EFFECT OF POSTHARVEST TREATMENT AND ETHREL ON RIPENING AND QUALITY OF MANGO

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Dedicated to
My
Beloved
Parents & Teachers

CERTIFICATE

This is to certify that the thesis entitled, "*EFFECT OF POSTHARVEST TREATMENT AND ETHREL ON RIPENING AND QUALITY OF MANGO*" submitted to the Faculty of Agriculture, Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE* in *HORTICULTURE* embodies the result of a price of bona fide research work carried out by *RAHIMA KHATOON* Registration No. 25185/00314 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:
Place: **Gazipur, Bangladesh**

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Supervisor

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ABSTRACT

An experiment was conducted at the laboratory of the Plant Physiology Section and Postharvest Laboratory under the Horticulture Research Centre (HRC), Joydebpur, Gazipur, during the period from June to July, 2006 to study the effect of postharvest treatment and ethrel on ripening and quality of mango fruits during storage. Mature green mangoes (cv. Langra) were treated with normal and hot water with four ethrel concentrations viz. control (0 ppm), 500 ppm, 1000 ppm and 1500 ppm ethrel. The experiment was laid out in a completely randomized design (factorial) with three replications. Types of solutions, different ethrel concentrations and their combinations showed significant variation on ripening and quality of mango fruits except moisture content. The hot water treatment with 1000 ppm ethrel treated mangoes gave the highest shelf life (14 days), TSS (22.64%), reducing sugar (5.96%), ascorbic acid (18.16 mg/100g pulp), P^H (5.77) at 8^{th} days of storage and non-reducing sugar (16.93%) and total sugar (20.80%) at 6^{th} days of storage. On the other hand, the lowest percent rottening (33.27%), titrable acidity (0.08%) and weight loss (11.27%) were found in hot water with 1000 ppm ethrel during 8^{th} days of storage. The quick ripening (1day) and lowest value of ascorbic acid were found in hot water with 1500 ppm ethrel treatment. From the investigation, it may be concluded that hot water with 1000 ppm ethrel treatment was found most effective for ripening and better quality of mango.

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ABBREVIATIONS AND ACRONYMS

BARI	Bangladesh Agricultural Research Institute
HRC	Horticulture Research Center
BBS	Bangladesh Bureau of Statistics
^0C	Degree Celsius
TSS	Total Soluble Solid
RH	Relative Humidity
IPGRI	International Plant Genetic Resources Institute
DAS	Days after Storage
g	Gram
NS	Non Significant
N	Normality
ppm	Parts per million
ml	Milliliter
ha	Hectare
%	Percent
et al.	and others (at elli)
P^H	Hydrogen ion concentration
df	Degree of freedom
LSD	Least Significant Difference
var.	Variety
% CV	Percentage of Coefficient of Variance

Chapter 1

INTRODUCTION

INTRODUCTION

The mango (*Mangifera indica L.*) is the second most important tropical fruit crop in the world. It has been cultivated for more than 4000 years and was originated in Eastern India, Assam, Burma or further in the Malayan region (Candole, 1984). Mukherjee (1949) reported that the genus *Mangifera* was originated in Burma, Siam, Indo-China and the Malayan Peninsula; but the mango itself had its origin in the Assam-Burma region which includes the area what is now called Bangladesh. The Wild mango, particularly *Mangifera sylvatica* Roxb, is still found in Chittagong Hill Tracts of Bangladesh (Vavilov, 1926).

The mango is a commercial crop in many countries of South-East Asia, the Philippines, Pakistan, India, Indonesia, Java, Thailand, Burma, Malaysia and Srilanka. It is gaining popularity in Egypt, South-East Africa, South Africa, Hawaii and West Indices. Efforts are also being made to extend its cultivation to Florida, Israel, Mexico and Brazil. In early 16th century the Portuguese carried the mango plant and seed from Goa to East Africa, then to West Africa and adjacent island and subsequently to Brazil. The mango was first introduced to Barbados, Jamaica, Florida and Egypt respectively in 1742, 1782, 1833 and 1925 (Mukherjee, 1967). The mango grows in almost all parts of Bangladesh but the commercial and good quality grafted mangoes with known varietals identify are mostly grown in North-Western districts and mangoes of unknown varieties (Gooti mangoes) are grown in the South-Eastern and other parts of the country (Bhuyan, 1995).

The world production of mango is about 14 million tons per year of which India, the largest producer, alone produces 9.30 million tons; followed by Brazil, Pakistan, Mexico, the Philippines, Indonesia, Haiti, China, Bangladesh, Egypt, Sudan, Sri Lanka and Cuba (Bhuyan, 1995). The mango tops the list in terms of area and occupies third position in terms of production among the

fruits grown in Bangladesh. At present, Bangladesh produces 662100 MT of mangoes annually from 25054.656 hectares of land with an average yield of 10.989 tons per hectare (BBS, 2005).

Mango is the choicest fruit of the country and because of its great utility, characteristic pleasant aroma and flavor it is acknowledged as the king of fruit (Shahjahan *et al.*, 1994). It has medium calorific and high nutritional values. Carbohydrate content in ripe mango pulp is 16.9% (Salunkhe & Desai 1984). It is also a rich source of vitamins, minerals and total soluble solid (TSS) and therefore, prevent deficiency diseases (Samad *et al.* 1975; Purohit, 1985). 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. Bumper harvest over a narrow period of time causes a glut in the market with the resultant poor returns. One of the methods of achieving this is to grow suitable early and late varieties, the other being to delay or hasten the process of fruit development and its ripening.

The process of ripening depends on the maturity or the optimum development of the fruit. Immature fruits do not ripen properly or not at all. Another important aspect is that the storage life of the fruit depends upon the process of ripening. It was well established that ethylene, the ripening hormone, accelerates ripening in all climacteric fruit (Biale, 1960).

Exogenous application of ethylene stimulated biosynthesis of ethylene, fruit ripening pigment synthesis, chlorophyll destruction and yellowing, respiration and senescence in climacteric fruit (Nair and Singh, 2003). It has been reported that exogenous application of ethylene in the form of ethrel accelerated ripening, increased color and eating quality with reduced spoilage in various varieties of mango.

Warner and Leopold (1969) reported that ethrel has been found to be effective in causing ripening of fruits; Ruiz and Guadarrama (1992) reported that 2000 ppm of ethrel under $30^0C \pm 2^0C$ and 55-60% relative humidity was the best dose to get ripened fruits with edible quality. The pulp obtained from these fruits had stability for three months at -10^0C. However, higher rates caused additional maturity advances, but result the unacceptable crop phytotoxicity when air temperature exceeded 35^0C for extended period. Furthermore, there were variable cultivars responses to similar ethrel rates.

There was a significant variation in respect of days to ripening due to the combined effect of types of solution and ethrel concentration. The concentration of growth regulator i.e. ethrel should be such that might not affect the quality (Murry and Hartz, 2001). Such types of information are lacking in our country and that's why the present experiment was undertaken with the following objectives.

- To know the effect of ethrel in enhancing the ripening and quality of mango
- To determine physio-chemical changes in mango with types of solution and different concentrations of ethrel application.
- To investigate the effect of ethrel on the shelf life of mango.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In Bangladesh mango is considered to be the best of all the indigenous fruit. In fact, it will be no exaggeration to say that because of its excellent flavor, attractive fragrance, beautiful color, delicious taste; mango is now recognized as one of the best fruits in the world market. It is also acknowledged as the king of the fruit. A large number of research works have been done on different aspects of mango in different parts of the world. Although considerable literatures dealing with extending shelf life, reducing post harvest losses due to physio-chemical changes during ripening of mango is available, particularly the information is not available in artificial ripening. It has been reported that exogenous application of ethylene in the form of ethrel accelerated ripening and increased color of eating quality in various varieties of mango.

It is essential to understand the physiochemical changes that determine the quality of fruits after application of different concentrations of ethrel at maturity stages of fruit. Changes in physiochemical characteristics during storage as well as ripening must be determined for assessing the fitness of mango for consumption.

The scientific literatures include a very few studies on physio-chemical changes in mango but those are neither adequate nor conclusive. However, available literature on mango and some other fleshy fruits that are related to the present study have been reviewed in the following section.

2.1. Changes in physical characteristics of mango fruit

2.1.1 Color development and ripening of fruit

Color is an important mango quality characteristic. For the consumer color development is an important indicator of 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 ± 1^0 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.

Madhavi *et al.* (2005) conducted an experiment on ripening of sapota during November 1999 to January 2000 with different concentrations of ethrel (500, 1000, 2000, and 3000, ppm). They observed that ripening increased significantly with the increasing concentration of ethrel.

Mohamed and Abu-Goukh (2003) 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.

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 35^0C for extended period. Furthermore, there were variable cultivar responses to similar ethaphone rates.

Yahia *et al.* (2000) performed an experiment with hot water treatment at 46^0C 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, Jobling (2000) 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^{0}C and relative humidity of 85 to 90%.

Ghosh and Hossain (1997) noticed that ripening process was enhanced rapidly by either dipping fruits in or spraying them with 500 ppm ethrel. They also mentioned that, when the fruits were stored under conditions with adequate oxygen availability registered better color development and the required softness.

Kajuna *et al.* (1997) found that green banana when treated with ethylene (1000 ppm for 24 h at RT) showed reduced TPA parameters (Texture Profile Analysis) viz., hardness, chew ness, gumminess, cohesiveness and springiness, as compared with untreated fruits.

In Japan, Dong *et al.* (1996) reported that respiration i.e. ethylene evolution increased at the green fruit stage but declined at the physiological maturity stage. They said that up to green fruit stage, the fruit contained mainly chlorophyll. This chlorophyll decreased gradually until the physiological maturity stage is reached. The fruit gradually turned red as lycopene content increased.

According to Kodikara *et al.* (1996) hot water double dip treatment (42^0 C for 15 minutes followed by within 3 minutes by 48 C for 20 minutes) was assessed for its ability to control storage disease of papaya. They also mentioned that shelf life was increased. Ripening was slightly accelerated but there was no significant weight loss.

Jacobi *et al.* (1995) studied the effect of post harvest hot water treatment on fruit quality of mango cv. Kensington and noticed that hot water treatment (46^0 C for 30 minute at a fruit core temperature of 45^0 C) increased fruit softening and reduced disease incidence.

An experiment was conducted by Kumar and Dhawan (1995) to study the effect of post harvest 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 ($50^0 \pm 5^0$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 Singh *et al.* (1995) 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 β-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). Enhanced ripening of banana with ethrel was also reported by Aziz and Tanahy (1975); Hewage *et al.* (1995)

Masarirambi *et al.* (1995) carried out an experiment at University of Florida, USA, with mature green fruits of tomato CV. Agriset 761 which were exposed to ethylene (100 ppm) at 20, 25, 30, 35 or 40^0 C and 95% RH for 24, 48, or 72 hours and then transferred to normal air at 20^0C for repining. It was observed that tomato exposed to ethylene at high temperature for 24 hours showed a little difference in color development compared to those exposed to ethylene at

lower temperatures increasing the duration of ethylene at lower temperatures. Increasing the duration of ethylene high temperature treatment (48 or 72 hours at 35 or 40^0C) inhibited subsequent red color development at 20^0C, while prior to exposure to 30^0C stimulated color development.

Balla *et al.* (1994) carried out an experiment in Slovenia and reported that visual color did not change during over ripening but the texture was softened. They also stated that chlorophyll content decreased and β-carotene that is lycopene contents increased. There was a strong correlation between the co-efficient of elasticity that is visual color score during ripening.

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 ripening significantly improved the fruit quality (TSS, sugar, ascorbic acid and β-carotene) and reduced spoilage loss during storage.

Bhowmick (1992) set up an experiment to investigate the effect of ethrel (200, 400, 600, and 800 ppm) on ripening of fruit. They observed that increasing the ethrel concentration shortened the ripening time.

Ruiz and Guadarrama (1992) performed an experiment where mature mangoes were treated with ethrel (0, 2000, and 4000 ppm) for 1 min. They were stored under two different conditions ($25^0 \pm 3$ and 55-60% RH; 15^0 C ±1 and 85-90% RH). They observed that in both storages mangoes with 2000 ppm and 4000 ppm treatments reduced ripening time.

Mehta *et al.* (1980) performed an experiment with different concentrations of ethrel on sapota fruits. They observed that increase in ethrel concentration from 250 ppm to 500 ppm hastened early ripening.

Feng *et al.* (1991) mentioned that hot water treatment (52-54^{0}C for 8-10 min) controlled mango anthracnose.

