postharvest Laboratory, Kumar and Dhawan (1995) showed that the concentration of ethylene required for the ripening of different products varies. The concentration applied is within the range of 1 and 100 ppm. The time and temperature of treatment also influences the rate of ripening with fruit being ripened at temperatures 15 to 21 °C and relative humidity of 85 to 90%.

An experiment was conducted by Kumar and Dhawan (1995) to study the effect of postharvest treatment on the enhancement of ripening of mango fruit (cv. Dashchari). Fruits were harvested at the green mature stage and were treated with hot water (50° ± 5°C for 10 minutes). Fruits were then packed in cardboard boxes that are stored at room temperature. Data revealed that fruits treated with hot water maintained good texture that is color even up to 8 days of storage.

An experiment was conducted by Kumar and Singh (1993) with GA_3 and ethrel to enhance ripening and improve the quality and shelf life of mango (cv. "Amrapali"). They found that ethrel at 500 ppm was very effective in enhancing the ripening and improving the quality in terms of TSS, total sugar, ascorbic acid and 3-carotene content.

Experiments with ethrel (ethylene releasing chemical) on different cultivars of banana have indicated that 100 to 250 ppm of ethrel is required to get optimum qualities in the ripe banana fruit (Krishnamurthy, 1993).

2.3.2 Total weight loss

Weight loss reduced when mango fruits were stored in polythene bag as reported by Wavhal and Athale (1989), Shrivarma and Thimmaraju (1989). Gonzalez (1990) also reported that modified atmosphere packaging with polythene bags were delayed ripening and reduced weight loss.

Manzano *et al.* (1997) observed that 6.2 percent fresh weight loss of mango occurred when stored at 25 °C temperature for 20 days. Reddy and Haripriya (2002) reported that mango fruits treated with GA**3** and stored in polythene bags with ethylene absorbent significantly reduced physiological' weight loss. Physiological weight loss were reduced in mango fruits cv. 'Kensington pride' which were wrapped with polythene bags and stored in 13°C (Zora, 2001).

2.3.3 Rottening of mango fruit

Hossain *et al.* (2014) conducted an experiment with varying concentrations of ethrel (0, 50, 250 and 500 mg/1) to investigate fruit quality of mango. They reported that fruit quality has been improved with ethrel treatment and reduced rottening. They also noticed that post-harvest spray of GA_3 (50 or 75 ppm) or ethrel (500 ppm) hastened fruit maturity by 8-11 days and reduced spoilage loss during storage and also stated that malic hydrazide (MH) was useful in ripening but failed to retard spoilage in prolonged storage condition.

Moisture content

Srivastava (1967) reported that the green mango contained higher percentage of moisture as compared to ripe mangoes. Shahajahan (1994) reported that the moisture content of pulp of mature hard 'Fazli' mango was 79.95% but found it as 91% and in ripe mango 78-86%. Salunkhe and Desai (1984) observed that mango pulp contain 81% moisture.

Absar *et al*. (1993) reported that moisture content at the early stage of development varied from 87.4% to 90.1%, gradually decreased as the maturity advanced and at ripening stage it varied from 71:22 to 79.4%. They also observed that the decreasing tendency of moisture content with the advancement of maturity of varieties Gopalbagh (82.13 to 79.23%), Khirsapat (82.1 to 79.25%), Langra (81.75 to 78.29%) and Fazli (82.30 to 79:95%).

Mollah and Siddique (1973) conducted an experiment with 12 varieties of mango and found that moisture content of the pulp of all the varieties of mango ranged from 81.03 to 87.12%. They also studied the fruits of ten varieties of mango. The moisture percentage was the highest (87.55) in Ranibhog whereas it was the lowest (78.96%) in Misribhog. This trait for the different varieties under consideration ranged from 78.96 to 87.55%.

2.3.4 Dry matter content

Literature is not available that deals with the changes in dry matter content of mango fruits during storage: However, Paramanik (1995) found that the dry matter content in Fazli increase from 17.14 to 28.86% during storage of ambient temperature. It is also evident that as ripening progress some carbohydrate is completely oxidized to CO_2 and as a result of respiration (Palmer, 1971). This indicated an actual decrease in dry matter content.

2.3.5 Total soluble solids content

The soluble solids in mango flesh mainly consisted of sugars, soluble protein, starch, soluble pectin, organic acids, vitamin C etc. Studies on changes in most of these parameters have already been reviewed. Some more information on change in total soluble solid are cited below.

The increased percentage of total soluble solid during storage in mango was reported by Singh (1968). Dhaka *et al.* (2001) reported that lower TSS was obtained in cool chamber storage, on the other hand higher TSS was obtained in hot water treated mango fruits than those of non hot treated fruits. Working on mango cv. Amrapali' Ahmed and Singh (2000) reported that mango treated with GA_3 and kept in perforated polythene bags had the highest TSS (22.15%).

Nyanjage *et al.* (1998) observed that mango treated with hot water at 46.5°C for 45 minutes in combination with intermittent warming (34°C) during 12 days of cool storage (13°C) showed higher TSS and better general appearance than those of non-hot treated fruits. Singh (1998) carried out an experiment on mango cv.Amrapali' and found that TSS contents at mature and ripe stage were 8.12 and 20.05 percent respectively.

Hossain and Ahmed (1994) recorded 18.3% TSS in Aswina'. Absar *et al.* (1993) reported that the total soluble solid content was increased with maturity of fruit. They found that Langra' showed the highest (22.2%) and Fonia' the lowest (16.8%) TSS content at ripen stage.

Mollah and Siddique (1973) reported that Fazli' and Langra' showed to 14.8 % and 12.15 to 18.00 % TSS respectively: They also noticed that TSS varied from cultivar to cultivar.

Nair and Singh (2003) conducted an experiment with varying concentrations of ethrel (0, 50, 250 and 500 mg/1) to investigate fruit quality of mango.They

reported that fruit quality has been improved with the ethrel treatment including increased TSS, total sugar and eating quality.

Mohamed and Abu-Goukh (2003) conducted an experiment with different concentrations of ethrel solution (250, 500, 1000 ppm) on mango fruit. They analyzed three varieties of mango for chemical composition and reported that ethrel treatments significantly increased TSS compared to untreated fruits.

Pinaki *et al.* (2002) conducted an experiment with hot water treatment and artificial ripening of mango. They observed that the differences between treated and controlled mangoes in taste and the appearance are large and TSS content is higher than the non-treated fruit.

Absar *et al*. (1993) reported that TSS in ripe stage of mango varieties ranged from 16.80-22.20%. They observed the highest TSS (22.2) in Langra, while Fonia the lowest (16.80%) one.

Mollah and Siddique (1973) reported that TSS of mango cultivars Fazli and Langra were 7.70 to 14.8% and 12.15 to 18.00%, respectively. Popenoe (1964) made a report on the chemical composition of different varieties of mango and noted that TSS was more than 20%.

Increase in the percentage of total soluble solids during storage was recorded in mango (19.68) by Srivastava (1967). He found that total soluble solids increased while the acidity of the fruit generally decreased.

Disease incidence and severity on shelf life and quality of mango

Hofinan *et al.* (1999) examined that the treated fruits performed less disease incidence compared to without treated fruits. Non-treated fruits were attacked by the sunken black spots on the surface of the fruits as well as anthracnose *(Colletotrichum gloeosporioides*). In case of packaging technique, fruits packed in different packaging materials (like corrugated fiber board carton, plastic crate, perforate and nonperforated polyethylene bag) had the maximum shelf life, lower

physiological loss in weight and less disease incidence than without package. Among the different packaging materials, fruits packed in corrugated fiber board carton had the maximum shelf life (13.02 days), lower physiological loss in weight (4.11%) and less disease incidence (1.12%) without excessive deterioration compared to others. The shelf life of mango could be extended up to 5 days by hot water treatment and packed in corrugated fiber board carton compared to others. The color and quality of mango was very better in treated fruits compared to non-treated fruits. Hofinan *et al.* (1999) observed that the effect of bagging of mango (*Mangifera indica* L.) fruit was evaluated in order to improve fruit quality of late maturing cultivars. Fruit calcium concentrations were reduced by bagging for 56 days or less in the 1994/1995 trial, but not by longer bagging times (82-131 days). Percent dry matter (% DM) was higher, and days to ripen shorter, in bagged fruit from one orchard during 1993/1994. Fruit-mass, flesh color, total soluble solids, acidity and eating quality were generally not affected by bagging. These results indicate that bagging can improve fruit quality through reduction in disease, and this benefit outweighs the negative effects of bagging on skin color in the 'Keitt' cultivar.

Absar *et al*. (1993) this study investigated treatment of mango *(Mangifera indica* L.) fruit with 2 host deference promoting compounds for suppression of anthracnose disease *(Colletotrichum gloeosporioides).* Cultivar 'Kensington Pride' fruit were treated at concentrations of up to 1000 mg/L with either potassium phosphonate or salicylic acid. Applications were by various combinations of pre- and postharvest dips and vacuum infiltration.

The major causal agent for this group of rots varies among different production areas. One of the most destructive mango diseases is anthracnose, caused by *Colletotrichum gloeosporioides*, a fungal pathogen. It infects new flushes of leaves or may occur at the various stages of development from fruit set to maturity. The disease is common during wet season as it spreads and reproduces

rapidly specially in warm areas. At present, pesticide is the most widely recommended and adopted method of controlling the pest. However, the increasing concern on health and environment risks associated with pesticide use has led to the exploration of insecticidal properties of botanical pesticides. Hofinan *et al.* (1999) evaluated the efficacy of promising botanical materials against anthracnose of Hawaiian and native mango seedlings. The botanical materials evaluated were neem *(Azadirachta indica* A. Juss), 'Malunggay' *(Moringa oleifera* L.), and garlic *(Allium sativum).* The effect of the botanical extracts was compared with those of untreated plants and fungicide-treated plants. The botanical plants were weighed and washed with 10% sodium hypoclorite for 5 minutes and rinsed thrice with distilled water. These were placed in Waring blender and for every kilogram of plant materials; 1 L of water was added until a homogenous mixture was attained. The crude extract was filtered using a clean muslin cloth. Ten healthy mango seedlings per treatment with three replications were assigned. Seedlings were sprayed with the appropriate treatments when they started to produce new leaves. Each seedling was sprayed with 40 ml botanical extract and for the fungicide; manufacturer's recommendation was followed using an atomizer.