Khan *et al.* (1977) conducted an experiment with ethrel at 1000-3000 ppm and CaC_2 (10-25) in banana. They observed the shortest ripening time with the highest exposure rates when both the chemicals were used.

Singh *et al.* (1977) experimented with banana cv. Basrai Dwarf and found that banana treated with Ethrel (5 x 10^3, 3 x 10^3 ppm) and covered with dry banana leaves gave induced ripening which was 2-2.5 days for 5 10^3 ppm and 3-3.5 days for 3 x 10^3 ppm. Ethrel, an ethylene releasing compound, is very effective in accelerating the ripening and quality regulation in different fruits (Rauhani and Bassiri, 1977; Bal and Chohan, 1981; Singh *et al.* 1987; Sadhu and Chattopadhyay, 1989).

Bhattcharya and Mohan (1977) reported that var. Khatti in ethrel at 250 ppm solution improved the fruit color and also accelerated the ripening time about 2 to 3 days.

Bauna (1976) investigated the artificial ripening with ethrel at the concentrations of 100, 250, 500 and 1000 ppm at ambient temperature. He obtained satisfactory ripening condition 4 and 6 days after treatment at higher concentrations.

Lakshminarayan *et al.* (1974) worked on mango cv. Alphonso and opined that hot water treatment (54^{0}C ± 1) for 5 minutes accelerated ripening and reduced post harvest microbial spoilage by 50%.

Subramanyam *et al.* (1973) observed that Alphonso that is Pairi mangoes showed improved color, texture and aroma after 7 days when the fruits were

treated with hot water (52^0C) either alone or with Zineb (0.375%) for 1 or 7 days after harvest.

Campbell and Malo (1969) conducted an experiment to investigate the effect of ethrel on ripening period of mango. They reported that application of ethrel shortened the ripening period.

Working with both Kishanbhog and Langra varieties, it was observed that the commencement of ripening rate there was a climacteric rise in the respiration rate. It was further recorded that the respiratory quotients were less than unity and this indicated that a mixture of carbohydrates and fats in mangoes constituted the respiratory substratum (Singh *et al.*, 1937).

2.1.2 Weight loss of mango

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

In Turkey, Kaynas and Surmeli (1995) observed that weight loss was more severe in fruits at an early stage of maturity and increased as storage temperature increased. They also stated that at green mature stages tomato were stored at 4 and 8^0C, the total weight loss over 35 days ranged from 3 to 8%, depending on cultivars, maturity and temperature.

Yoltas *et al.* (1994) observed that a 1.2% semperfresh (a fatty acid sucrose ester mixture) significantly reduced the weight loss in tomato fruit (cv. Galit-135) during storage at 21^0C (Aziz and Tanahy, 1975).

Tauqur *et al.* (1989) conducted an experiment in India, with mango fruits (cvs. Des and Duschvi) treated with CaC_2 (2g/Kg fruit). Both treated and control fruits were wrapped up in paper held in wooden perforated boxes for up to 12

days. After storage they observed that CaC_2 treatment accelerated ripening and resulted in higher percentage of weight loss during storage.

2.1.3 Rottening of mango fruit

Nair and Singh (2003) conducted an experiment with varying concentrations of ethrel (0, 50, 250 and 500 mg/l) to investigate fruit quality of mango. They reported that fruit quality has been improved with ethrel treatment and reduced rottening.

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 reduced spoilage loss during storage. Joarder (1980) stated that malic hydrazide (MH) was useful in ripening but failed to retard spoilage in prolonged storage condition.

Sharma and Kaul (1990) commented that hot water treatment (50^0 C) for four minute in combination with 200 ppm carbendazim was effective in controlling brown rot of apple.

2.1.4 Shelf life of mango

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 20^0 C for 24 hr to induce ripening prior to transfer at 13^0 C. The fruits were packed with nylon sponge and sealed in modified atmosphere polythene bags and stored at 13.5 ± 0.5^0 C. Preliminary results showed that modified atmosphere packaging improved fruit quality and prolonged shelf life of mango (Singh and Janes, 2001).

At Hariana in India, Sandooja *et al.* (1987) studied the effect of Ethrel/CaC_2, Kinetin, GA_3 and $KMnO_4$ on tomato fruit quality during storage and reported that treatment of fruits with $KMnO_4$ at 1000 ppm immediately after green

mature stage resulted in prolonged storage life and decreased weight loss and decay during storage.

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 (CO_2, H_2O, NH_3) (Salunkhe and Desai, 1984)

2.2 Changes in chemical characteristics of mango fruit

2.2.1 Moisture content

An investigation was carried out by Absar and Amin (1993) to find out the moisture content of mango at different stages of maturity. They reported that at the full ripe stage moisture varied from 71.22 to 79.40%.

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%. Samad *et al.* (1975) 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%.

Moisture content in ripe pulp of mangoes were 79-81% (Salunkhe and Desai, 1984). Steward (1960) stated that respiration involved the degradation of sugar to carbon dioxide and water with the absorption of oxygen. However, the loss of estimated carbohydrate was observed to be at times lower with the rate of increase of water.

Srivastava (1967) reported that the green unripe mango contained higher percentage of moisture as compared to ripe mango. Moisture content of green pulp of fazli mangoes was found 79.95% and ripe mango 90% (Shahjahan *et al.* (1994).

In Pakistan, Chaudhary and Farooqui (1969) observed 79.83.0% moisture in the cultivars Sindhry, Bombay. Ali and Mazher (1960) studied the various characteristics and chemical composition of mango and reported that the fruits contained water from 76 to 86% according to variety.

2.2.2 Ascorbic acid content of mango pulp

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.* (1995) with GA_3 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 and Amin (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/100g).

In Uttar prodesh, India, Yadev *et al.* (1984) studied the chemical characteristics of some common mango varieties and reported that Dashehari had the highest ascorbic acid content (16.15mg/100g).

Suryanarayana and Goud (1984) conducted an experiment to find out the effect of ethrel treatment on ripening and quality of sapota cv. Pala fruits. They reported that decrease in Vitamin-C with the progress of ripening period and with the increasing concentration of ethrel.

Mehta *et al.* (1980) conducted an experiment with different concentrations of ethrel on sapota fruits. They observed that increase in ethrel concentration depleted the ascorbic acid content.

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.

Borooah and Mohan (1975) studied in an experiment in India, with 11 varieties of mango and found that the largest fruit size had less ascorbic acid content and the smallest fruit had the highest ascorbic acid content of 20 -30 mg/100g.In India, Lodh *et al.* (1974) analyzed eight varieties of mango and pointed out that Langra had the best source of vitamin C (123mg/100 g). On the contrary, it was the lowest in Bombay Green (9.50 mg/100 g). Palaniswamy *et al.* (1974) commented that vitamin C content of ripe mangoes varied from 3.2 to 62.9 mg/100 g.

2.2.3 P^H

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 hot water treated fruit gave the higher P^H values compared to non treated fruit.

Deming *et al.* (2002) conducted an experiment with hot water treatment and artificial ripening on its quality of mango. They observed that hot water treatment can make the color of both peel and pulp homogenous. The P^H values are higher than those non-hot-treated fruit.

P^H content in Fazli mango at harvest and last day of storage respectively has been reported as 3.84 and 4.88 (fruit harvested at 127 days after fruit set) (Shajahan *et al.* 1994)

In an experiment in Brazil, Botrel *et al.* (1993) observed that ripe pineapple(cv. Sarawak) fruits held at 5^0 C had a higher P^H values.

Absar and Amin (1993) observed the highest pulp P^H in Khirsapat (5.2) and the lowest (4.0) in Ashwina. On the contrary, Kumar *et al.* (1993) found the maximum P^H (4.64) in Fazli.

Joshi and Roy (1988) stated that there was a steady rise in P^H of the fruits of Alphonso mango during storage.

Samad *et al.* (1975) conducted an experiment to study the bio-chemical characteristics of some common mango varieties of Bangladesh. They reported that P^H of the juice of mango was in the range between 4.0 and 4.5. Fazli ranks the first position (4.45) whereas it was the lowest in the pulp of Ranibhog (4.0).

Singleton and Gortner (1965) found that the P^H of the fruit pulp of developing pineapple (cv. Smotth Cayenne) showed almost a straight-line fall from the early readings.

2.2.4 Titrable acidity

Singh and Janes (2001) 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%). Chaudhari *et al.* (1997) 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.

Sharma and Josan (1995) estimated 0.253 to 0.473% acidity in five common varieties of mango in India. In Shujabad, Pakistan, Haq and Javaid (1995) conducted an experiment on physio-chemical characteristics of local and exotic mango varieties and noted the highest titrable acidity (0.55%) in Zafran and the lowest in Alphonso (0.23%). According to Shahjahan *et al.* (1994) percent acidity in ripe mango fruit of cultivars Fazli, Langra, Khirsapat and Gopalbhog were 0.10, 0.06, 0.26, and 0.21, respectively.

Suryanarayana and Goud (1984) conducted an experiment to find out the effect of ethrel treatment on ripening and quality of sapota cv. Pala fruits. They reported that decrease in acidity with the progress of ripening period and with the increasing concentrations of ethrel.

Significant difference in total acidity was observed by Prasad (1977), where the highest acids (0.585%) in the variety Bangalora and lowest in Aalphonso (0.32%). Lodh *et al.* (1974) investigated the chemical composition of eight varieties of mango and observed that acidity varied from 0.11 to 1.33 percent.

2.2.5 Reducing sugar

Oosthuyse *et al.* (2000) conducted an experiment with different concentration of ethrel (250, 500, 1000, 1500 and 2000 ppm) to investigate the effect on the quality of mango. They reported that ethrel treatments significantly increase the reducing sugar.

Bhadra and Sen (1999) conducted an experiment with custard apple and mentioned that reducing sugar content increased as storage progressed. Reducing sugar content of mango varied from 2.6 to 7.1% as described by Chaudhari *et al.* (1997). Sharma and Josan (1995) carried out an experiment with five mango varieties namely Ashonso, Dashweri, Langra, Mallika, Amrapali and Alpahanso. They noted the highest reducing sugar (4.18%) in Dashehari and the lowest in Ashonso (2.56%).

Increase in reducing sugar during ripening was reported by Tripathi (1988). In Bihar, India, Syamal and Mishra (1987) conducted an experiment with some important mango varieties to determine the chemical composition and found the highest reducing sugar (5.82%) in Langra. Reducing sugar increased gradually with fruit ripening (Upadhyay and Ttripathi, 1985).

Mehta *et al.* (1980) conducted an experiment with different concentration of ethrel on sapota fruits. He reported that increase in ethrel concentration from 250 ppm to 500 ppm increased the amount of reducing sugar.

Lodh *et al.* (1974) analyzed eight varieties of mango and stated that reducing sugar varied from 2.70 to 3.85. Samad *et al.* (1975) evaluated ten varieties of

mango and reported that the reducing sugar content of the fruits under the study was in the range of 3.26 and 5.98%. They further observed highest reducing sugar in Gopalbhog (5.98%) and Ranibhog (3.26%) had the least one. Reducing sugar content was 4.23% in Fazli as reported by Sarker and Mushi (1978).

2.2.6 Non-reducing sugar content

Oosthuyse *et al.* (2000) conducted an experiment with different concentrations of ethrel (250, 500, 1000, 1500 and 2000 ppm) to investigate the effect of ethrel on the quality of mango. They reported that ethrel treatments significantly increase the non-reducing sugar.

According to Chaudhari *et al.* (1997) percent non-reducing sugar in ripe mango fruit differed widely. They evaluated South Indian mango varieties under Semi-arid region of Maharashtra and observed 6.2 to 11.5% non-reducing sugar. Rangavalli *et al.* (1993) studied mango and found a gradual increase in non-reducing sugar content.

In a study with two cultivars (cv. Langra and Mallika), Tandon and Kalra (1985) found an increase in fructose of mango during ripening. Sarker and Muhsi (1978) worked on non-reducing sugar content at ripening stage and found 17.35% and 15.75% non-reducing sugar in Fazli and Gopalbhog respectively.

Samad *et al.* (1975) conducted an experiment with some common mango varieties of Bangladesh. They reported that non-reducing sugar content was within the range of 1.62 to 6.60%.

In India, Lodh *et al.* (1974) conducted an experiment at the Indian Institute of Horticulture Research, Hessarghatta. They analyzed eight varieties of mango for their chemical composition. In case of non-reducing sugar the variety

Malgoa attained the first position (19.75), whereas Totapuri the least one (4.42).