2.4 Postharvest physiochemical changes of mango

The need to develop the best off vine mango ripening technique for both consumption and processing was investigated. Some physical and chemical measurements were performed on mature Green Dodo mangoes before and during a 3-day and 6-day ripening period by smoked pit ripening (SPR), ethylene (fruit generated) pit ripening (EPR), untreated pit ripening (UPR) and room temperature ripening (RTR) as a control method. The postharvest ripening changes in the quality characteristic of ripe mangoes were correlated among treatments and compared with similar changes in other mango varieties. Changes such as

formation of sugars, decreased acidity, and increased carotene reflected the most significant chemical changes in ripeness stage (Peter *et al.,* 2007).

Fruit flesh taste is highly dependent on the balance between organic acids and soluble sugars, which are predominantly represented in mango by citric and malic acids, and sucrose, fructose and glucose, respectively (Medlicott and Thompson, 1985). The patterns of these compounds during mango development and maturation are well described, even if many studies deal with the evolution of fruit flesh composition during ripening according to harvest date. To our knowledge, only a few results of pre harvest factor effects on mango taste have been reported.

Aina (1990) reported that the some physical and chemical measurements were applied to mature green African mango fruits *(Irvingia gabonensis* Baill) during a 7- day storage ripening period at tropical ambient conditions (27-30^{o}C and 68-70% relative humidity). Changes in fruit weight, texture and colour reflected the most significant chemical changes in the fruit such as starch degradation, formation of sugars and increase in total carotenoids. The postharvest ripening changes observed are discussed and compared with similar changes in other mango varieties.

From the above reviews, it is clear that quite large volumes of works have been done in different parts of the world. Different issues related to the physiochemical changes, shelf life extension, and diseases have been cited above. Similar reports are scanty in Bangladesh. Very little information is available in Bangladesh regarding to the use of botanical extracts as a postharvest treatment on physiochemical changes, shelf life and diseases during storage and ripening. Hence, the present study attempts to investigate the physiochemical changes, shelf life and quality of mango of Amrapali variety using different promising postharvest treatments.

2.4.1 Vitamin C

Mango is a good source of vitamin C at early stages of development, which decreases rapidly 5-7 weeks after fruit set as reported by Gofur *et al.* (1994). They also reported that at 12 weeks after fruit set ascorbic acid content was 105.2, 65:7 and mg/100 g in Langra, Ashwini and Fazli varieties, respectively. They also reported that ascorbic acid decreased with increased of storage duration.

The green fruits stored at 10-12°C temperature for 7 weeks had little change on vitamin C content. Maximum portion vitamin C was lost when the fruits were stored at room temperature (20-30°C). In addition, reduction in vitamin C with progress of fruit maturity and ripening was found in cv. Gopalbhog', Khirshapat', Langra' and Fazli' described by Shahlahan *et al*. (I994).

There was a tendency for ascorbic acid content to be higher in cold storage. El and Ahmed (2001) noted that the lower the temperature the higher the vitamin C content. The same, fact also verified. They reported that higher ascorbic acid content was obtained in the mango fruits stored in cool chamber.

Mango contained considerable amount of ascorbic acid (Vitamin C) when it was green and tender, with a value as high as 348.5 mg per 100g of edible portion of mango pulp. In ripe fruit it was much lower. Ascorbic acid generally decreased during ripening. When they were overripe the percentage of ascorbic acid decreased progressively.

An experiment was conducted by Singh *et al.* (1993) with GA3 and ethrel and found to enhance the ripening and improve the quality of mango (cv.Amrapali).They found that ethrel at 500 ppm was very effective to improve the quality in terms of ascorbic acid content. Reduction in ascorbic acid with advancement of maturity and ripening was observed in cv. Gopalbhog, Khirshapat, Langra and Fazli (Shahjahan *et al*. 1994)

Kumar and Singh (1993) noticed that post-harvest spray of GA_3 (50 or 75 ppm) or ethrel (500 ppm) hastened fruit maturity by 8-11 days and significantly improved the fruit quality (ascorbic acid).

Absar *et al*. (1993) studied ten varieties of mango at different stages of maturity. At ripe stage the highest vitamin C was obtained in Fonia (28.85) preceded by Ashwina (22.36), Langra (22.0), Fazli (20.40), Himsagar (15.24), Jalibanda (12.60), Kanchamitha (10.81), Khirsapat (10.65) and Gopalbhog (8.66 mg/l00g).

Samad *et al.* (1975) evaluated ten varieties of mango namely Fazli, Langra, Gopalbhog, Mohanbhog, Misribhog, Koapahari, Dashehari, Ashwina, Ranibhog and Local variety. They narrated that ascorbic acid (Vitamin C) in different varieties of mango differed greatly. It was however maximum (28.08 mg/100 g) in Ranibhog and minimum (12.91 mg/100 g) in Dashehari.

2.4.2 Titratable acidity

Freshly harvested mango fruits *(Mangifera indica* cv. Nam Doc Mai), were heated at 38^o C for 3 days or heated and then stored at 4^{o}C for 3 weeks before ripening at 25^{o}C, then compared with non-heated fruits for quality changes. When not refrigerated, heated and non-heated fruits ripened within 7 days to a comparable quality, although titratable acidity were remained higher in heated fruits. The peel of heated fruits was initially yellower in cold-stored fruits, and soluble solids content was initially greater, whereas firmness and titratable acidity were less than that of non-heated fruits during ripening at 25^{o}C. After cold storage and ripening, heated fruits had a lower incidence of disease and developed less chilling injury than non-heated fruits. Non-heated fruits stored at 4^{o}C also developed off-flavor whereas the heated fruits did not. Heat treatment did not inhibit ripening Tripathi (1985).

Titratable acidity was declined slowly when mango fruits were stored at 13^{o}C temperature. Similarly, Tripathi (1985) reported that titratable acidity decreased

during storage in a refrigerated room. According to Hossain *et al.,* (1999) titratable acidity was decreased during storage and ripening. Medlicott *et al.,* also observed similar results. According to them acidity was reduced during later growth stage on attainment of maturity and ripening. Shahjahan *et al*., (1994) revealed that acidity of mango was decreased gradually at the time of storage and ripening.

Shahjahan *et al*., (1994) also performed an experiment to find out the effect of ethrel concentrations (250, 500, 1000, and 1500 ppm) on shelf life of mango. They reported that ethrel treatments significantly reduced the acid content compared to untreated fruits.

Jana *et al.* (1998) studied the 20 mango varieties of West Bengal, India and found that variety Daudia had the highest titrable acids (0.58%). They also carried out an experiment with 21 mango cultivars and chemical analysis was performed. They narrated that titrable acidity of mango varieties differed greatly. It was the maximum (0.59%) in Himsagar and the minimum (0.14%) in Jahangir.

2.4.3 Shelf life

Romphophak *et al.* (2004) mentioned that the shelf life of mango determined by senescent peel spotting was 6 to 7 days in PVC packing compared with 3 to 4 days. Pinaki *et al.* (1997) found that matured banana fruits of uniform sites were dipped into gibberellic acid (GA_3) at 150 ppm were most effective treatment for prolonging the shelf life of mango. Bhadra and Sen (1997) reported that the most effective treatments for prolonging the shelf life of fruits were brown paper wrapping, followed by dipping on gibberellic acid (GA_3) and polythene bagging + $KMnO_4$, Ethrel and hot water treatment enhanced ripening of fruits compared to the control and other treatments. Kumar and Singh (1993) conducted an experiment with $GA_3$and found that the quality and shelf life of mango cv. Amrapali were improved.

In a study Romphophak *et al.* (2004) determined the shelf life of banana by senescence peel spotting was 6-7 days in PVC packaging, compared with 3-4 days in the control. Packaging bananas with modified atmosphere (MA) using polythene bags (0.03) at 22°C was unsuitable for prolonging shelf life because it inhibited ripening and resulted in a flavor of fermentation.

Giami and Ali (1994) conducted an experiment on the unripe fruit had relatively low polyphenol oxidase (catechol oxidase) activity and low total polyphenol content but had hogh ascorbic acid and caroenoid contents and showed the least browning potential. Shelf life is the most important aspect in loss reduction bio-technology of fruits. There is a natural tendency of fruits to degrade to the simpler inorganic compound (CO_2, HO_2, and NH_3) from which they were synthesized in the first place through spontaneous bio-chemical reaction which occur with the decreased in free energy and increase in the randomness (entrophy) of the system, consequently reduce the shelf life as well as other qualities of fruits.

The fruit, mango is very popular due to its wide range of adaptability, high nutritive value and richness in variety. Long time storage is essential for extending the consumption period of mango, regulating their supply to market and also for transformation. MA packaging with postharvest treatments can delay ripening and reduces water loss of mango. Many research works have been done on mango, but only very are related to the varieties in our country few works had done. Therefore, this research has been done so that we can find out the proper postharvest treatments to extend shelf life of some mango varieties of Bangladesh.

Mature fruits of mango (cv. Kesington Pride) were dipped for five minutes either in distilled water or in aqueous solutions containing Tween 80 (0.01%) and ethephon at 250, 500, 1000, 1500, or 2000 ppm and kept at 20°C for 24 hr to induce ripening prior to transfer at 13° C. The fruits were packed with nylon sponge and sealed in modified atmosphere polythene bags and stored at 13.5 ±0.

5°C. Preliminary results showed that modified atmosphere packaging improved fruit quality and prolonged shelf life of mango (Singh and Janes, 2001).

Shelf life is the most important aspect in loss reduction biotechnology of fruits and vegetables. There is a natural tendency for the perishable fruits and vegetables to degrade to simpler inorganic compounds ($C0_2$, H_20, NH_3) (Salunkhe and Desai, 1984).