Chaudhary and Farooqui (1969) estimated 7.27 to 12.35% non-reducing sugar in some common and local varieties of mango in Pakistan.

2.2.7 Total sugar content

Madhavi *et al.* (2005) conducted an experiment during November 1999 to January 2000 with different concentrations of ethrel (500, 1000, 2000 and 3000 ppm) on sapota. They observed that total sugar increased significantly with the increasing concentrations of ethrel compared with untreated fruits.

Oosthuyse *et al.* (2000) conducted an experiment with different concentrations of ethrel (250, 500, 1000, 1500 and 2000 ppm) to investigate the effect of ethrel on the quality of mango. They reported that ethrel treatments significantly increased the total sugar as compared to untreated fruits. Bhadra and Sen (1999) conducted an experiment with custard apple and mentioned that total sugar content increased as storage progressed.

Jana *et al.* (1998) analyzed the nutrient composition of some varieties of mango grown in West Bengal, India and noted the highest content of total sugar 21.6% in the variety Bimli.

In Korea, Kim *et al.* (1996) reported that the respiration rate increased at higher storage temperatures but decreased with storage period. Ethylene production was suppressed at 0, 5, 10, 30, or 35^0 C but was high for fruits stored at 20^0C due to mould infection. They also stated that total sugar content of fruits decreased with storage. Sucrose content of fruits increased but glucose and fructose decreased when fruits were stored at lower temperature.

An experiment was conducted by Singh *et al.* (1995) with GA_3 and ethrel (ethephone) 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 total sugar content.

Total sugar in Gopalbhog, Khirshapat, Langra and Fazli was found to be increasing at later stage of harvesting and this sugar contents further increased on storage of harvesting mangoes (Shahjahan *et a.* 1994).

Absar and Amin (1993) pointed out that at the full ripe stage; the variety Langra contained the highest total sugar (20.32) and the lowest in Ashwina (14.72%).

Kumar and Singh (1993) noticed that postharvest spray of GA_3 (50 or 75 ppm) or ethrel (500 ppm) hastened fruit maturity by 8-11 days and ripening significantly improved fruit quality (Total sugar) during storage.

In Uttar Pradesh, India, Yadav *et al.* (1984) studied the chemical characteristics of some mango varieties and found the highest content of total sugar (15.46) in Dashehari.

Mehta *et al.* (1980) conducted an experiment with different concentrations of ethrel on sapota fruits. They reported that increase in ethrel concentrations from 250 ppm to 500 ppm increased the amount of total sugar.

Sarker and Mushi (1978) carried out an experiment to determine the sugar content of mango. They revealed that at the ripening stage, fruits of Fazli and Gopalbhog contained 21.87% of total sugar, respectively as against 5.45% in the local variety.

Salem *et al.* (1976) found that banana cv. Dwarf Cavendish when sprayed with Ethrel (Ethephon) at 1200ppm and covered with polythene for 2 days followed by partial covering for 3 days gave the best chemical characteristics.

Lodh *et al.* (1974) conducted an experiment at the Indian Institute of Horticulture Research, Hessarghatta. They analyzed eight varieties of mango for their chemical constituents and found that total sugar varied from 7.35 to 13.20 percent. Total soluble sugar was found to be the lowest i.e. 5.53% in mango cv. Samad *et al.* (1975) studied the chemical quality of mango varieties whereas the variety Alphonso attained top in the list (18.382% total sugar).

Ali and Mazher (1960) studied the various characteristics and chemical composition of mango and reported that the fruit contained sugar ranging from 11 to 20% according to variety. Total sugar content of mango varied from 11.5 to 25% as reported by Singh (1968). In Pakistan, Chaudhry and Farooqui (1969) observed the composition of the cultivars Sindhry, Bombay, Alphono, Banganpalli and some seedling mangoes of Sindh province. Total sugars of those varieties ranged from 10.0 to 17.3%. On the other hand, Palaniswamy *et al.* (1974) found 7.09 to 17.20% total sugar in 29 cultivars of mango in Tamilnadu, India.

2.2.8 Total soluble solids (TSS) content of mango

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.

Madhavi *et al.* (2005) conducted an experiment during November 1999 to January 2000 with different concentrations of ethrel (500, 1000, 2000 and 3000 ppm) for sapota. They reported ethrel treated fruits recorded higher TSS

compared to the fruits under control but had no significant difference between the higher three concentrations (1000, 2000 and 3000 ppm) of ethrel.

Nair and Singh (2003) conducted an experiment with varying concentrations of ethrel (0, 50, 250 and 500 mg/l) 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.

Deming *et al.* (2002) conducted and experiment with hot water treatment and artificial ripening on its quality of mango. They observed that hot water treatment can make the color of both peel and pulp homogenous. The soluble solid content was higher than those in non-hot-treated fruit.

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.

Oosthuyse *et al.* (2000) conducted an experiment with different concentration of ethrel (250, 500, 1000, 1500 and 2000 ppm) to investigate the effect of ethrel on the quality of mango. They reported that ethrel treatments significantly increased the total soluble solids.

An experiment was conducted by Singh *et al.* (1995) with GA_3 and ethrel (ethephone) to enhance the ripening and improve the quality and of mango

(cv.Amrapali).They found that ethrel at 500 ppm was very effective to improve the quality in terms of total sugar content.

Desai *et al.* (1994) performed an experiment to investigate the effect of ethrel (0, 250, and 750 ppm) on quality of watermelon fruits. They reported that ethrel improved TSS and among the treatments 750 ppm gave the highest TSS.

Absar and Amin (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.

In an experiment Sardar and Hossain (1993) found the total soluble solid content of Amrapali, were 24.5%, 23.7% and 25.2%, respectively under the climatic conditions of Rajshahi. In another study, carried out by Sardar *et al.* (1998) revealed that TSS of mango fruits varied from 16.8 to 21.6%. In India, Sharma and Josan (1995) evaluated five mango cultivars under arid irrigated region of Punjab and reported that Dashehari had the higher TSS (20.7%). The minimum TSS (15.2%) was recoded from Alphonso. Chaudhari *et al.* (1997) in a study with mango fruits found that TSS varied from 16.5 to 23.5%.

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%.

Lodh *et al.* (1974) analyzed eight varieties of mango where TSS ranged from 15.40% (Totapuri) to 21.40% (Bombay green). On the other hand, Palaniswamy *et al.* (1974) observed 11.8-26.8% TSS in South Indian mango cultivars. Prasad (1977) found the maximum total soluble solids (21.5%) in Alphanso and minimum (16.41) in Banglora when he evaluated South Indian mango varieties in Northern India.

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.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Experimental site

The present investigation was carried out in the laboratories of the Plant Physiology Section of the Horticulture Research Centre (HRC) under the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from 10 June to 30 July, 2006. The Plant Physiology Laboratory room was used to keep mango for ripening conditions. The Laboratory of the Postharvest Section was used for chemical analysis of mango at different stages.

3.2 Physical condition of the storage room

The temperature and relative humidity of the storage rooms were recorded daily with a digital temperature, humidity meter. The maximum temperature of the storage room was 32^0 C and relative humidity 86%. Detailed of the diurnal temperature and humidity of storage room has been furnished in appendix I.

3.3 Materials used in the experiment

The materials used for the study were freshly harvested mangoes of the variety Langra. The mango fruits were collected from the HRC field. Mango fruits were harvested in the morning hours immediately transferred to the physiology laboratory of HRC carefully. Fruits were soaked in two types of solution i. e. solution in normal water and hot water and four levels of ethrel solution. Mangoes were soaked in both solutions for 10 minutes.

3.4 Treatments and Experimental Design

The experiment consisted of two factors as follows:

Factor A: Two levels of treatment

1. M_1= Normal water (4^0C)
2. M_2= Hot water (55^0C)

Factor B: Four levels of ethrel concentrations

1. T_0 – Control
2. T_1 - 500 ppm ethrel
3. T_2 – 1000 ppm ethrel
4. T_3 – 1500 ppm ethrel

Thus, there were (2 x 4 = 8) treatment combinations. The combinations were as follows:

M_1T_0: Normal water + Control

M_1T_1: Normal water + 500 ppm ethrel

M_1T_2: Normal water + 1000 ppm ethrel

M_1T_3: Normal water + 1500 ppm ethrel

M_2T_0: Hot water + Control

M_2T_1: Hot water + 500 ppm ethrel

M_2T_2: Hot water + 1000 ppm ethrel

M_2T_3: Hot water + 1500 ppm ethrel

The two-factor experiment was conducted in a Completely Randomized Design (CRD) with three replications. Sixteen uniform sized mango fruits were kept in each replication.

3.5 Details of the experimental factors

3.5.1 Maturity stage

The mangoes used in the experiment were harvested at matured stage. The fruits were seen to start developing color within few days.

3.5.2 Preparation of ethrel solution

'Ripen-15' was the trade name of ethrel source which is marketed by National Agro Care Pvt. Ltd. Ripen-15 had the ethrel concentration of 39%. So, to prepare 500 ppm ethrel solution, 1.3 ml of Ripen -15 was added to 1 liter of distilled water. As such for the preparation of 1000 ppm ethrel concentrations,

2.6 ml of Ripen-15 was added to 1 liter of distilled water that is for the preparation of 1500 ppm ethrel concentration, 3.9 ml of Ripen-15 was added to 1 liter distilled water respectively. After preparing the solution the mangoes were dipped in different concentrations of ethrel solution for 10 minutes.

3.6 Collection of data

To assess the effect of types of solution with different ethrel concentrations on ripening process that is the physio-chemical changes of mango fruits during storage, the data on different physical and chemical parameters were collected at 2 days interval during the storage period. The shelf life, color development, weight loss or gain (%), rottening (%) were studied during the entire storage period. All the chemical characteristics were studied only up to 8^{th} days of storage of fruits while shelf life of mango was recorded until 12 days of storage.

3.7 Parameters studied

3.7.1 Changes in physical characteristics of mango fruit

i. Color development of fruits that is ripening of fruits
ii. Percent weight loss
iii. Percent rottening
iv. Shelf life of mango

3.7.2 Changes in chemical characteristics of mango fruit

i. Percent moisture content
ii. Ascorbic acid content of mango pulp
iii. P^H of mango juice
iv. Titrable acidity of mango pulp
v. Reducing sugar content of mango pulp
vi. Non-reducing sugar content of mango pulp
vii. Total sugar content of mango pulp
viii. Total soluble solid (TSS) content of mango pulp

3.8 Method of studying different parameters

3.8.1 Color development and ripening of fruit

The peel color of fruit was recorded by matching with a standard color chart (IPGRI, 1992). Development of various spots on the peel of fruits and softening and rotting of fruits were also recorded.

3.8.2 Percent weight loss

The weight loss of mango fruit sample was calculated by using the following formula:

$$\% \text{ Weight loss of fruit} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100$$

The weight losses of the sample were recorded periodically during the storage period.

3.8.3 Percent rottening

The rottening of mango fruit was calculated by using the following formula:

$$\% \text{ Rottening of fruit} = \frac{\text{No. of rotted fruit}}{\text{Total No. of fruit}} \times 100$$

3.8.4 Shelf life of mango

The shelf life was calculated by counting the days required to attain the last stage of ripening, but up to the stage when fruits remained still acceptable for marketing.

3.8.5 Percent moisture content

Five gram of the pulp was taken in porcelain crucibles for five times and oven-dried at 80^0 C until the weight becomes constant. Percent moisture content was calculated according to the following formula:

$$\% \text{ Moisture content} = \frac{I - F}{I} x100$$

Where,

I= Initial weight of pulp

F= Final weight of oven dried pulp

3.8.6 Ascorbic acid content of mango pulp

Ascorbic acid in mango pulp was estimated by 2.6–dichlorophenol indophenol's visual titration method as described by Rangana (1979). The reagents used for the estimation of ascorbic acid were as follows:

i. Metaphosphoric acid (6%)
ii. Standard ascorbic acid solution
iii. 2-6 dichlorophenol indophenols' dye.

For estimation of ascorbic acid, the following steps were followed:

a) ***Standardization of dye solution:*** Five millimeter standard ascorbic acid solution was taken in a conical flask and 5 ml metaphosphoric acid ($HP0_3$) was added to it and shaken. A micro burette was filled with dye solution. Then the mixed solution was titrated with dye using phenolphthalein indicator solution to a pink color end point that persisted at least for 15 seconds. Dye factor was calculated using the following formula.

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

b) ***Preparation of solution*** : Ten gram of fresh mango pulp was taken in a blender machine and homogenized with 6% metaphosphoric acid and then the blender material was filtrated and transferred to a 100 ml volumetric flask and the volume was made up to the mark with 6% metaphosphoric acid.

c) ***Titration:*** Five millimeter of metaphosphoric acid extracted sample was taken in an aliquot and titrated with standard dye solution, using phenolphthalein indicator to a pink colored end point that persisted at

least 15 seconds. The filtration was replicated thrice for each fruit. Ascorbic acid content was calculated by using the following formula.

$$\text{Ascorbic acid content (mg/100 g of fruit pulp)} = \frac{T \times D \times V1}{V2 \times W} \times 100$$

Where,

T = titrate

D = Dye factor

V_1 = Volume made up

V_2 = Volume of extract taken for estimation and

W = Weight of sample taken for estimation

3.8.7 P^H of mango juice

The pH of the sample was determined by the method described by Rangana (1979). One gram of sample was homogenized in 1 ml of boiled distilled water and 1 ml of de-ionized water of pH 7.0 and the pH of mango juice was recorded by an electric pH meter. The pH meter was standardized with the help of buffer solution.

3.8.8 Titrable acidity of mango pulp

Ten gram pulp was taken in a blender machine and homogenized with distilled water. The blender material was then filtered and transferred to a 100 ml volumetric flask and the volume was made up to the mark with distilled water and titrated with 0.1 N Na0H just below the end point using phenolphthalein indicator. The titration was done for three times. Percentage of titrable acidity was calculated using the following formula:

$$\% \text{ total titrable acidity content of mango pulp} = \frac{T \times N \times E \times V1}{W \times V2 \times 1000} \times 100$$

Where,

T = Titrate

N = Normality of Na0H

V_1 = Volume made up

V_2 = Volume of sample taken for estimation

E = Equivalent weight of acid

W = Weight of sample

3.8.9 Sugar content of mango pulp

Sugar content was estimated by determining the volume of unknown sugar solution of mango pulp required for complete reduction of standard Fehling's solution. The following procedure was followed in determining sugar content.

a. Standardization of Fehling's solution

Ten ml of both Fehling's solution A and Fehling solution B was mixed together in a beaker. Ten ml of mixed solution was pipetted into a 250 ml conical flask and 25 ml distilled water was added to it. Standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, three drops of methylene indicator solution was added to it without removing the flask. Mixed solution was titrated by standard sugar solution. The end point was indicated by decolonization of the indicator Fehling's factor was calculated by using the following formula:

$$\text{Fehling's Factor (gm of invert sugar)} = \frac{Titrate \times 2.5}{1000}$$

b. Preparation of sample

Twenty gram of fresh mango fruit pulp was taken in a blender machine that was homogenized with distilled water. Then the blender material was transferred to a 250 ml volumetric flask. The volume was made up to the mark with distilled water. The pulp solution was filtered. Hundred ml of filtrate was taken in 250 ml volumetric flask. Five ml of 45% neutral lead acetate solution was added to it and then shaken and waited for 10 minutes. Five ml of 22% potassium oxalate solution was further added to the flask that is volume was made up to the mark.

c. Titration of reducing sugar

Carbohydrates with a free aldehyde (CHO) on a free ketone group and their hemiacetal or hemiketal form are refereed to as reducing sugar. Ten ml of mixed Fehling's solution was taken in a 250 ml conical flask that is 50 ml distilled water was added to it. Purified pulp solution (filtrate) was taken in a burette. Conical flask containing the mixed Fehling's solution was heated on a hot plate. Three to five drops of methylene blue indicator were added to the flask when boiling started and titrated with solution taken in the burette. The end point was indicated by decolorization of indicator. Percentage of reducing sugar was calculated according to the following formula:

$$\% \text{ reducing sugar content of mango fruit pulp} = \frac{F \times D \times 100}{T \times W \times 1000}$$

Where,

F = Fehling's factor T = Titrate

D = Dilution W = Weight of sample

d. Titration of total invert sugar

Fifty ml of purified solution (filtrate) was taken in 250 ml conical flask. Five gm citric acid and 50 ml distilled water were added to it. The conical flask containing sugar solution was boiled and finally cooled. Then the solution was transferred to a 250 ml volumetric flask that is neutralized by 0.1 N NaOH using phenolphthalein as indicator. The volume was made up to the mark with distilled water. Then the mixed Fehling's was titrated using similar procedure followed as in case of invert reducing sugar mentioned earlier. The percentage of total invert sugar was calculated by using the formula used in case of reducing sugar.

e. Estimation of non-reducing sugar

Carbohydrates with aldehyde or ketone group are not free and they are in acetyl or ketal form is referred to as non-reducing sugar. It is estimated by

% Non-reducing sugar = % total invert sugar -% reducing sugar.

f. Estimation of total sugar

% Total sugar =% reducing sugar + % non-reducing sugar.

3.8.10 Total Soluble Solid content of mango pulp

The total soluble solid (TSS) content of mango fruit pulp was determined by using an refractometer by placing a drop of pulp solution on its prism. The percentage of TSS was obtained from direct reading of the refractometer. Temperature correction was made by using methods described by Rangana (1979).

3.9 Statistical analysis

The data obtained for physio-chemical characteristics of mango were statistically analyzed to find out the significance of the difference among the treatments. The analysis was performed by F-test that is the significance of the difference between pairs of treatment means were evaluated by LSD at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

In this chapter, experimental results pertaining of the effect of ethrel and types of solutions and their combinations on ripening and quality of mango have been presented along with discussion.

4.1 Changes in physical characteristics of mango fruit

4.1.1 Color development and ripening of fruits

Types of solution had significant effect on color development and ripening of mango. Hot water treatment enhanced ripening of mango than the normal water treated mangoes. It was found that normal water treated mango required 3.6 days to complete ripening of all the fruits and attain yellow color and hot water treated mango required 2.33 days for ripening (Fig. 1).Deming *et al.* (2002) also found that hot water treated mango attained good color.

Ethrel also had significant effect on ripening of mangoes. It was observed that increase in ethrel concentration enhanced the ripening period. Among the ethrel concentrations control (0 ppm ethrel) treatment required maximum (5 days) days to ripening and 1500 ppm ethrel concentration influenced quick ripening (1.6 days) (Figure 2).

Murray and Hartz (2001) also 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. Ethrel treated fruits were more uniform in ripening than the fruits under control (Madhavi *et al.*, 2005; Suryananayana and Goud 1984; Ingle *et al.*, 1982).

There was highly significant variation due to the combined effect of types of solution and ethrel concentrations in respect of ripening of mangoes (Appendix-II). Among the combinations, hot water with 1500 ppm ethrel

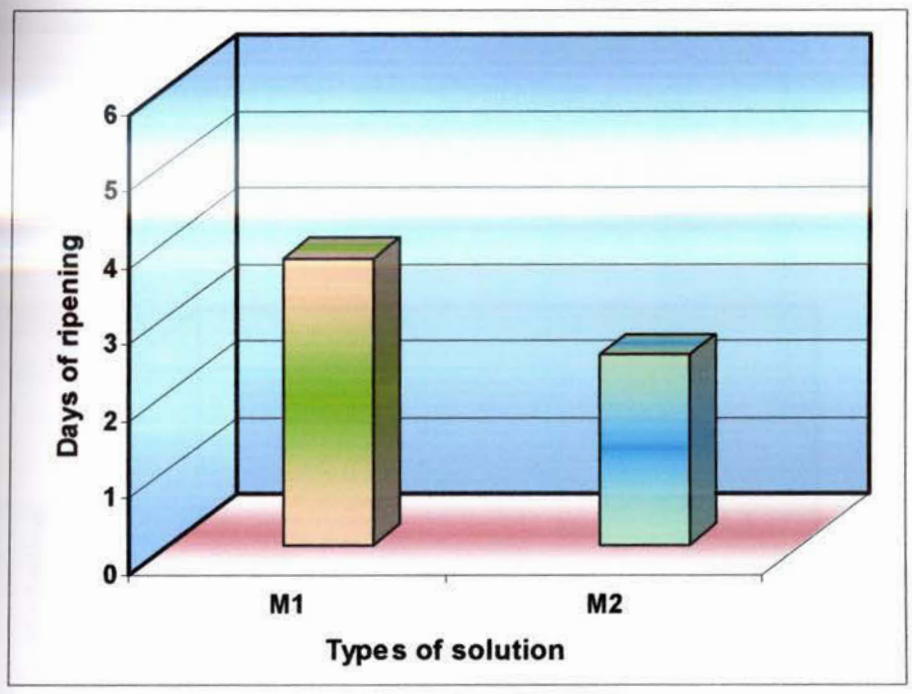


Figure 1. Color development of mango as influenced by types of solution (LSD at 5% = 0.30)

M_1=Normal water M_2=Hot water

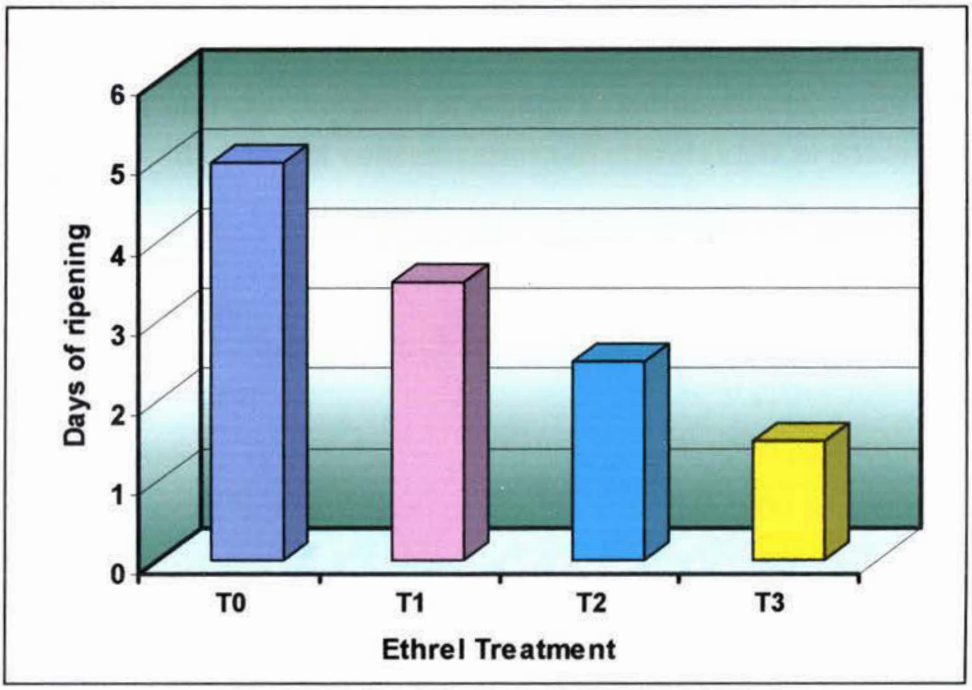


Figure 2. Color development of mango as influenced by different concentrations of ethrel (LSD at 5% = 0.43)

T_0=0 ppm ethrel, T_1=500 ppm ethrel, T_2=1000 ppm ethrel, T_3=1500 ppm ethrel

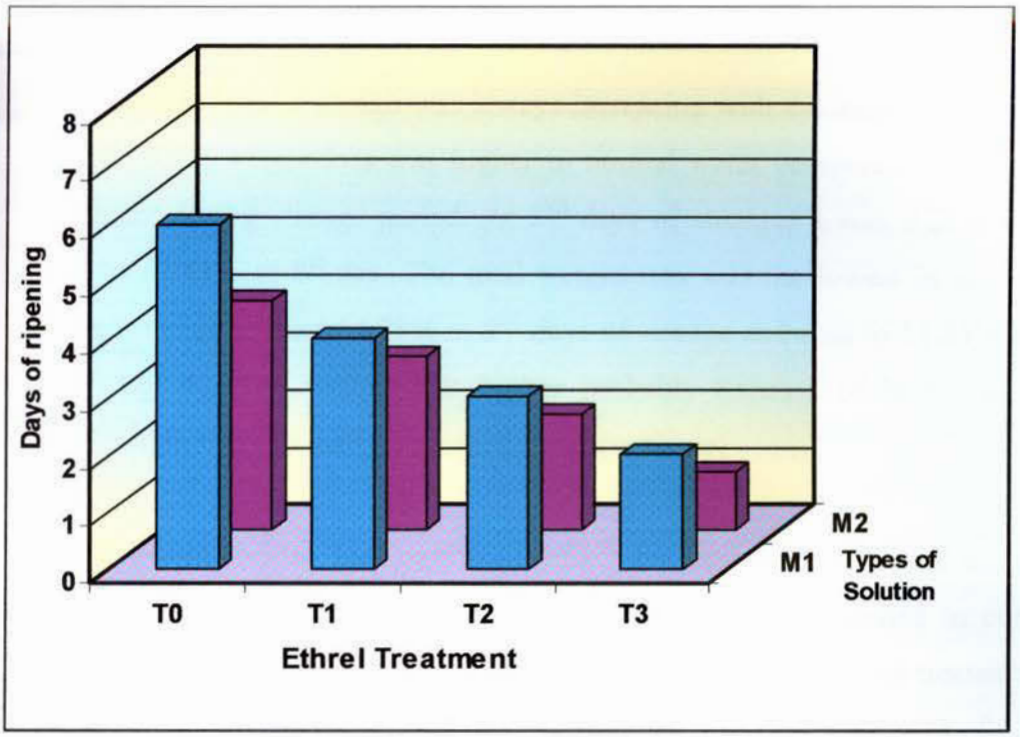


Figure 3. Color development of mango as influenced by types of solution and different concentrations of ethrel (LSD at 5% = 0.60)

Types of solution

M_1=Normal water

M_2=Hot water

Concentrations of ethrel

T_0=0 ppm ethrel

T_1=500 ppm ethrel

T_2=1000 ppm ethrel

T_3=1500 ppm ethrel

concentrations enhanced the ripening period than the normal water with ethrel treatments. The maximum ripening period (6 days) was required in normal water with 0 ppm ethrel treatment. The lowest ripening period (1 day) was required in hot water with 1500 ppm ethrel treatment (Fig. 3).