CHAPTER III

MATERIALS AND METHODS

The experiments were carried out at the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during 28 June to 25 July 2014.

3.1 Experimental materials

The experimental materials were mature hard fruits of two mango varieties, namely, Langraand Lakhanbhog. Mangoes used in the experiment were collected from the orchard of mango grower, ChapaiNawabgongon 27, June 2014. Maturity of mangoes was indicated when the shoulders were in line with the stem end and the color was olive green. Maturity was also judged by the grower's recommendation. The two commercially important mango varieties were used for the study as described below:

3.1.1 Langra

The Langra, also known as Banarasi Langra is a mango cultivar primarily grown in Northern India, Bangladesh and Pakistan. This cultivar retains a greenish tinge (Plate 1) while ripening. It is normally harvested during the last half of July. Around 2006, it was known to be gaining popularity on the international market. It is considered suitable for slicing and canning. Langra is an important commercial mango variety of north India, it is biennial- bearer and a mid-season variety, with good quality fruits. Flesh is firm, lemon yellow in color and scarcely fibrous. It has characteristic turpentine flavour. Keeping quality is medium. The leaf blades had an oval-lanceolate shape and were flat to slightly fold.

Plate 1. Langra mango

3.1.2 Lakhanbhog

The fruits of this variety were medium to small in size and moderate in quality. It is a mid-season variety and is liked both by sellers and consumers and occupies a prime market position because of its delicious taste, attractive shape, color and good keeping quality. Fruit shape is oval to oblong, basal cavity slight, shoulder sloping, ventral higher; beak obscure, apex rounded, skin color bottle green, medium thick, texture, rough, flesh yellow, firm, flavor mild, taste sweet, juicy, fiber present, scanty, fine. Average fruit weight is 150 – 200 g (Plate 2).

Plate 2. Lakhanbhog mangoes

3.2 Experimental treatments

The experiment consists of two factors

3.2.1 Factor A: Variety

1) V_1 :Langra
2) V_2: Lakhanbhog

3.2.2 Factor B: Postharvest treatments

1) T_0: Control
2) T_1: Hot water dips (50^0C)
3) T_2: Calcium chloride dips
4) T_3: Sodium metabisulphite dips
5) T_4: Citric acid dips
6) T_5: Bamboo baskets (Traditional)
7) T_6 : Plastic crates having mango wrapped with tissue paper
8) T_7 : Plastic crates having mango without wrapping

3.3 Experimental design

The two factor experiment was laid out in the completely randomized design with three replications of 6 fruits. A total of 288 fruits of more or less similar shape and size 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 8×2 treatments combinations. Each treatment combination comprised 18 fruits.

3.4 Methods

The postharvest treatments were randomly assigned to the experimental fruits. The treated fruits were kept on brown papers that were previously placed on laboratory table at ambient condition. 252 fruits were randomly divided into 2 groups of 126.

3.4.1 Control

Fruits of each variety were randomly selected from the lot and the fruits were kept on brown paper placed on the laboratory table at ambient conditions.

3.4.2 Fruit treated with hot water

Normal tap water was heated in hot water bath-tube at a temperature of 50°C. A thermometer was used to measure the temperature. Mango fruits were individually dipped into hot water for 5 minutes and then stored at ambient condition on brown paper on the laboratory table.

3.4.3 Calcium chloride dips

Eight hundred (800) gram of $CaCl_2$ was mixed into 20 litre water @ dosage of $40gL^{-1}$ then all of fruit keep in it for 10 minutes. Individual varietal fruit was reserved separately after the treatment.

3.4.4 Sodium metabisulphite

Four hundred twenty (420) g of Sodium metabisulphite was mixed into 20 litre water @ dosage of $21gL^{-1}$then all of fruit keep in it for 10 minutes. Individual varietal fruit was reserved separately after the treatment.

3.4.5 Citric acid dips

Hundred (100) g of Citric acid dips was mixed into 20 litre water @ dosage of $5gL^{-1}$then all of fruit keep in it for 10 minutes. Individual varietal fruit was reserved separately after the treatment.

3.4.6 Bamboo baskets (Traditional)

Traditional bamboo basket was used for this treatment. Fruits were taken into the bamboo baskets (Traditional) and covered by the jute made bag. Fruits of each variety were kept in this system and then placed on specified space for observations.

3.4.7 Plastic crates having mango wrapped with tissue paper

Plastic crates and tissue paper were used for this treatment. Fruits having mango wrapped with tissue paper were taken into the plastic crates and covered by the jute made bag. Fruits of each variety were kept in this system and then placed on specified space for observations.

3.4.8 Plastic crates having mango without wrapping

Only plastic crates were used for this treatment. No tissue paper was used. Fruits were taken into the plastic crates and covered by the jute made bag. Fruits of each variety were kept in this system and then placed on specified space for observations.

3.5 Parameters studied

In this experiment the following parameters were studied:

3.5.1 Physical parameters

1. Color
2. Firmness
3. Weight loss
4. Moisture content
5. Dry matter content

3.5.2 Chemical parameters

1. TSS (Total soluble solids.)
2. TA (Titratable acidity)
3. Vitamin C

3.5.3 Microbial characters

1. Disease incidence (%)

3.5.4 Shelf life

1. Duration (Days)

3.6 Observation

During the entire period of storage, the fruits used in the experiment were observed every day. Data were recorded at an interval of 3 days during storage is influenced by different postharvest treatments and varieties.

3.7 Methods of studying parameters listed earlier

3.7.1 Physical parameters

3.7.1.1 Color

Days required to reach different stages of color during storage and ripening were measured by using numerical rating scale of 1-7, where 1 = green, 2 =breaker, 3 = one-quarter-yellow (< 25%), 4 = two-quarter fruit skin yellow (<50%), 5 = three quarter yellow (<75%), 6 = fully yellow (75-100%) and 7 = blackened/ rotten (fully yellow and black).

3.7.1.2 Firmness

Days required to reach different stages of firmness during storage and ripening were determined using numerical rating scale of1-6, where 1 =mature hard, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe, 5 = over ripe, 6= totally unfit for consumption. Similar rating scale was used by Hassan (2006).

3.7.1.3 Estimation of total weight loss

The fruits of each treatment were individually weight by using electric balance andkept for storage. Percent total weight loss was calculated at an interval of 3 daysduring storage by using the following formula:

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

Where,

IW= Initial fruit weights (g) and

FW= Final fruit weight (g)

3.7.1.4 Estimation of moisture content

Ten gram of fruit pulp was weighed in a porcelain crucible (which was previously cleaned, dried and weighed) from each treatment and replications. The crucible was placed in electric oven at 80°C for 72 hours until the weight became constant. It was then cooled in desiccators and weighed again. Percent moisture content was calculated by using the formula:

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

Where,

IW= Initial weight of fruit pulp (g)

FW= Final weight of oven dried fruit pulp (g)

3.7.1.5 Estimation of dry matter content

Percent dry matter content of the pulp was calculated from the data obtained during moisture estimation using the following formula:

Dry matter (%) = 100 – %moisture content

3.7.2 Chemical parameters

3.7.2.1 Estimation of total soluble solids content

Total soluble solids content of mango 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).

3.7.2.2 TA (Titratable acidity)

Titratable acidity was estimated chemical analysis process by using mango pulp stored in refrigerator. Titratable acidity was declined slowly when stored in low temperature. The titratable acidity of mango pulp was determined by method of

Ranganna (1979). The procedure of lab test for Titratable acidity content was done and obtained results were recorded.

3.7.2.3 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.

3.7.3 Microbial characters

3.7.3.1 Assessment of disease incidence

The 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:

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

3.7.4 Estimation of shelf life

Shelf life of mango fruits as influenced by variety & different postharvest storage treatments was calculated by counting the days required to ripe fully as to retaining, maximum marketing and eating qualities.

3.7.5 Statistical analysis

The collected data were statistically analyzed by Analysis of Variance (ANOVA) tests. The mean of different parameters was compared by DMRT (Duncans' Multiple Range Test). The collected data on various parameters were statistically analyzed using MSTAT-C statistical package. The means for all the treatments were calculated and analysis of variances (ANOVA) for all the parameters was performed by F-test. The significance of difference between the pairs of means

was compared by least significant difference (LSD) test at the 1% and 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation of the results obtained from the present investigation. The data were recorded at 3 days interval after storage (DAS) on different characteristics of physical, chemical and microbial properties and also shelf life of mango. These results are presented under the following headings:

4.1 Colour

Significant influence was observed in respect of colour of two mango varieties with different harvest treatment and also their combined application under the present study at different days after storage (Appendix 1).

Longer period was required for Langra than Lakhanbhog to reach different stages of ripening due to varietal character. Significant variation was not found at 3 days after harvest but at 6, 9, 12 and 15 days after harvest significant variation was observed. The higher colour score (3.54, 4.39, 5.22 and 5.98) was observed in Lakhanbhog and lower colour score (3.28, 4.13, 4.97 and 5.68) in Langra at 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively (Table 1).

Postharvest treatments had also significant variation on the changes of peel colour of mango. The higher colour scores (1.89, 4.58, 5.27, 6.18 and 6.85) was observed in Plastic crates having mango without wrapping (T_7) and lowest colour score (1.03, 2.29, 3.20, 3.98 and 4.32) in Calcium chloride dips treatment (T_2) at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively followed by T_4 (Citric acid dips) and T_3 (Sodium metabisulphite) at different days after harvest (Table 1).

Combined effects of variety and postharvest treatments had also significant effect in colour changes of mango varieties at different day of harvest. The highest colour score (1.92, 4.70, 5.39, 6.23 and 7.00) was observed in Lakhanbhog when

stored at Plastic crates having mango without wrapping (V_2T_7) and lowest colour score (1.01, 2.16, 3.04, 3.88 and 4.16) was found in Langra stored in Calcium chloride dips (V_1T_2) at 3rd, 6th, 9th, 12th and 15th days of harvest respectively (Table 1). These findings were observed by Doreyappa-Gowda and Huddar (2001) who reported that the green peel colour of mature Alphanso and other varieties of mango turned from light green or green or dark green to light yellow or yellow or orange yellow due to the breakdown of chlorophyll due to a series of physico-chemical changes during ripening, leading to disappearance of green colour.