4.1.2 Percent weight loss

Total weight loss of mango was always increasing with the increase of storage period. Total weight loss was higher in normal water compared to hot water treatment during storage period. At 2^{nd} days of storage, it was 5.21% which rose to 12.41% at 8^{th} day. The total weight loss was the lowest in hot water treated mangoes, being 4.78% at 2^{nd} days of storage and rose to 11.35% at 8^{th} day (Fig. 4). The weight was higher probably because of higher rate of dehydration that gradually happened in tender tissue.

Ethrel treatment also had significant effect on total weight loss of mangoes during storage. The highest weight loss (12.37%) was recorded in control treatment (0 ppm), while it was the lowest (11.54%) in mangoes treated with 1500 ppm ethrel treated mango at the 8^{th} day of storage. Irrespective of ethrel concentration, the weight loss was found to be gradually increased with the advancing storage duration (Fig.5). Saidur Rahman (2005) also found that control treatment gave the highest weight loss and 1000 ppm ethrel treatment gave the lowest weight loss of tomato.

There was a significant variation among the treatments which resulted from the combination of types of solution and ethrel treatment in respect of weight loss of mangoes except 6^{th} days of storage (Appendix-III). Among the treatments normal water along with 0 ppm ethrel treatment showed maximum (12.83%)

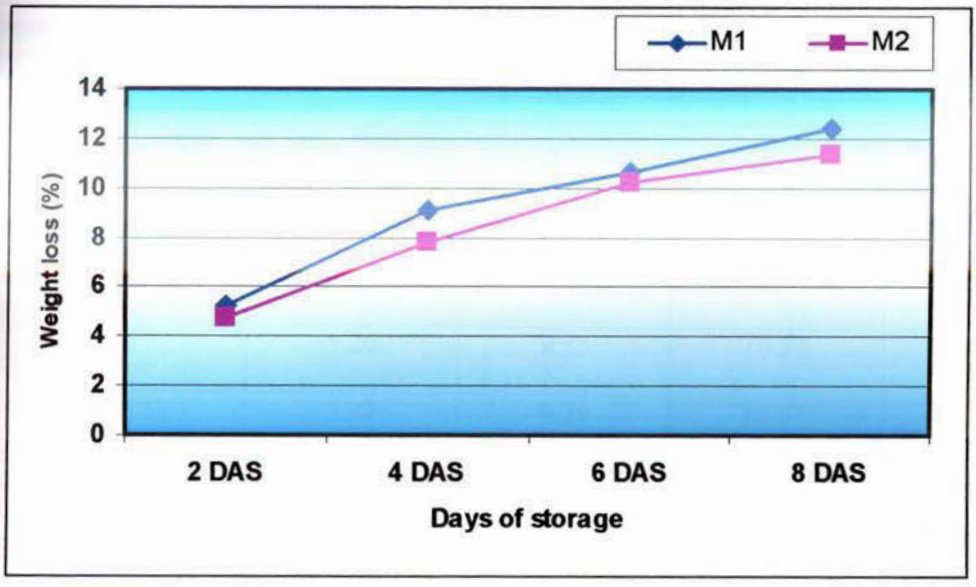


Figure 4. Weight loss (%) of mango at different days of storage shown by types of solution [LSD at 5% = 0.09 (2 days), 0.11 (4 days), 0.06 (6 days), 0.05 (8 days)]

M_1=Normal water M_2=Hot water

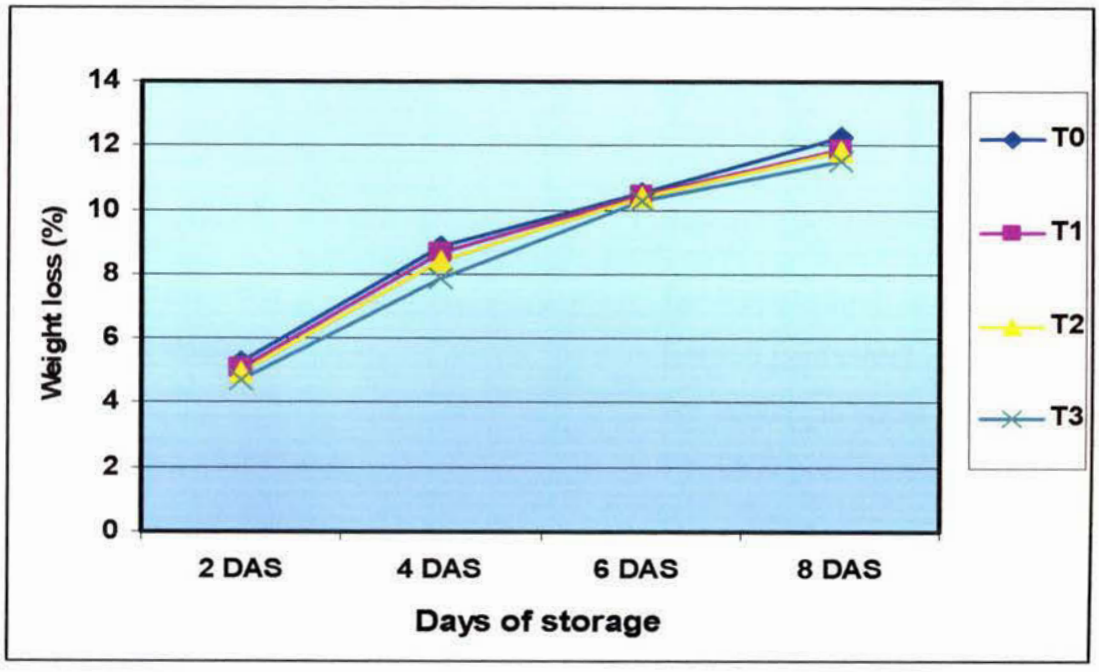


Figure 5. Weight loss (%) of mango at different days of storage shown by different ethrel concentrations [LSD at 5% = 0.13 (2 days), 0.15 (4 ays), 0.09 (6 days), 0.06 (8 days)]

T_0=0 ppm ethrel, T_1=500 ppm ethrel, T_2=1000 ppm ethrel, T_3=1500 ppm ethrel

Table 1. Combined effect of types of solution and ethrel on the percent weight loss of mangoes

Treatment	Percent weight loss			
	2DAS	4DAS	6DAS	8DAS
M_1T_0	5.63	9.57	10.74	12.83
M_1T_1	5.26	9.33	10.73	12.62
M_1T_2	5.22	9.29	10.55	12.48
M_1T_3	4.76	8.29	10.46	11.73
M_2T_0	4.89	8.20	10.36	11.91
M_2T_1	4.85	8.06	10.25	11.74
M_2T_2	4.72	7.49	10.20	11.31
M_2T_3	4.66	7.42	10.11	10.46
LSD at 5%	0.19	0.22	-	0.09
CV%	2.25	3.54	4.74	4.43

Types of solution

M_1= Normal water

M_2= Hot water

DAS=Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

weight loss and the lowest (10.46%) was found in hot water with 1500 ppm ethrel treatment at the 8th days of storage (Table 1). Weight loss was gradually increased with the advancement of ripening. Syamal (1981) reported that the greatest and least weight loss after 12 days of storage occurred in Maglobe and Pusha Rubi @ 15.8 and 14.07% respectively.

4.1.3 Percent rottening of mango fruit

In case of normal water 14.56% rottening occurred at the 4th days after storage which increased up to 74.02% at the 8th days after storage but in case of hot water treatment, 11.43% rottening was noted at the 4th days after storage which increased up to 49.48% at the 8th days after storage.

Ethrel treatment also had significant effect on rottening percent of mangoes. It was found that 1000 ppm gave the lowest rottening percent and it varied from 6.23% to 49.91% at different days after storage. The highest rottening percent was found in 1500 ppm ethrel treatment and it varied from 22.86% to 74.85% at different days after storage. Nair and Singh (2003) also reported that fruit quality was improved with ethrel treatment and reduced rottening. Kumar and Singh (1993) 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.

The combined effect of types of solution and ethrel treatment had significant effect in case of rottening percent of mangoes. Considering the combined effect of types of solution with ethrel concentrations, the maximum rottening percent was found in normal water with 1500 ppm ethrel treatment and it varied from

Table 2. Main effect of types of solution on percent rottening of mango

Treatment	Percent rottening		
	4DAS	6DAS	8DAS
M_1	14.56	44.49	74.02
M_2	11.43	27.86	49.48
LSD at 5%	0.42	0.09	1.82
CV%	3.73	3.49	3.42

Table 3. Main effect of ethrel on the percent rottening of mango

Treatment	Percent rottening		
	4DAS	**6DAS**	**8DAS**
T_0	14.55	37.42	64.87
T_1	8.32	34.93	57.38
T_2	6.23	24.95	49.91
T_3	22.86	47.40	74.85
LSD at 5%	0.59	0.54	2.58
CV%	3.73	3.49	3.42

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

Table 4. Combined effect of types of solution and ethrel on the percent rottening of mango

Treatment	Percent rottening		
	4DAS	6DAS	8DAS
M_1T_0	16.63	49.90	79.84
M_1T_1	8.34	44.91	69.86
M_1T_2	8.34	33.27	66.54
M_1T_3	24.95	49.90	79.84
M_2T_0	12.47	24.95	49.90
M_2T_1	8.34	24.95	44.91
M_2T_2	6.25	16.63	33.27
M_2T_3	20.78	44.91	69.86
LSD at 5%	0.83	2.18	3.65
CV%	3.73	3.49	3.42

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

24.95% to 79.84% at different days after storage. The minimum rottening percent was found in hot water with 1000 ppm ethrel treatment, which varied from 6.25% to 33.27% at different days after storage.

4.1.4 Shelf life of mango

Types of solution significantly affected the shelf life of mango. It was recorded that hot water treated mango had a higher storability than normal water treatments. The maximum shelf life (11.6 days) was recorded in hot water treated mango and minimum shelf life (10.3 days) was found in normal water treated mangoes (Fig. 6).

Ethrel treatments also had significant effect on shelf life of mango. The highest shelf life (13 days) was recorded in 1000 ppm ethrel treatment and the lowest shelf life was (9.6 days) recoded in control treatment (Fig. 7). Saidur Rahman (2005) also found that 1000 ppm ethrel treatment gave the highest shelf life of tomato than the control treatment.

The combined effects of types of solution and ethrel treatments in respect of shelf life were significant at different days of storage. The highest shelf life (14 days) was observed in hot water treated mangoes with 1000 ppm ethrel treatment and the lowest shelf life (9 days) was found in normal water treated mangoes with 0 ppm ethrel (Fig.8)

Hossain *et al.* (1996) also reported that mature green tomato treated with 1000 ppm ethrel treatment gave the longer shelf life.

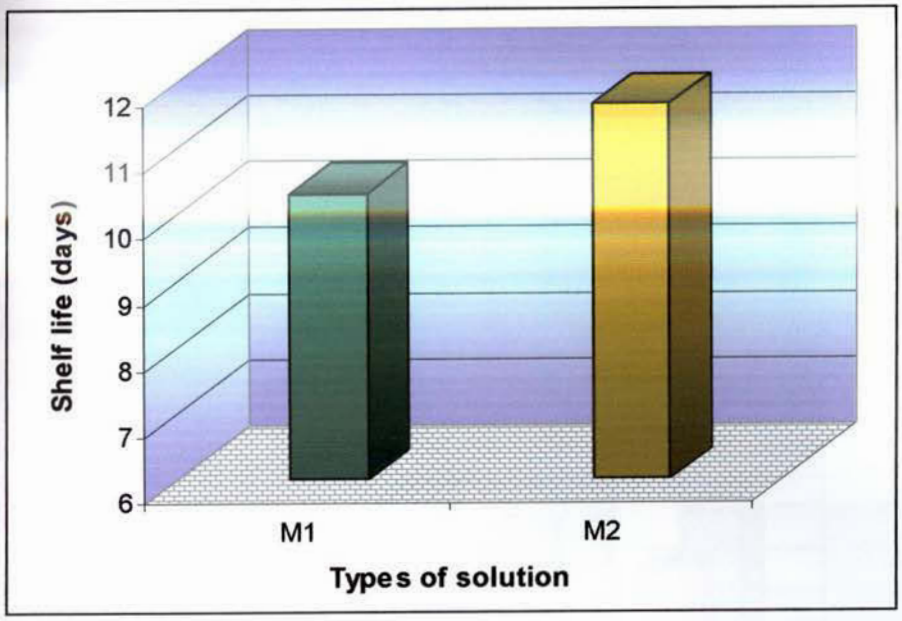


Figure 6. Shelf life of mango as influenced by types of solution (LSD at 5% = 0.24)

M_1=Normal water M_2=Hot water

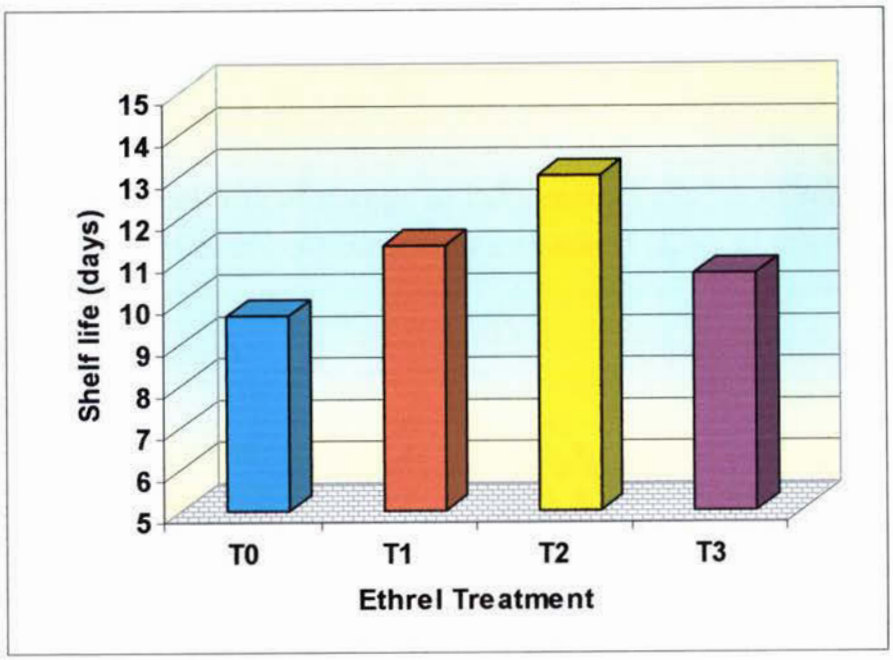


Figure 7. Shelf life of mango as influenced by different ethrel Concentrations (LSD at 5% = 0.34)

T_0=0 ppm ethrel, T_1=500 ppm ethrel, T_2=1000 ppm ethrel, T_3=1500 ppm ethrel

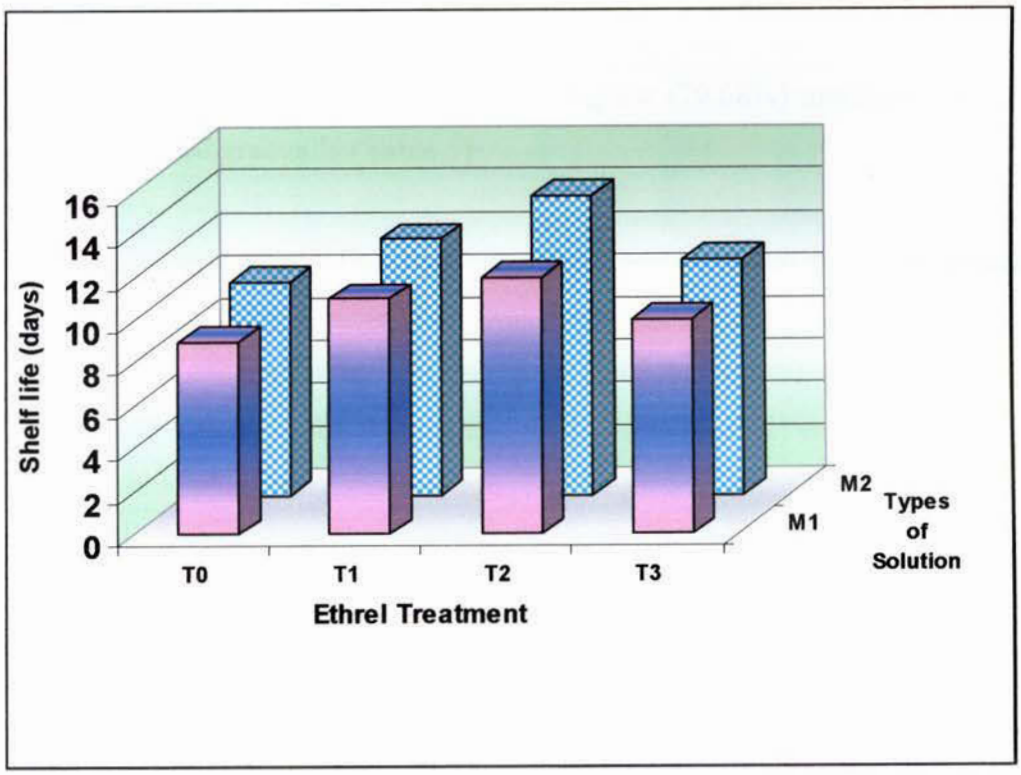


Figure 8. Shelf life of mango as influenced by types of solution and different concentrations of ethrel (LSD at 5% = 0.48)

Types of solution

M_1=Normal water

M_2=Hot water

DAS=Days after storage

Concentrations of ethrel

T_0=0 ppm ethrel

T_1=500 ppm ethrel

T_2=1000 ppm ethrel

T_3=1500 ppm ethrel

4.2 Changes in chemical characteristics of mango fruit

4.2.1 Moisture content of mango pulp

Types of solution had no significant effect on moisture content of mango pulp during storage. Among the treatments normal water treatment was observed to provide maximum moisture content compared to hot water treatment and it was the highest (80.69%) in normal water at 2 days and then declined. In case of hot water treatment at 2 days gave the highest (79.68%) moisture content and then declined gradually (Table 5)

Ethrel concentrations also had non-significant effect on moisture content of mango pulp during storage and it was decreased with increasing the time along with ethrel concentration. The maximum (80.84%) moisture content was found at 2 days with control treatment and the lowest (70.65%) was found at 8^{th} days with 1500 ppm ethrel concentration (Table 6).

Combined effect between types of solution and ethrel concentration was not significant. Among the treatment combinations normal water with ethrel concentration gave maximum moisture content compared to hot water with ethrel concentration which gradually declined.

In case of normal water along with 0 ppm (control) ethrel at 2 days gave the highest (81.46%) moisture content and the lowest (70.97%) was found at 8^{th} days with 1500 ppm ethrel concentration. On the other hand, hot water with 0 ppm (control) ethrel gave the highest (80.12%) moisture content at 2 days and the lowest (70.32%) was found at 8^{th} days of storage with 1500 ppm of ethrel concentration (Table 7).

These results are in partial agreement with the findings of Joshi and Roy (1988). Srivastava (1967) stated that the green unripe mango contained higher percentage of moisture as compared to ripe mango.

Table 5. Main effect of types of solution on moisture content of mango during storage

Treatment	Percent moisture content			
	2DAS	4DAS	6DAS	8DAS
M_1	80.69	78.40	74.65	71.69
M_2	79.68	77.74	73.35	70.96
LSD at 5%	-	-	-	-
CV%	4.45	3.31	3.31	3.31

Table 6. Main effect of ethrel on percent moisture content of mango during storage

Treatment	Percent moisture content			
	2DAS	4DAS	6DAS	8DAS
T_0	80.74	78.54	74.44	71.95
T_1	80.34	78.31	74.23	71.49
T_2	79.92	77.96	73.76	71.22
T_3	79.74	77.46	73.56	70.65
LSD at 5%	-	-	-	-
CV%	4.45	3.31	3.31	3.31

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

Table 7. Combined effect of types of solution and ethrel on the percent moisture content of mango during storage

Treatment	Percent moisture content			
	2DAS	2DAS	2DAS	2DAS
M_1T_0	81.46	78.84	75.04	72.26
M_1T_1	80.56	78.61	74.74	71.90
M_1T_2	80.36	78.19	74.54	71.62
M_1T_3	80.36	77.97	74.28	70.97
M_2T_0	80.12	78.24	73.85	71.63
M_2T_1	80.02	78.02	73.73	71.08
M_2T_2	79.47	77.73	72.98	70.82
M_2T_3	79.11	78.96	72.85	70.32
LSD at 5%	-	-	-	-
CV%	4.45	3.31	3.31	3.31

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

Bhatnagar and Subramanyan (1973) reported 90% moisture content in green unripe mango whereas pulp ripe mango contained 81% moisture.

The decrease in percent moisture content was probably due to transpiration and starch hydrolysis. Total decrease from this process was probably more than the increase in water due to osmotic withdrawal from peel to pulp and complete break down of starch to CO_2 and net moisture decrease was reflected in increased moisture content.

4.2.2Ascorbic acid content of mango pulp

Ascorbic acid content of mango pulp varied significantly in fruits at different solution except 4th days of storage. Irrespective of treatments there was a continuous decrease in ascorbic acid content of mango fruits with the progress of ripening period. Results showed that ascorbic acid content was decreased with the advancement of ripening of mango fruits (Table 8). It was observed that normal water treated mango had higher quantity of ascorbic acid (47.47, 45.09, 21.37 and 15.06 mg/100g-mango pulp) than hot water treated mango (46.04, 45.00, 19.33 and 11.01 mg/100g-mango pulp) at 2nd 4th 6th and 8th days of storage.

The ascorbic acid content of mango pulp also varied significantly due to different ethrel concentrations at different days of storage (Table 9). However, it was found to decrease in all storage conditions with the advancement of ripening process. The maximum ascorbic acid content were found (47.27, 45.78, 21.74 and 13.04 mg/100g-mango pulp) at 2nd 4th 6th and 8th days of storage in 0 ppm ethrel treated fruits while the minimum ascorbic acid (46.14, 44.85, 19.61 and 12.14 mg/100g-mango pulp) was recoded in 1500 ppm ethrel treated fruits. Ascorbic acid content was decreased with the increasing concentration of ethrel (Madhavi *et al.*, 2005)

Table 8. Main effect of types of solution on the ascorbic acid and P^H of mango at different days of storage

Treatment	Ascorbic acid (mg/100g)				P^H			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
M_1	47.47	45.09	21.37	15.06	4.24	4.38	4.75	5.41
M_2	46.04	45.00	19.33	11.01	4.32	4.49	4.87	5.56
LSD at 5%	0.02	-	0.16	0.38	0.04	0.03	0.02	0.02
CV%	4.08	4.24	3.96	3.37	3.05	4.01	4.38	4.15

Table 9. Main effect of ethrel treatment on the ascorbic acid and P^H of mango at different days of storage

Treatment	Ascorbic acid (mg/100g)				P^H			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
T_0	47.27	45.78	21.14	13.04	4.25	4.31	4.66	5.28
T_1	46.85	44.93	20.69	12.62	4.26	4.42	4.83	5.36
T_2	46.77	44.62	19.96	12.36	4.33	4.55	4.96	5.69
T_3	46.14	44.85	19.61	12.14	4.29	4.45	4.80	5.61
LSD at 5%	0.03	0.13	0.23	0.53	0.05	0.05	0.03	0.04
CV%	4.08	4.24	3.96	3.37	3.05	4.01	4.38	4.15

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

The combined effect of types of solution and different ethrel concentrations in respect of ascorbic acid were significant at different days of storage (Appendix-VII). The highest ascorbic acid (48.13, 46.11, 22.09 and 18.16 mg/100g-mango pulp) was recorded in normal water treatment with 0 ppm ethrel concentration. On the other hand, the lowest ascorbic acid (45.57, 44.64, 18.37 and 10.51 mg/100g-mango pulp) was observed in hot water treated mango with 1500 ppm (control) ethrel treatment combination at 2^{nd}, 4^{th}, 6^{th} and 8^{th} days of storage (Table 10).