Table 1. Effect of different varieties and postharvest treatments on color of mango

Treatments	Color at different days after harvest (DAH)				
	3 DAH	6 DAH	9 DAH	12 DAH	15 DAH
Effect of variety					
V_1	1.37	3.28	4.13	4.97	5.68
V_2	1.45	3.54	4.39	5.22	5.98
$LSD_{0.05}$	NS	0.183	0.152	0.144	0.256
Effect of postharvest treatments					
T_0	1.33	3.29	4.04	5.04	6.00
T_1	1.42	3.72	4.35	5.40	6.30
T_2	1.03	2.29	3.20	3.98	4.32
T_3	1.21	2.85	3.67	4.43	5.32
T_4	1.05	2.43	3.74	4.12	4.63
T_5	1.75	4.20	5.03	5.89	6.72
T_6	1.60	3.93	4.75	5.72	6.50
T_7	1.89	4.58	5.27	6.18	6.85
$LSD_{0.05}$	0.124	0.377	0.398	0.436	0.554
Interaction effect of variety and postharvest treatments					
V_1T_0	1.30	3.11	3.90	4.86	5.88
V_1T_1	1.40	3.56	4.22	5.33	6.18
V_1T_2	1.01	2.16	3.04	3.88	4.16
V_1T_3	1.16	2.76	3.48	4.31	5.16
V_1T_4	1.01	2.28	3.65	3.98	4.43
V_1T_5	1.70	4.12	4.95	5.74	6.58
V_1T_6	1.54	3.81	4.62	5.56	6.33
V_1T_7	1.86	4.45	5.15	6.12	6.68
V_2T_0	1.36	3.46	4.18	5.22	6.12
V_2T_1	1.44	3.88	4.48	5.47	6.43
V_2T_2	1.04	2.42	3.36	4.08	4.48
V_2T_3	1.26	2.94	3.86	4.54	5.47
V_2T_4	1.09	2.58	3.82	4.27	4.82
V_2T_5	1.81	4.23	5.11	6.04	6.86
V_2T_6	1.66	4.06	4.88	5.88	6.67
V_2T_7	1.92	4.70	5.39	6.23	7.00
$LSD_{0.05}$	0.175	0.447	0.388	0.415	0.509
CV (%)	5.11	6.57	6.52	5.54	7.45

Score: 1 = green, 2 =breaker, 3 = one-quarter-yellow (< 25%), 4 = two-quarter fruit skin yellow (<50%), 5 = three quarter yellow (<75%), 6 = fully yellow (75-100%) and 7 = blackened/ rotten (fully yellow & black)

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.2 Firmness

Statistically non-significant variation was found in terms of firmness of mango pulp between two varieties of mango during different days after harvest (Appendix 2). But comparatively higher rates of firmness score (1.95, 2.91, 3.93, 4.87 and 5.56) were found in Lakhanbhog and lower firmness score (1.92, 2.87, 3.85, 4.76 and 5.46) in Langra at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest (Table 2).

Different postharvest storage treatments showed a significant effect (Appendix 2) on firmness score of mango pulp. Variation among the treatment means was observed at all dates of data recording. The firmness score was found to be the higher (5.50 and 6.00 respectively) with control treatment (T_0) at 12 and 15 DAS but at 3 and 6 DAS Citric acid dips treatment (T_4) showed the highest score (2.24 and 3.11 respectively) and also Calcium chloride dips treatment (T_2) showed the highest score of firmness (4.24) at 6 DAS. In case of lowest score (1.60, 2.61, 3.40, 4.07 and 5.07 at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively) was observed in Hot water dips treatment (T_1) (Table 2).

Combined effect of varieties and postharvest treatments in respect of firmness was also found significant at different days of harvest (Appendix 2). The maximum change in firmness (6.00) was observed in Langra with control treatment (V_1T_0) and Lakhanbhog with control treatment (V_2T_0). The minimum changes in firmness (5.01) were found in Langra with Hot water dips (V_1T_1) at 15^{th} day of harvest followed by V_1T_3 and V_2T_1 (Table 2).

Table 2: Effect of different varieties and postharvest treatments on firmness of mango

Treatments	Firmness at different days after harvest (DAH)				
	3 (DAH)	6 (DAH)	9 (DAH)	12 (DAH)	15 (DAH)
Effect of variety					
V_1	1.92	2.87	3.85	4.76	5.46
V_2	1.95	2.91	3.93	4.87	5.56
$LSD_{0.05}$	NS	NS	NS	NS	NS
Effect of postharvest treatments					
T_0	1.81	2.74	3.51	5.50	6.00
T_1	1.60	2.61	3.40	4.07	5.07
T_2	2.08	2.85	4.24	4.58	5.30
T_3	1.92	2.97	4.09	4.32	5.21
T_4	2.24	3.11	3.89	4.87	5.58
T_5	2.02	2.90	4.06	5.24	5.69
T_6	2.15	3.10	3.88	4.67	5.52
T_7	1.67	2.82 b	4.06	5.27	5.70
$LSD_{0.05}$	0.129	0.15	0.124	0.245	0.171
Interaction effect of variety and postharvest treatments					
V_1T_0	1.45	2.72	3.46	5.48	6.00
V_1T_1	1.36	2.48	3.37	4.01	5.01
V_1T_2	2.48	3.12	4.21	4.52	5.26
V_1T_3	1.58	2.55	4.05	4.26	5.14
V_1T_4	2.60	3.22	3.86	4.81	5.52
V_1T_5	2.28	2.92	3.94	5.16	5.62
V_1T_6	2.12	3.10	3.89	4.58	5.48
V_1T_7	1.76	2.83	4.02	5.20	5.63
V_2T_0	1.83	2.76	3.57	5.52	6.00
V_2T_1	2.16	2.67	3.42	4.06	5.12
V_2T_2	1.67	2.57	4.28	4.63	5.34
V_2T_3	2.27	3.47	4.12	4.37	5.28
V_2T_4	1.87	2.97	3.91	4.92	5.63
V_2T_5	1.76	2.88	4.18	5.32	5.75
V_2T_6	2.18	3.12	3.86	4.76	5.56
V_2T_7	1.58	2.80	4.10	5.34	5.76
$LSD_{0.05}$	0.183	0.140	0.106	0.346	0.211
CV (%)	7.22	6.94	5.73	7.62	8.45

Score: 1 = mature hard, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe, 5 = over ripe, 6 = totally unfit for consumption

Variety

V_1 : Langra

V_2 : Lakhanbhog

Postharvest treatments

T_0 : Control

T_1 : Hot water dips

T_2 : Calcium chloride dips

T_3 : Sodium metabisulphite

T_4 : Citric acid dips

T_5 : Bamboo baskets (Traditional)

T_6 : Plastic crates having mango wrapped with tissue paper

T_7 : Plastic crates having mango without wrapping

4.3 Weight loss of mango

No Significant variation was observed in respect of total weight loss between the two varieties (Appendix 3). But it was observed that the weight loss trended to increase with the advancement of storage period in both the varieties. The weight loss was greater in Lakhanbhog compared to Langra during 15^{th} day of storage (Table 3).

The present investigation showed that the postharvest treatments of mango harvest had significant effects on total weight loss (Appendix 3). Here, it was also observed gradually increased weight loss was happened with the advancement storage duration. The total weight loss was found to be the highest (2.78%, 5.91%, 7.89%, 9.11% and 9.44% at3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively) at all stages in case of Control treatment (T_0) where the treatment of Hot water dips (T_1) represented the lowest weight loss (2.78%, 5.91%, 7.89%, 9.11% and 9.44% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively) (Table 3). Among the treatments Hot water dips (T_1) was the best in terms of controlling weight loss followed by T_3 (Sodium metabisulphite) and T_2 (Calcium chloride dips).

The combined effect of treatments and fruits variety on total weight loss was highly significant in all stages of observation (Appendix 3). Gradually increased weight loss was found with increased duration. The variety, Lakhanbhog under control treatment (V_2T_0) gave the highest weight loss at all stages of harvest observation (5.20%, 8.71%, 10.33%, 11.32% and 13.32% at 3, 6, 9, 12 and 15 days of observation respectively) which was closely followed by the treatment combination of V_1T_0, V_2T_7 and V_1T_7. Alternatively the lowest weight loss (2.74%. 5.88%, 7.85%, 9.05% and 9.36% at 3, 6, 9, 12 and 15 days of observation respectively) was found in Langra with Hot water dips treatment (V_1T_1) followed by V_2T_1, V_1T_3 and V_2T_3 (Table 3). The result of the present study is in support of the findings of Shahajahan (1994). He reported that the moisture content of pulp in Fazli was 79.95%. Shahajahan (1994) also recorded that the decreasing tendency

of moisture content with the advancement of maturity of varieties Gopalbhogh (82.13 to 79.23%), Khirsa (82.1 to 79.25%), Langra (81.75 to 78.29%) Fazli (82.30 to 79.95%).