The decrease in ascorbic acid may be attributed to the enhanced activity of oxidative enzymes which may oxidize the ascorbic acid causing reduction. Decreased ascorbic acid content of ethrel treated fruits may be due to acceleration of ripening under the influence of ethylene. Madhava Rao *et al.* (1971), Ingle *et al.* (1982) also reported similar decrease in ascorbic acid of fruits.

4.2.3 P^H content of mango pulp

Significant variation in pulp P^H was observed in types of solutions at different days of storage (Appendix-VIII). Result showed that it was increased with the advancement of ripening of fruits. An increasing trend of pulp P^H was observed in both solutions with duration of storage. The maximum P^H (4.32, 4.49, 4.87 and 5.56) was recorded in hot water treatment at 2^{nd}, 4^{th}, 6^{th} and8^{th} days of storage, while the values for normal water treated mango were 4.24, 4.38, 4.47 and 5.41 at same days of storage (Table 8). Higher P^H value was found in hot water treated mango (Deming et al., 2002).

The effect of growth regulator (ethrel) treatment on P^H showed significant variation at different days of storage (Appendix-VIII). 1000 ppm ethrel treated fruit showed comparatively higher P^H value (4.33, 4.55, 4.96 and 5.69) at 2^{nd}, 4^{th}, 6^{th} and 8^{th} days of storage. On the other hand, lower P^H values (4.25, 4.31, 4.66 and 5.28) were recoded in control (0 ppm ethrel) at 2^{nd}, 4^{th}, 6^{th} and 8^{th} days of storage (Table 9).

Table 10. Combined effect of types of solution and ethrel treatment on the ascorbic acid and P^H of mango at different days of storage

Treatment	Ascorbic acid (mg/100g)				P^H			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
M_1T_0	48.13	46.11	22.09	18.16	4.25	4.24	4.64	5.17
M_1T_1	47.83	45.23	21.78	14.37	4.24	4.42	4.73	5.27
M_1T_2	47.53	44.69	21.56	13.97	4.27	4.46	4.89	5.61
M_1T_3	46.40	44.34	20.06	13.77	4.23	4.41	4.77	5.59
M_2T_0	46.71	45.45	20.19	11.93	4.26	4.38	4.68	5.39
M_2T_1	46.02	45.02	19.76	10.88	4.28	4.43	4.93	5.45
M_2T_2	45.88	44.91	19.61	10.76	4.39	4.65	5.04	5.77
M_2T_3	45.57	44.64	18.37	10.51	4.36	4.49	4.83	5.64
LSD at 5%	0.05	0.18	0.33	0.76	-	0.07	0.05	0.05
CV%	4.08	4.24	3.96	3.37	3.05	4.01	4.38	4.15

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

The combined effects of types of solution and ethrel concentrations were also found significant (Appendix VIII). The highest P^H content (5.77) was recorded in hot water treated mango with 1000 ppm ethrel at 8th day of storage while it was the lowest (5.17) in normal water treatment at 8th day of storage.

The increase of pulp P^H may be due to continuous decrease in acidity during ripening. In present investigation increase in P^H was recorded during storage and this result was an agreement with findings of Kumar and Singh (1993) who observed that pulp P^H of mango was increased for storage.

4.2.4 Percent titrable acidity content of mango pulp

There had a significant variation as regards the total acidity due to types of soluton (Appendix IX). Irrespictive of treatments there is a continuous decrease in acidity content of mango fruits with the progress of ripening (Table-11). Normal water treated mango pulp contained the highest quantity of total titrable acidity (0.19%) than hot water (0.13%) at 8th day of storage. Titrable acidity was decreased gradually with the progress of storage period.

Titrable acidity of mango fruits subjected to different ethrel treatments showed significant variation at different days of storage. The maximum titrable acidity 2.02%, 0.74%, 0.60% and 0.23% at 2nd, 4th, 6th and 8th days of storage in control (0 ppm ethrel) treatment while the minimum titrable acidity (1.29%, 0.45%, 0.31%and 0.10%) was noticed in 1000 ppm ethrel treated fruits (Appendix-IX).

Acidity decreased with the increasing concentration of ethrel. Decrease in acidity might be attributed to the convesion of acids into sugars and utilization of organic acids during respiration (Pool *et al.*, 1972). Decreased acidity content of ethrel treated fruits may be due to acceleration of ripening under the influence of ethylene (Madhava *et al.*, 1971; Ingle *et al.*, 1982 ;)

Table 11. Main effect of types of solution on the percent titrable acidity and percent reducing sugar of mango at different days of storage

Treatment	% Titrable acidity				% Reducing sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
M_1	1.76	0.66	0.50	0.19	2.46	3.24	4.54	5.68
M_2	1.38	0.52	0.36	0.13	2.58	3.44	4.73	5.80
LSD at %	0.04	0.02	0.02	0.02	0.09	0.09	0.03	0.03
CV%	3.44	3.45	5.01	5.92	4.24	4.87	4.22	4.28

Table 12. Main effect of ethrel on the percent titrable acidity and percent reducing sugar of mango at different days of storage

Treatment	% Titrable acidity				% Reducing sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
T_0	2.02	0.74	0.60	0.23	2.36	3.10	4.63	5.68
T_1	1.54	0.64	0.48	0.18	2.42	3.30	4.67	5.75
T_2	2.29	0.45	0.31	0.10	2.68	3.59	4.71	5.85
T_3	1.41	0.53	0.35	0.13	2.61	3.39	4.54	5.69
LSD at %	0.06	0.03	0.04	0.03	0.12	0.14	0.04	0.04
CV%	3.44	3.45	5.01	5.92	4.24	4.87	4.22	4.48

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

The combined effect of types of solution and growth regulation (ethrel) treatments in respect of titrable acidity was significant at different days of storage except 8th days (Appendix-IX). The highest titrable acidity (0.26%) was recorded at 8th days of storage in normal water treated mango with 0.ppm ethrel treatment. On the other hand, the lowest acidity (0.08%) was observed in hot water with 1000-ppm ethrel treatment combination at 8th day of storage (table 13).

4.2.5 Reducing sugar content of mango pulp

Significant variation between the types of solution was recorded in respect of reducing sugar content of the fruit pulp. Result showed that reducing sugar content was increased with the advancement of ripening of fruit up to 8th days of storage. Hot water treated mango contained the highest quantity of reducing sugar (5.80%) while the normal water treated mango contained the lowest quantity of reducing sugar at same days of storage (Table 11).

The ethrel involved in the investigation was found when highly significant variation in relation to reducing sugar content (Appendix X). The highest quantity (5.85%) of reducing sugar content was recorded under 1000 ppm ethrel treatment at 8th days of storage, while the control was found to show less value (5.68%) in this regard (Table 12) at same days of storage. Oosthuyse *et al.* (2000) also reported that ethrel treatment significantly increased reducing sugar in mango. Increase in reducing sugar can be attributed to enzymatic conversion of starch to reducing sugar (Islam, 1998).

The combined effect of types of solution and ethrel treatment significantly affected the reducing sugar content at 6th and 8th days of storage (Table 13). Hot water treated mango with 1000 ppm ethrel treatment gave the highest (5.96%) reducing sugar at 8th days of storage while it was minimum (5.64%) in normal water with 0 ppm ethrel at same days of storage. Increase in reducing sugar might be attributed to enzymatic conversion of starch to reducing sugar and also by conversion of some non-reducing sugar to reducing sugar.

Table 13. Combined effect of types of solution and ethrel treatment on the percent titrable acidity and percent reducing sugar of mango at different days of storage

Treatment	% Titrable acidity				% Reducing sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
M_1T_0	2.12	0.82	0.64	0.26	2.27	3.00	4.56	5.64
M_1T_1	1.84	0.75	0.58	0.22	2.32	3.17	4.59	5.71
M_1T_2	1.44	0.51	0.38	0.13	2.67	3.52	4.61	5.75
M_1T_3	1.62	0.58	0.42	0.16	2.59	3.29	4.43	5.65
M_2T_0	1.92	0.67	0.56	0.20	2.45	0.21	4.70	5.72
M_2T_1	1.24	0.53	0.39	0.15	0.52	3.42	4.75	5.80
M_2T_2	1.14	0.40	0.24	0.08	2.70	3.66	4.81	5.96
M_2T_3	1.20	0.48	0.28	0.10	2.64	3.49	4.66	5.73
LSD at 5%	0.09	0.05	0.05	-	-	-	0.05	0.05
CV%	3.44	3.45	5.01	5.92	4.24	4.87	4.22	4.28

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

4.2.6 Non-reducing sugar content of mango pulp

Non-reducing sugar was found to be significant in types of solution at 2nd and 4th days of storage. The highest non-reducing sugar was found in hot water treatment (15.99%) at 6th days of storage.

Ethrel treatment also significantly affected the non-reducing sugar content of mango pulp except 8th days of storage. However, mango treated with 1000 ppm ethrel recorded somewhat more quantity (16.34%) in the content of non-reducing sugar at 6th days of storage and the lowest (13.28%) at 8th days of storage in control treatment (Table 15).

The combined effect of types of solution and ethrel treatment were found significant on the change of non-reducing sugar content of mango pulp except 8th days of storage. The highest non-reducing sugar (16.93%) at 6th days of storage was found in hot water with 1000 ppm ethrel while it was the lowest (13.13%) in normal water with 0 ppm ethrel at 8th days of storage (Table 16). The non-reducing sugar increase at the initial stage may be due to breakdown of starch into non-reducing sugar and finally this non-reducing sugar was converted into reducing sugar.

4.2.7 Total sugar content of mango pulp

Total sugar content of mango pulp varied significantly at 2nd, 4th, 6th and 8th days of storage (Appendix XII). Results showed that total sugar content was increased with the advancement of ripening during storage. During 2nd day of storage, the total sugar contents were 16.08% and 16.81% which increased and reached 19.08% and 19.68 % at 8th day of storage in normal and hot water treatment respectively and then changed slowly after 6th days of storage (Table 14).

There was a significant variation as regards the sugar content due to the different concentration of ethrel. Total sugar content was 20.18% in 1000 ppm ethrel treated mango at 6th day of storage. At same day of storage, the minimum

Table 14. Main effect of types of solution on the Non-reducing sugar and Total sugar of mango at different days of storage

Treatment	% Non-reducing sugar				% Total sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
M_1	13.75	14.68	15.53	14.25	16.17	17.29	19.04	18.37
M_2	14.13	14.80	15.99	14.87	16.81	18.32	19.68	19.11
Lsd (%)	0.18	0.08	-	-	0.17	0.07	0.17	0.09
CV%	3.48	5.65	3.92	4.36	4.21	4.49	4.06	4.57

Table 15. Main effect of ethrel on the non-reducing sugar and total sugar of mango at different days of storage

Treatment	% Non-reducing sugar				% Total sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
T_0	13.44	14.63	15.08	13.28	15.73	17.25	18.29	17.64
T_1	13.72	14.64	15.61	13.35	16.19	17.42	19.26	18.61
T_2	14.40	14.91	16.34	13.86	17.14	18.40	20.18	19.47
T_3	14.22	14.79	16.01	13.76	16.90	18.15	19.70	19.25
Lsd (%)	0.25	0.12	0.75	-	0.24	0.11	0.25	0.12
CV%	3.48	5.65	3.92	4.36	4.21	4.49	4.06	4.57

Types of solution

M_1= Normal water

M_2= Hot water

DAS = Days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

Table 16. Combined effect of types of solution and ethrel treatment on the non-reducing sugar and total sugar of mango at different days of storage

Treatment	% Non-reducing sugar				% Total sugar			
	2DAS	4DAS	6DAS	8DAS	2DAS	4DAS	6DAS	8DAS
$M_1T_{0=}$	13.22	13.61	14.14	13.13	15.34	16.71	18.16	17.65
M_1T_1	13.24	13.68	14.58	13.34	15.60	16.71	18.80	18.16
M_1T_2	14.38	14.75	15.75	13.35	16.96	17.97	19.57	18.97
M_1T_3	14.18	14.69	15.65	13.19	16.78	17.79	19.37	18.71
M_2T_0	13.66	14.58	14.59	13.21	16.13	17.80	18.42	17.63
M_2T_1	14.20	14.68	15.08	14.58	16.77	18.13	19.73	19.06
M_2T_2	14.42	15.13	16.93	15.38	17.32	18.84	20.80	20.22
M_2T_3	14.26	14.83	16.37	14.34	17.02	18.51	20.04	19.53
LSD at 5%	0.36	0.16	1.07	-	0.34	0.15	0.35	0.18
CV%	3.38	5.65	3.92	4.36	4.21	4.49	4.06	4.57

Types of solution

M_1= Normal water

M_2= Hot water

DAS=days of storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

(18.29%) total sugar content was found in control (0 ppm ethrel) treatment. Total sugar content increased at 2nd and 4th day but decreased after 6th days (Table 15).