Table 3. Effects of different varieties and postharvest treatments on weight loss (%) of mango

Treatments	Weight loss (%) at different days after harvest (DAH)				
	3 DAH	6 DAH	9 DAH	12 DAH	15 DAH
Effect of variety					
V_1	3.73	7.19	9.01	10.12	11.46
V_2	3.85	7.23	9.06	10.18	11.59
$LSD_{0.05}$	NS	NS	NS	NS	NS
Effect of postharvest treatments					
T_0	5.18	8.69	10.28	11.20	13.22
T_1	2.78	5.91	7.89	9.11	9.44
T_2	3.18	6.62	8.42	9.84	10.82
T_3	2.89	6.13	8.19	9.45	10.28
T_4	3.81	7.40	9.13	10.34	12.02
T_5	4.35	7.91	9.63	10.48	12.46
T_6	3.57	6.93	8.83	10.17	11.41
T_7	4.57	8.12	9.90	10.62	12.52
$LSD_{0.05}$	0.402	0.496	0.542	0.433	0.518
Interaction effect of variety and postharvest treatments					
V_1T_0	5.16	8.68	10.23	11.08	13.12
V_1T_1	2.74	5.88	7.85	9.05	9.36
V_1T_2	3.12	6.56	8.45	9.88	10.76
V_1T_3	2.86	6.18	8.16	9.42	10.14
V_1T_4	3.82	7.28	9.16	10.29	11.91
V_1T_5	4.22	7.88	9.58	10.46	12.44
V_1T_6	3.51	6.97	8.78	10.22	11.26
V_1T_7	4.36	8.12	9.87	10.57	12.46
V_2T_0	5.20	8.71	10.33	11.32	13.32
V_2T_1	2.81	5.95	7.92	9.16	9.52
V_2T_2	3.24	6.68	8.39	9.80	10.87
V_2T_3	2.92	6.08	8.22	9.48	10.42
V_2T_4	3.80	7.52	9.11	10.38	12.14
V_2T_5	4.48	7.95	9.69	10.49	12.48
V_2T_6	3.62	6.88	8.88	10.12	11.56
V_2T_7	4.78	8.11	9.92	10.66	12.58
$LSD_{0.05}$	0.303	0.463	0.398	0.312	0.509
CV (%)	6.62	8.34	6.35	7.32	9.27

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.4 Moisture content of pulp

Significant variation in respect of percent moisture content was observed between two varieties used in the present study at 3rd, 6th, 9th and 12th day of harvet (Appendix 4). It was also showed that moisture percent decreased with the increase in harvest period in both varieties and the moisture content were ranged from 87.82 to 80.83% in Langra and 86.54 to 79.67% in Lakhanbhog (Table 4). Results also indicated that the maximum moisture content (87.82%, 86.65%, 83.87% and at 3rd, 6th, 9th and 12th days of harvest respectively) was found from Langra where the minimum moisture content (86.54%, 83.73%, 81.73% and 79.67% at 3rd, 6th, 9th and 12th days of harvest respectively) was found from Lakhanbhog. The result of the present study is in support of the findings of Shahajahan (1994). He reported that the moisture content of pulp in Fazli was 79.95%. Shahajahan (1994) also recorded that the decreasing tendency of moisture content with the advancement of maturity of varieties Gopalbhogh (82.13 to 79.23%), Khirsa (82.10 to 79.25%), Langra (81.75 to 78.29%) and Fazli (82.30 to 79.95%).

The variation among the treatment was significant in respect of moisture content at 3rd, 6th, 9th and 12th days of harvest (Appendix 4). The maximum moisture content (92.19%, 89.83%, 86.94% and 84.06 %) was recorded in Hot water dips treatment (T_1) followed by T_2 (Calcium chloride dips), T_3 (Sodium metabisulphite) and T_4 (Citric acid dips) treatments where the minimum moisture content (79.03%, 76.60%, 75.14 and 73.81%) in control treatment (T_0) at 3rd, 6th, 9th and 12th days of harvest followed by T_7 (Plastic crates having mango without wrapping) (Table 4).

The combined effect of variety and postharvest treatments varied significantly in respect of moisture content at different days of harvest period (Appendix 4). At 3rd, 6th, 9th and 12th day of harvest, the highest moisture content (93.18%, 91.12%, 88.40% and 85.45% respectively) was recorded in V_1T_1 treatment combination followed by V_2T_1, V_1T_2 and V_2T_2 where the lower moisture content (78.31%,

75.35%, 74.38% and 72.37 respectively) was found in V_2T_0 followed by V_1T_0 and V_2T_7 (Table 4).The result of the present study is in support of the findings of Shahajahan (1994). He reported that the moisture content of pulp in Fazli was 79.95%. Shahajahan (1994) also recorded that the decreasing tendency of moisture content with the advancement of maturity of varieties Gopalbhogh (82.13 to 79.23%), Khirsa (82.1 to 79.25%), Langra (81.75 to 78.29%) Fazli (82.30 to 79.95%).

Table 4. Effects of varieties and postharvest treatments on moisture content (%) of mango

Treatments	Moisture content (%) at different days after harvest (DAH)			
	3 DAH	6 DAH	9 DAH	12 DAH
Effect of variety				
V_1	87.82	86.65	83.87	80.83
V_2	86.54	83.73	81.73	79.67
$LSD_{0.05}$	1.245	2.366	1.113	1.012
Effect of postharvest treatments				
T_0	79.03	76.60	75.14	73.81
T_1	92.19	89.83	86.94	84.06
T_2	91.84	89.51	86.85	83.97
T_3	91.55	89.24	85.87	83.26
T_4	88.85	86.65	84.41	81.64
T_5	85.03	83.47	80.96	78.38
T_6	86.06	86.46	84.26	81.01
T_7	82.87 d	79.74	78.00	75.83
$LSD_{0.05}$	2.622	2.834	2.428	2.871
Interaction effect of variety and postharvest treatments				
V_1T_0	79.75	77.85	75.89	75.25
V_1T_1	93.18	91.12	88.40	85.45
V_1T_2	92.20	90.76	87.20	84.72
V_1T_3	91.19	89.20	86.49	82.83
V_1T_4	88.31	87.57	84.35	81.35
V_1T_5	84.28	81.45	80.66	78.50
V_1T_6	86.47	85.50	83.27	80.68
V_1T_7	83.82	80.29	78.75	76.27
V_2T_0	78.31	75.35	74.38	72.37
V_2T_1	92.65	90.83	87.55	85.30
V_2T_2	91.47	89.28	87.39	83.77
V_2T_3	90.45	88.55	85.48	82.75
V_2T_4	89.40	88.26	85.24	82.49
V_2T_5	85.78	82.48	81.25	78.25
V_2T_6	85.65	85.35	81.28	78.55
V_2T_7	81.92	79.19	77.25	75.39
$LSD_{0.05}$	2.326	2.778	1.858	1.608
CV (%)	8.55	7.82	8.49	9.03

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.5 Dry matter content

Significant variation was observed in dry matter content between two varieties during harvest (Appendix 5). The higher dry matter content (13.46%, 16.27%, 18.27% and 20.33%) was observed in Lakhanbhog and the lower dry matter content (12.19%, 13.35%, 16.13% and 19.18%) was found in Langra at 3^{rd}, 6^{th}, 9^{th} and 12^{th} days of harvest (Table 5).

Postharvest treatments revealed significant differences in dry matter content during harvest (Appendix 5). Dry matter content was on the increasing trend at varying degrees as influenced by different postharvest treatments. The highest dry matter content (20.97%, 23.40%, 24.86% and 26.19 %) was observed in control treatment (T_0) followed by T_7 (Plastic crates having mango without wrapping) and T_5 (Bamboo baskets (Traditional)) treatments where the lowest (7.81%, 10.16%, 13.06% and 15.94%) was in Hot water dips (T_1) treatment followed by T_2 (Calcium chloride dips) and T_3 (Sodium metabisulphite) at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of harvest, respectively (Table 5).

Combined effect of varieties and different harvest treatments had significant effect on dry matter content of mango (Appendix 5). Results revealed that the highest dry matter content (21.69%, 24.65%, 25.61% and 27.63% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of harvest, respectively) was found in V_2T_0 pursued by V_1T_0 and V_2T_7 where the lowest dry matter content (6.81%, 8.88%, 11.61% and 14.55% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of harvest, respectively) was observed in V_1T_1 followed by V_2T_1, V_1T_2 and V_2T_2 (Table 5).The result of the present study is in support of the findings of Pramanik (1995). He stated that the dry matter content in Fazli increased from (17.14 to 28.86%) during harvest.

Table 5. Combined effects of varieties and postharvest treatments on dry matter (%) of mango

Treatments	Dry matter (%) at different days after harvest (DAH)			
	3 DAH	6 DAH	9 DAH	12 DAH
Effect of variety				
V_1	12.19	13.35	16.13	19.18
V_2	13.46	16.27	18.27	20.33
$LSD_{0.05}$	0.625	1.142	1.006	0.589
Effect of postharvest treatments				
T_0	20.97	23.40	24.86	26.19
T_1	7.81	10.16	13.06	15.94
T_2	8.16	10.49	13.15	16.74
T_3	8.45	10.76	14.13	16.03
T_4	11.15	13.34	15.58	18.37
T_5	14.96	16.53	19.05	21.63
T_6	13.94	13.55	15.75	18.98
T_7	17.14	20.26	21.99	24.17
$LSD_{0.05}$	1.477	1.161	1.485	1.589
Interaction effect of variety and postharvest treatments				
V_1T_0	20.25	22.15	24.11	24.75
V_1T_1	6.81	8.88	11.61	14.55
V_1T_2	7.80	9.24	12.61	15.29
V_1T_3	8.81	10.80	13.51	17.17
V_1T_4	11.69	12.44	15.65	18.65
V_1T_5	15.71	18.55	19.35	21.76
V_1T_6	13.54	14.50	16.74	19.31
V_1T_7	16.19	19.71	21.24	23.73
V_2T_0	21.69	24.65	25.61	27.63
V_2T_1	7.35	9.16	12.45	14.70
V_2T_2	8.52	10.71	12.80	16.22
V_2T_3	9.55	11.45	14.51	17.25
V_2T_4	10.60	11.74	14.76	17.51
V_2T_5	14.35	17.51	18.75	21.50
V_2T_6	14.21	14.65	18.71	21.45
V_2T_7	18.09	20.81	22.75	24.61
$LSD_{0.05}$	1.259	1.642	1.276	1.506
CV (%)	8.36	7.12	9.37	7.59

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.6 Total soluble solids (TSS) content

The variation in terms of total soluble solids content (TSS) between two varieties of mango was found to be statistically non-significant during harvest (Appendix 6). But the results showed that the percentage of total soluble solids (TSS) content was increased with increased during of storage. The variety Lakhanbhog showed comparatively higher TSS content than Langra at all days of storage (Table 6).

Various postharvest storage treatments used in the present study showed statistically significant variation in respect of total soluble solids (TSS) content at all days of harvest (Appendix 6). Percent TSS content increased in fruits during storage. The 3rd day of harvest to at 12 DAS, the percent of TSS content of fruits were in the range between 15.99% to 27.47% in control followed by T_7 (Plastic crates having mango without wrapping) where the lowest range (12.66% to 23.76%) was observed in T_1 (Hot water dips). Here it can be mentioned that among the treatments, the ranges were found as significant and that were 12.66% to 15.99%, 17.75% to 21.43%, 21.82% to 25.56% and 23.76% to 27.47% at 3rd, 6th, 9th and 12th day of harvest, respectively (Table 6).

The combined effect of variety and postharvest treatments of mango in respect of TSS content was significant during storage period (Appendix 6). The maximum TSS content (16.05%, 21.75%, 25.81% and 27.65% at 3rd, 6th, 9th and 12th day of harvest, respectively) was observed in Lakhanbhog with control treatment (V_2T_0) followed by V_1T_0 where the minimum TSS content (12.45%, 17.59%, 21.66% and 23.59 at 3rd, 6th, 9th and 12th day of harvest, respectively) was observed in Langra with Hot water dips (V_1T_1) followed by V_2T_1 (Table 6).Mollah and siddique (1973) reported that ‘Fazli’ and ‘Langra’ showed (7.70 to 14.8%) and (12.15 to 18.00%) TSS respectively. They also found that TSS varied cultivar to cultivar.

Table 6. Effects of varieties and postharvest treatments on total soluble solids (TSS) of mango

Treatments	Total soluble solids (TSS %) at different days after harvest (DAH)			
	3 DAH	6 DAH	9 DAH	12 DAH
Effect of variety				
V_1	14.35	19.53	23.63	25.67
V_2	14.62	19.87	23.87	25.80
$LSD_{0.01}$	NS	NS	NS	NS
Effect of postharvest treatments				
T_0	15.99	21.43	25.56	27.47
T_1	12.66	17.75	21.82	23.76
T_2	13.97	19.05	23.24	25.09
T_3	13.46	18.57	22.70	24.54
T_4	14.70	19.92	24.04	26.03
T_5	15.11	20.39	24.15	26.38
T_6	14.39	19.57	23.74	25.68
T_7	15.61	20.92	24.78	26.92
$LSD_{0.01}$	0.761	0.910	0.519	0.948
Interaction effect of variety and postharvest treatments				
V_1T_0	15.92	21.11	25.32	27.29
V_1T_1	12.45	17.59	21.66	23.59
V_1T_2	13.82	18.95	23.08	25.12
V_1T_3	13.25	18.35	22.49	24.41
V_1T_4	14.62	19.79	23.92	25.95
V_1T_5	14.95	20.15	24.18	26.35
V_1T_6	14.28	19.45	23.62	25.71
V_1T_7	15.49	20.85	24.81	26.89
V_2T_0	16.05	21.75	25.81	27.65
V_2T_1	12.88	17.90	21.97	23.92
V_2T_2	14.12	19.16	23.41	25.05
V_2T_3	13.67	18.79	22.91	24.67
V_2T_4	14.78	20.05	24.16	26.11
V_2T_5	15.27	20.62	24.11	26.41
V_2T_6	14.49	19.69	23.85	25.65
V_2T_7	15.72	20.99	24.76	26.95
$LSD_{0.01}$	0.570	0.543	0.735	0.829
CV (%)	8.22	6.41	4.60	3.13

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.7 Titratable acidity

Varietal difference in terms of titratable acidity was not significantly influenced during storage (Appendix 7). But it was observed that Langra had higher titratable acidity than Lakhanbhog at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of storage. Titratable acidity decreased gradually with the progresses of harvest time (Table 7).

Significant difference was found in titratable acidity of mango fruits subjected to different postharvest treatments at different day of storage (Appendix 7). The maximum titratable acidity (2.01%, 1.72%, 1.05% and 0.71%) was recorded in Hot water dips (T_1) followed by T_2 (Calcium chloride dips) at 3^{rd}, 6^{th}, 9^{th} and 12^{th} days of harvest. The minimum titratable acidity (1.04%, 0.88%, 0.49% and 0.33%) was observed in control treatment (T_0) followed by T_7 (Plastic crates having mango without wrapping) at 3^{rd}, 6^{th}, 9^{th} and 12^{th} days of harvest (Table 7).

The combined effects of variety and different postharvest treatments in respect of titratable acidity were statistically significant at different day of storage (Appendix 7). The higher titratable acidity (2.04%, 1.76%, 1.12% and 0.72%) recorded in V_1T_1 treatment combinations followed by V_2T_1 and the lower (1.02%, 0.87%, 0.48% and 0.32%) were found in V_2T_0 followed by V_1T_0 at 3^{rd}, 6^{th}, 9^{th} and 12^{th} days of harvest (Table 7).

Table 7. Effects of varieties and postharvest treatments on titrable acidity of mango

Treatments	Titrable acidity(%) at different days after harvest (DAH)			
	3 DAH	6 DAH	9 DAH	12 DAH
Effect of variety				
V_1	1.42	1.23	0.73	0.53
V_2	1.39	1.21	0.71	0.51
$LSD_{0.01}$	NS	NS	NS	NS
Effect of postharvest treatments				
T_0	1.04	0.88	0.49	0.33
T_1	2.01	1.72	1.05	0.71
T_2	1.62	1.41	0.83	0.69
T_3	1.16	1.08	0.63	0.40
T_4	1.59	1.38	0.82	0.64
T_5	1.24	1.13	0.64	0.45
T_6	1.45	1.24	0.75	0.58
T_7	1.10	0.92	0.54	0.37
$LSD_{0.01}$	0.075	0.091	0.053	0.065
Interaction effect of variety and postharvest treatments				
V_1T_0	1.06	0.89	0.50	0.34
V_1T_1	2.04	1.76	1.12	0.72
V_1T_2	1.55	1.38	0.82	0.70
V_1T_3	1.17	1.10	0.65	0.41
V_1T_4	1.66	1.40	0.84	0.65
V_1T_5	1.26	1.14	0.63	0.46
V_1T_6	1.48	1.22	0.77	0.60
V_1T_7	1.12	0.94	0.52	0.38
V_2T_0	1.02	0.87	0.48	0.32
V_2T_1	1.98	1.68	0.98	0.70
V_2T_2	1.68	1.44	0.84	0.67
V_2T_3	1.15	1.06	0.61	0.39
V_2T_4	1.52	1.36	0.80	0.62
V_2T_5	1.22	1.12	0.66	0.44
V_2T_6	1.42	1.26	0.74	0.56
V_2T_7	1.08	0.90	0.56	0.35
$LSD_{0.01}$	0.106	0.129	0.075	0.091
CV (%)	3.62	3.19	3.71	3.31

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.8 Vitamin C content

Vitamin C content of mango pulp was significantly influenced between two varieties of mango during harvest period (Appendix 8). The higher vitamin C content (23.22, 21.18 and 18.18 mg/100g) was found in Langra and lower vitamin C content (22.77, 20.75 and 17.74 mg/100g) was observed in Lakhanbhog at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively (Table 8). There was a decreasing trend in relation to vitamin C content of fruit pulp during harvest.

Effects of different postharvest treatments in respect of vitamin C content were statistically significant at different days of harvest (Appendix 8). The higher vitamin C content (28.31, 26.28 and 23.29 mg/100g) was recorded in Citric acid dips (T_4) treatment followed by Sodium metabisulphite treatment (T_3) and lower vitamin C content (16.99, 14.98 and 11.92 mg/100g) was found in control (T_0) followed by Plastic crates having mango without wrapping (T_7) at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively (Table 8).

Combined effects of variety and postharvest treatments on vitamin C content were significant during harvest period (Appendix 8). The higher vitamin C content (28.49, 26.42 and 23.47 mg/100g) was found in V_1T_4 treatment combination followed by V_1T_2, V_1T_3, V_2T_3 and V_2T_4 at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively. The lower vitamin C content (16.72, 14.76 and 11.69 mg/100g) was observed in V_2T_0 treatment combination followed by V_1T_0, V_1T_7 and V_2T_7 at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively (Table 8).The result of the present study has got the support of Mondal *et al*. (1998) and Absar *et al*. (1993). They reported that vitamin C content decreased gradually during harvest, ripening and transport. The decreased in vitamin content with harvest duration is attributed to the oxidation of ascorbic acid in to dehydro ascorbic acid by enzyme ascorbic acid oxidase (Singh and Abidi, 1986).

Table 8. Effects of varieties and postharvest treatments on Vitamin C of mango

Treatments	Vitamin C (mg/100g)at different days after harvest (DAH)		
	3 DAH	6 DAH	9 DAH
Effect of variety			
V_1	23.22	21.18	18.18
V_2	22.77	20.75	17.74
$LSD_{0.01}$	0.452	0.263	0.385
Effect of postharvest treatments			
T_0	16.99	14.98	11.92
T_1	22.06	19.96	16.99
T_2	26.20	24.17	21.18
T_3	27.08	25.06	22.06
T_4	28.31	26.28	23.29
T_5	20.20	18.25	15.26
T_6	23.94	21.91	18.91
T_7	19.18	17.11	14.05
$LSD_{0.01}$	1.430	1.339	1.023
Interaction effect of variety and postharvest treatments			
V_1T_0	17.25	15.19	12.15
V_1T_1	22.25	20.11	17.12
V_1T_2	26.35	24.22	21.21
V_1T_3	27.21	25.28	22.35
V_1T_4	28.49	26.42	23.47
V_1T_5	20.36	18.41	15.35
V_1T_6	24.12	22.16	19.20
V_1T_7	19.75	17.65	14.58
V_2T_0	16.72	14.76	11.69
V_2T_1	21.88	19.81	16.85
V_2T_2	26.05	24.11	21.15
V_2T_3	26.96	24.84	21.78
V_2T_4	28.12	26.15	23.11
V_2T_5	20.05	18.09	15.17
V_2T_6	23.76	21.67	18.62
V_2T_7	18.61	16.58	13.52
$LSD_{0.01}$	2.022	1.385	1.447
CV (%)	5.27	4.57	4.83

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.9 Disease incidence

Highly significant variation was found in the incidence of disease between two mango varieties on different dates of counting (Appendix 9). No fruits were found diseased till the 3rd day of harvest. The highest (12.51%, 30.57%, 79.83% and 87.64%) disease incidence levels were observed in Lakhanbhog than Langra (9.73%, 29.68%, 74.62% and 84.65%) at 6th, 9th, 12th and 15th day harvest respectively (Table 9).

Postharvest harvest treatments had significant variation in respect of disease incidence during harvest(Appendix 9). The lowest disease incidence (0.00, 11.15%, 55.55% and 67.61%) was found with Hot water dips treatment (T_1) followed by T_3 (Sodium metabisulphite) treatment at 6th, 9th, 12th and 15th day harvest respectively. Similarly, the highest disease incidence (33.35%, 85.36%, 89.89% and 100.00%) was observed in control treatment (T_0) followed by T_7 (Plastic crates having mango without wrapping) at 6th, 9th, 12th and 15th day harvest respectively (Table 9).

In terms of combined effect of variety and postharvest treatments during storage on percent disease incidence had significant variation (Appendix 9). There was no disease incidence till 6th day of harvest with the treatment combination of V_1T_1, V_1T_2, V_1T_3, V_1T_4, V_2T_1 and V_2T_3 and the lowest disease incidence (11.11%, 55.55% and 65.11%) was found in V_1T_1 followed by V_2T_1 at 9th, 12th and 15th day harvest respectively. The treatment combination of V_2T_0 gave the highest disease incidence (33.37%, 88.88% and 90.90%) at 6th, 9th and 12th day harvest respectively which was closely followed by V_1T_0, V_1T_7, V_2T_5 and V_2T_7 and finally (at 15 DAS) fruits were completely damaged by disease with these treatment combinations (Table 9).

Table 9. Effects of varieties and postharvest treatments on disease incidence (%) of mango

Treatments	Disease incidence (%) at different days after harvest (DAH)			
	6 DAH	9 DAH	12 DAH	15 DAH
Effect of variety				
V_1	9.73	29.68	74.62	84.65
V_2	12.51	30.57	79.83	87.64
$LSD_{0.05}$	2.163	0.844	2.117	2.274
Effect of postharvest treatments				
T_0	33.35	85.36	89.89	100.00
T_1	0.00	11.15	55.55	67.61
T_2	5.56	22.24	70.81	77.05
T_3	0.00	11.15	72.21	72.50
T_4	5.57	22.20	82.88	91.98
T_5	11.13	27.77	85.36	97.50
T_6	11.13	22.24	72.20	82.54
T_7	22.24	38.90	88.88	100.00
$LSD_{0.05}$	1.014	1.800	1.879	1.402
Interaction effect of variety and postharvest treatments				
V_1T_0	33.33	81.84	88.88	100.00
V_1T_1	0.00	11.11	55.55	65.11
V_1T_2	0.00	11.15	66.62	77.03
V_1T_3	0.00	11.15	66.66	70.00
V_1T_4	0.00	22.22	81.88	90.05
V_1T_5	11.11	33.33	81.88	95.00
V_1T_6	11.15	22.22	66.62	80.04
V_1T_7	22.26	44.44	88.88	100.00
V_2T_0	33.37	88.88	90.90	100.00
V_2T_1	0.00	11.18	55.55	70.11
V_2T_2	11.11	33.33	75.00	77.07
V_2T_3	0.00	11.15	77.77	75.00
V_2T_4	11.15	22.18	83.88	93.91
V_2T_5	11.15	22.22	88.85	100.00
V_2T_6	11.11	22.26	77.78	85.04
V_2T_7	22.22	33.37	88.88	100.00
$LSD_{0.05}$	1.434	2.545	2.658	1.982
CV (%)	7.74	5.07	6.06	5.38

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

4.10Shelf life

In the present study non-significant variation was observed on shelf life between the two varieties of mango (Appendix 10). The shelf life of Langra was longer (10.6 days) than that of Lakhanbhog (10.2 days) (Table 10).

Postharvest treatments exerted significant effects in extending shelf life of mango (Appendix 10). The results of the study revealed that the shelf life of mango fruits ranged from 5.17 to 15.33 days. The longest shelf life (15.33 days) was found in Hot water dips treatment (T_1) followed by T_3 (Sodium metabisulphite), T_2 (Calcium chloride dips) and T_6 (Plastic crates having mango wrapped with tissue paper) where the shortest shelf life (5.17 days) was recorded in control (Table 10) followed T_7 (Plastic crates having mango without wrapping) and T_5 (Bamboo baskets, Traditional).

The combined effects of variety and postharvest treatments were significant in extending shelf life (Appendix 10). The longest shelf life (15.67 days) was observed in V_1T_1 treatment followed by V_2T_1 (15.00). On the other hand, the shortest shelf life (5.00 days) was observed in V_2T_0 followed by V_1T_0 (5.33), V_1T_5 (8.33), V_1T_7 (8.33), V_2T_5 (8.00) and V_2T_7 (8.00) (Table 11).The extension of shelf life of fruit has been one of the prime concerns of marketing throughout the record of history. Similar results were found by Salunkhe and Desai, 1984

Table 10. Effect of different varieties and postharvest treatments on shelf life of mango

Treatments	Shelf life (days)
Effect of variety	
V_1	10.67
V_2	10.21
$LSD_{0.05}$	NS
Effect of postharvest treatments	
T_0	5.17
T_1	15.33
T_2	12.67
T_3	13.50
T_4	9.50
T_5	8.17
T_6	11.00
T_7	8.17
$LSD_{0.05}$	0.801
Interaction effect of variety and postharvest treatments	
V_1T_0	5.33
V_1T_1	15.67
V_1T_2	13.00
V_1T_3	13.67
V_1T_4	9.67
V_1T_5	8.33
V_1T_6	11.33
V_1T_7	8.33
V_2T_0	5.00
V_2T_1	15.00
V_2T_2	12.33
V_2T_3	13.33
V_2T_4	9.33
V_2T_5	8.00
V_2T_6	10.67
V_2T_7	8.00
$LSD_{0.05}$	1.132
CV (%)	6.51

Variety

V_1: Langra

V_2: Lakhanbhog

Postharvest treatments

T_0: Control

T_1: Hot water dips

T_2: Calcium chloride dips

T_3: Sodium metabisulphite

T_4: Citric acid dips

T_5: Bamboo baskets (Traditional)

T_6: Plastic crates having mango wrapped with tissue paper

T_7: Plastic crates having mango without wrapping

CHAPTER V

SUMMARY AND CONCLUSION

The experiments were carried out at the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during 28 June to 25 July 2014. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The present research was conducted on the aspect of shelf life and quality of mango through two variety and various postharvest treatments. Two important varieties of mango namely, Langra and Lakhanbhog were assigned to different postharvest treatments (Control; Hot water dips; Calcium chloride dips; Sodium metabisulphite; Citric acid dips; Bamboo baskets (Traditional); Plastic crates having mango wrapped with tissue paper and Plastic crates having mango without wrapping were used in the present study.

In this study observations were made on external and internal fruit attributes, physiochemical properties such as total weight loss, moisture content, dry matter content, total soluble solids content, disease severity, disease incidence and shelf life. External fruit attributes were evaluated by unaided eye, and standard colour chart was used for the determination of skin colour. In this experiment (Langra and Lakhanbhog) mango of each treatment from three replications were collected randomly at 3, 6, 9, 12 and15 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 above factors.

In case of varietal performance, results revealed that the parameters indicated to firmness, weight loss, TSS and titratable acidity were not significantly influenced

by both the variety of Langra and Lakhanbhog. Results also showed that in case of variety, Lakhanbhog showed the best performance in terms of colour score (3.54, 4.39, 5.22 and 5.98 at 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively), dry matter content (13.46%, 16.27%, 18.27% and 20.33% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} days of harvest respectively), disease incidence (12.51%, 30.57%, 79.83% and 87.64% at 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively) where the variety; Langra showed lower performance in terms of colour score (3.28, 4.13, 4.97 and 5.68 at 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively), dry matter content (12.19%, 13.35%, 16.13% and 19.18% at 3^{rd}, 6^{th} , 9^{th} and 12^{th} days of harvest respectively), disease incidence (9.73%, 29.68%, 74.62% and 84.65% at 6^{th}, 9^{th}, 12^{th} and 15^{th} day harvest respectively). The higher vitamin C content (23.22, 21.18 and 18.18 mg/100g) was found in Langra and lower vitamin C content (22.77, 20.75 and 17.74 mg/100g) was observed in Lakhanbhog at 3^{rd}, 6^{th} and 9^{th} day of harvest, respectively. The shelf life of Langra was also longer (10.67 days) than that of Lakhanbhog (10.21 days).

In terms of different treatment during harvest, results showed that the higher colour scores (1.89, 4.58, 5.27, 6.18 and 6.85) was observed in Plastic crates having mango without wrapping (T_7) and lowest colour score (1.03, 2.29, 3.20, 3.98 and 4.32 at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively) was in Calcium chloride dips treatment (T_2). Again, he firmness score was found to be the higher (5.50 and 6.00 respectively) with control treatment (T_0) at 12 and 15 DAS but at 3 and 6 DAH Citric acid dips treatment (T_4) showed the highest score (2.24 and 3.11 respectively) and also Calcium chloride dips treatment (T_2) showed the highest score of firmness (4.24) at 6 DAH. The lowest firmness score (1.60, 2.61, 3.40, 4.07 and 5.07 at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively), lowest weight loss (2.78%, 5.91%, 7.89%, 9.11% and 9.44% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} days of harvest respectively), maximum moisture content (92.19%, 89.83%, 86.94% and 84.06 % at 3^{rd}, 6^{th}, 9^{th} and 12^{th} days of harvest), lowest dry

matter content (7.81%, 10.16%, 13.06% and 15.94% at 3rd, 6th, 9th and 12th day of harvest, respectively), lowest TSS content (12.66%, 17.75%, 21.82% and 23.76% at 3rd, 6th, 9th and 12th days of harvest respectively), maximum titratable acidity (2.01%, 1.72%, 1.05% and 0.71% at 3rd, 6th, 9th and 12th days of harvest), lowest disease incidence (0.00, 11.15%, 55.55% and 67.61% at 6th, 9th, 12th and 15th day harvest respectively), and longest shelf life (15.33 days) were obtained from Hot water dips treatment (T_1). Again, the higher vitamin C content (28.31, 26.28 and 23.29 mg/100g at 3rd, 6th and 9th day of harvest, respectively) was recorded in Citric acid dips treatment (T_4). On the other hand, total weight loss was found to be the highest (2.78%, 5.91%, 7.89%, 9.11% and 9.44% at 3rd, 6th, 9th, 12th and 15th days of harvest respectively), minimum moisture content (79.03%, 76.60%, 75.14 and 73.81% at 3rd, 6th, 9th and 12th days of harvest), highest dry matter content (20.97%, 23.40%, 24.86% and 26.19 % at 3rd, 6th, 9th and 12th day of harvest, respectively), highest TSS content (15.99%, 21.43%, 25.56% and 27.47% at 3rd, 6th, 9th and 12th days of harvest respectively), minimum titratable acidity (1.04%, 0.88%, 0.49% and 0.33% at 3rd, 6th, 9th and 12th days of storage at 3rd, 6th, 9th and 12th days of harvest), highest disease incidence (33.35%, 85.36%, 89.89% and 100.00% at 6th, 9th, 12th and 15th day harvest respectively), lower vitamin C content (16.99, 14.98 and 11.92 mg/100g at 3rd, 6th and 9th day of harvest, respectively) and the shortest shelf life (5.17 days) were observed in control treatment (T_0).

Combined effect of variety and different treatments had significant effect on different parameters during harvest. Results revealed that the highest colour score (1.92, 4.70, 5.39, 6.23 and 7.00 at 3rd, 6th, 9th, 12th and 15th days of harvest respectively) was observed in Lakhanbhog when stored at Plastic crates having mango without wrapping (V_2T_7) and lowest colour score (1.01, 2.16, 3.04, 3.88 and 4.16) was found in Langra stored in Calcium chloride dips (V_1T_2) at 3rd, 6th, 9th, 12th and 15th days of harvest respectively. The higher vitamin C content (28.49,

26.42 and 23.47 mg/100g) was found in Langra stored in Citric acid dips (V_1T_4) treatment combination at 3rd, 6th and 9th day of harvest, respectively where lower vitamin C content (16.72, 14.76 and 11.69 mg/100g at 3rd, 6th and 9th day of harvest, respectively) was observed in Lakhanbhog with control treatment (V_2T_0).

Again, The minimum changes in firmness (1.36, 2.48, 3.37, 4.01 and 5.01 at 3, 6, 9, 12 and 15 days of observation respectively), lowest weight loss (2.74%. 5.88%, 7.85%, 9.05% and 9.36% at 3, 6, 9, 12 and 15 days of observation respectively), highest moisture content (93.18%, 91.12%, 88.40% and 85.45% at 3rd, 6th, 9th and 12th day of storage respectively), the lowest dry matter content (6.81%, 8.88%, 11.61% and 14.55% at 3rd, 6th, 9th and 12th day of storage, respectively), minimum TSS content (12.45%, 17.59%, 21.66% and 23.59 at 3rd, 6th, 9th and 12th day of storage, respectively), higher titratable acidity (2.04%, 1.76%, 1.12% and 0.72% at 3rd, 6th, 9th and 12th days of storage), lowest disease incidence (11.11%, 55.55% and 65.11% at 9th, 12th and 15th day storage respectively), and longest shelf life (15.67 days) was observed in Langra stored in hot water dips (V_1T_1)treatment. On the other hand, the maximum change in firmness (5.48 and 6.00 at 12th and 15th days of storage respectively) was observed in, highest weight loss (5.20%, 8.71%, 10.33%, 11.32% and 13.32% at 3, 6, 9, 12 and 15 days of observation respectively), lower moisture content (78.31%, 75.35%, 74.38% and 72.37 respectively), highest dry matter content (21.69%, 24.65%, 25.61% and 27.63% at 3rd, 6th, 9th and 12th day of harvest, respectively), maximum TSS content (16.05%, 21.75%, 25.81% and 27.65% at 3rd, 6th, 9th and 12th day of harvest, respectively), lower titratable acidity (1.02%, 0.87%, 0.48% and 0.32% at 3rd, 6th, 9th and 12th days of harvest), highest disease incidence (33.37%, 88.88% and 90.90% at 6th, 9th and 12th day harvest respectively), and shortest shelf life (5.00 days) was observed in Lakhanbhog with control treatment (V_2T_0).

Finally, it can be concluded that mango should be treated with hot water dips, packaging materials as plastic crates, wrapping with tissue paper for long term storage quality control, transportation and marketing.

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APPENDICES

Appendix 1:Effect of different varieties and postharvest treatments on color of mango

Mean Square	Degrees of Freedom	Mean square of color at different days after harvest (DAH)				
		3	6	9	12	15
Replication	2	0.001	0.003	0.004	0.002	0.003
Factor A	1	NS	0.819	0.806	0.715	1.144
Factor B	7	0.607**	4.192*	3.138*	4.229*	5.577*
AB	7	0.021**	0.007**	0.008*	0.012**	0.004**
Error	30	0.011	0.102	0.114	0.137	0.221

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 2: Effect of different varieties and postharvest treatments on firmness of mango

Mean Square	Degrees of Freedom	Mean square of firmness at different days after harvest (DAH)				
		3	6	9	12	15
Replication	2	0.001	0.004	0.003	0.004	0.003
Factor A	1	NS	NS	NS	NS	NS
Factor B	7	0.313**	0.175**	0.518*	1.495*	0.550*
AB	7	0.574**	0.292*	0.008**	0.006**	0.003**
Error	30	0.012	0.017	0.011	0.043	0.021

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 3: Effects of different varieties and postharvest treatments on weight loss (%) of mango

Mean Square	Degrees of Freedom	Mean square of weight loss (%) at different days after harvest (DAH)				
		3	6	9	12	15
Replication	2	0.001	0.005	0.002	0.000	0.024
Factor A	1	NS	NS	NS	NS	NS
Factor B	7	4.387*	5.859*	4.391*	2.683*	9.765*
AB	7	0.033**	0.120**	0.207**	0.218**	0.439**
Error	30	0.116	0.177	0.211	0.135	0.193

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 4: Effects of varieties and postharvest treatments on moisture content (%) of mango

Mean Square	Degrees of Freedom	Mean square of moisture content (%) at different days after harvest (DAH)			
		3	6	9	12
Replication	2	0.036	1.377	2.813	1.169
Factor A	1	9.559*	10.346*	4.848*	6.078*
Factor B	7	13.770*	14.879*	13.877*	9.535*
AB	7	1.306**	9.243**	6.378*	11.346*
Error	30	4.946	5.775	4.241	5.930

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 5: Effects of varieties and postharvest treatments on dry matter (%) of mango

Mean Square	Degrees of Freedom	Mean square of dry matter (%) at different days after harvest (DAH)			
		3	6	9	12
Replication	2	0.071	0.195	0.166	0.595
Factor A	1	0.130**	0.104**	0.007**	0.125**
Factor B	7	11.246*	11.092*	16.758*	14.543*
AB	7	2.707**	3.492**	3.210**	4.341*
Error	30	0.863	0.787	1.659	2.304

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 6: Effects of varieties and postharvest treatments on total soluble solids (TSS) of mango

Mean Square	Degrees of Freedom	Mean square of total soluble solids (TSS) at different days after haevest (DAH)			
		3	6	9	12
Replication	2	0.237	2.781	0.204	0.380
Factor A	1	NS	NS	NS	NS
Factor B	7	7.357*	9.012*	8.304*	9.146*
AB	7	1.019**	1.040**	3.061*	5.043*
Error	30	0.417	0.596	0.194	0.647

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 7: Effects of varieties and postharvest treatments on titrable acidity of mango

Mean Square	Degrees of Freedom	Mean square of titrable acidity at different days after harvest (DAH)			
		3	6	9	12
Replication	2	0.024	0.006	0.002	0.007
Factor A	1	NS	NS	NS	NS
Factor B	7	0.645*	0.469*	0.198*	0.137*
AB	7	0.108**	0.203*	0.105**	0.411*
Error	30	0.024	0.106	0.202	0.103

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 8: Effects of varieties and postharvest treatments on Vitamin C of mango

Mean Square	Degrees of Freedom	Mean square of Vitamin C content at different days after harvest (DAH)		
		3	6	9
Replication	2	1.377	2.813	1.169
Factor A	1	10.346*	5.848*	6.078*
Factor B	7	14.879*	11.877*	9.535**
AB	7	9.243**	6.378**	11.346*
Error	30	5.775	4.241	5.930

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 9: Effects of varieties and postharvest treatments on disease incidence (%) of mango

Mean Square	Degrees of Freedom	Mean square of disease incidence (%) at different days after harvest (DAH)			
		6	9	12	15
Replication	2	1.575	0.864	0.807	0.106
Factor A	1	9.880*	9.479**	5.052**	10.042*
Factor B	7	24.366*	33.888*	19.200*	19.815*
AB	7	9.807**	16.433*	13.880*	9.317**
Error	30	1.740	2.330	2.540	1.413

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Appendix 10: Effect of different varieties and post-harvest treatments on shelf life of mango

Mean Square	Degrees of Freedom	Mean square of shelf life of mango
Replication	2	1.750
Factor A	1	2.521*
Factor B	7	6.521*
AB	7	1.045**
Error	30	0.461

* = Significant at 5% level of significance

** = Significant at 1% level of significance