The increase in sugar of fruits could be attributed to the conversion of starch and other insoluble carbohydrates into soluble sugars. The sugar was utilized for respiration.

The total sugar content in fruit pulp was statistically significant due to combined effect of types of solution and different ethrel treatment at different days of storage (Appendix-XII). However, it was the highest (20.80%) in hot water treated mango with 1000 ppm ethrel treatment and the lowest (18.16%) in normal water treated mango with 0 ppm ethrel treatment at 8th days of storage (Table 16).

4.2.8 Total soluble solid content of mangoes

Total soluble solid is one of the most important quality factors for mangoes. In the present experiment, the TSS content of mango juice varied significantly in types of solution. Results showed that hot water treatment gave the highest TSS (22.10%) at 8th days of storage and the lowest TSS (14.55%) in normal treatment at 2nd days of storage. Total soluble solid increased gradually with the advancement of ripening process (Table 17). The highest TSS content in hot water treated mango fruits was obtained by Deming *et al.*, 2002.

Ethrel treatments were also found to have significant effects on TSS content of mango juice at 2nd, 4th, 6th and 8th days of storage (Table 18). The highest TSS content (21.36%) was recorded in 1000 ppm ethrel treatment while it was the lowest (20.49%) in control condition at 8th days of storage. Oosthyse *et al.* (2000) also reported that the ethrel treatment significantly increased total soluble solids. Ethrel treated fruits recorded higher value of TSS compared to

the control. Moreover, 1000 ppm maintained comparatively higher TSS. The effect of ethrel on TSS could be due to ethylene activity, the hydrolytic enzymes that brought about softening of fruit tissues and hydrolysis of starch to sugars (McGlasson, 1970).

The TSS content was also found to be significantly influenced by the combined effect of types of solution and ethrel treatment during whole period of ripening (Table 18). The TSS content was found to increase with the progress of the storage period. The highest quantity of TSS content (22.62%) at 8^{th} days at storage was recorded in hot water treated with 1000 ppm ethrel whereas; it was the minimum (19.64%) in normal water treated mango under control (0 ppm ethrel) treatment. The increase in TSS of fruit could be attributed to the conversion of starch and other insoluble carbohydrates into soluble sugar. The TSS was utilized for respiration.

Table 17. Main effect of types of solution on the percent total soluble solid of mango pulp at different days of storage

Treatment	Total soluble solids (%)			
	2DAS	4DAS	6DAS	8DAS
M_1	14.55	16.49	18.91	19.88
M_2	16.27	17.65	19.94	22.10
LSD at 5%	0.14	0.05	0.17	0.17
CV%	4.26	3.36	4.06	3.97

Table 18. Main effect of different concentrations of ethrel on percent total soluble solid of mango

Treatment	**Total soluble solids (%)**			
	2DAS	**4DAS**	**6DAS**	**8DAS**
T_0	13.63	15.78	18.95	20.49
T_1	15.30	17.14	19.41	21.07
T_2	16.65	17.84	19.81	21.36
T_3	16.07	17.52	19.53	21.03
LSD at 5%	0.20	0.08	0.25	0.25
CV%	4.26	3.36	4.06	3.97

Types of solution

M_1= Normal water

M_2= Hot water

DAS=days after storage

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

Table 19. Combined effect of types of solution and ethrel on the percent Total soluble solids of mango

Treatment	Total soluble solids (%)			
	2DAS	4DAS	6DAS	8DAS
M_1T_0	13.16	15.21	18.71	19.64
M_1T_1	14.56	16.40	18.92	19.83
M_1T_2	15.47	17.34	19.07	20.09
M_1T_3	15.03	17.02	18.96	19.96
M_2T_0	14.11	16.35	18.99	21.16
M_2T_1	16.04	17.89	20.12	22.50
M_2T_2	17.83	18.35	20.55	22.64
M_2T_3	17.12	18.02	20.10	22.10
LSD at 5%	0.28	0.10	0.35	0.35
CV%	4.26	3.36	4.06	3.97

Types of solution

M_1= Normal water

M_2= Hot water

Concentration of ethrel

T_0= 0 ppm ethrel

T_1= 500 ppm ethrel

T_2= 1000 ppm ethrel

T_3= 1500 ppm ethrel

DAS = Days after storage

Chapter 5

SUMMERY AND CONCLUSION

SUMMARY AND CONCLUSION

An experiment was carried out in the Laboratory of the Plant Physiology Section of Horticulture Research Centre (HRC) and Postharvest Laboratory under the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from June to July, 2006 to study the ripening and quality of mango fruits during storage as influenced by types of solution and ethrel. Types of solution viz. normal water, hot water and ethrel concentrations viz. control (0 ppm), 500 ppm, 1000 ppm and 1500 ppm ethrel were used in the experiment. Mature green mangoes (cv. Langra) were collected from the Horticulture Research Centre (HRC), Gazipur. The experiment was carried out in a Completely Randomized Design with three replications.

Various observations were made on the physical and chemical properties as well as shelf life. Mango pulp was taken for physio-chemical analysis to determine moisture content, ascorbic acid, titrable acidity, P^H, reducing sugar, non-reducing sugar, total sugar, and total soluble solids. One mango of each treatment from three replications was collected at 2, 4, 6 and 8 days of storage for physio-chemical analysis.

Types of solution showed significant variation on ripening and quality of mango studied except moisture content at all days and non-reducing sugar at 6^{th} days and 8^{th} days of storage. Considering the types of solution highest days of ripening (3.6 days), weight loss (12.41%) at 8^{th} days, rottening percent (74.02%) at 8^{th} days, moisture content (80.69%) at 2^{nd} days, titrable acidity (1.76%) at 2^{nd} days and highest ascorbic acid (47.47 mg/100 g) at 2^{nd} days were found in normal water treated mangoes and highest shelf life (11.6 days), P^H (5.56) at 8^{th} days, reducing sugar (5.80%) at 8^{th} days, non-reducing sugar (15.99%) at 6^{th} days, total sugar (19.68%) at 6^{th} days and total soluble solids (22.20%) at 8^{th} days were found in hot water treated mangoes. On the contrary, the lowest values in days to ripening (2.33 days), weight loss (4.78%) at 2^{nd}

days, rottening percent (11.43%) at 2nd days, moisture content (70.96%) at 8th days, ascorbic acid (11.01 mg/100 g) at 8th days and titrable acidity (0.19%) at 8th days were found in hot water treatment and lowest shelf life (10.3 days), P^H (4.21) at 2nd days, reducing sugar (2.46%) at 2nd, non-reducing sugar (13.75%) at 2nd days, total sugar (16.17%) at 2nd days and total soluble solids (14.55%) at 2nd were found in normal water treatment.

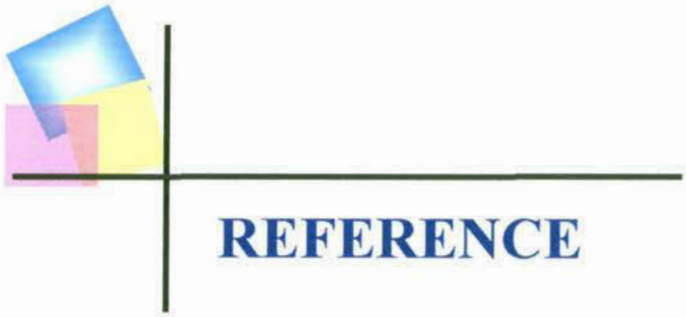
The ethrel treatments also showed significant influence on different parameters studied except moisture content at all days and non-reducing sugar at 8th days of storage. The highest shelf life (13 days), P^H (5.69) at 8th days, reducing sugar (5.85%) at 8th, non-reducing sugar (16.34%) at 6th days, total sugar (20.18%) at 6th days and total soluble solids (21.36%) at 8th days were recorded in 1000 ppm ethrel treatment and the highest rottening percent (49.91%) at 8th days was found in 1500 ppm ethrel treatment and the highest days to ripening (5day), weight loss (12.28%) at 8th days, moisture content (80.74%) at 2nd day, ascorbic acid (13.04 mg/100 g) at 8th days and titrable acidity (2.02%) at 2nd days were recorded in control treatment. On the contrary, the lowest values in shelf life (9.6 days), P^H (4.25), reducing sugar (2.36%), non-reducing sugar (14.40%), total sugar (15.73%) and total soluble solids (13.63%) at 2nd days of storage were recorded in control treatment. The lowest rottening percent (49.91%) at 8th days was found in 1000 ppm ethrel treatment and lowest value of ascorbic acid (12.14 mg/100 g) at 8th days, quick ripening (1.6 days) was recorded in 1500 ppm ethrel treatment.

The combined effect of types of solution and ethrel treatment also had significant except moisture content at all days and reducing sugar at 2nd, 4th days, weight loss 6th days, non-reducing sugar 8th days, P^H 2nd days, acidity 8th days of storage. The highest shelf life (14 days), P^H (5.77) at 8th days, reducing sugar (5.96%) at 8th days, non-reducing sugar (16.93%) at 6th days, total sugar (20.80%) at 6th days and total soluble solids (22.64%) at 8th days were recorded by hot water with 1000 ppm ethrel treatment. The maximum days to ripening

(6 days), rottening percent (79.84%) at 8th days, moisture content (81.46%) at 2nd days, weight loss (12.83%) at 8th days and titrable acidity (2.12%) at 2nd days were found in normal water with control treatment. The maximum rottening percent (33.27%) at 8th days, weight loss (11.31%) at 8th days and titrable acidity (0.08%) at 8th days were recorded in hot water with 1000 ppm ethrel treatment and the lowest days to ripening (1day), moisture content (70.32%) at 8th days and ascorbic acid (10.51 mg/100 g) at 8th days were found in hot water with 1500 ppm ethrel treatment. The minimum shelf life (9.6 days), non-reducing sugar (13.22%), total sugar (14.13%), total soluble solids (13.61%) and P^{H} (4.25) at 2nd days of storage were recorded in normal water with control treatment.

The findings of the present investigation indicated that the total soluble solid, sugar (reducing, non-reducing and total sugar), P^{H} of fruits were increased during storage under different concentration of ethrel. At the same time ascorbic acid, titrable acidity and moisture content were decreased. Among the treatment hot water with 1000 ppm ethrel treatment was found superior to other combinations.

From the present investigation it may be concluded that hot water and ethrel treatment influenced the ripening and quality of mango during storage. In these respects, combination of hot water with 1000 ppm ethrel treatment was found most effective for ripening and better quality of mango.



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APPENDICES

APPENDICES

Appendix I. Daily temperature and relative humidity of the storage room recorded during the period of study

Date	Room temperature (^{0}C)		Relative humidity (%) (9am)
	Maximum	Minimum	
10.06.06	30.5	25.1	81
11.06.06	31.9	26.1	83
12.06.06	31.1	24.8	86
13.06.06	30.1	24.7	84
14.06.06	30.5	26.3	79
15.06.06	31.5	24.7	81
16.06.06	32.0	25.1	83
17.06.06	31.9	27.1	86
18.06.06	31.1	28.7	81
19.06.06	31.6	27.2	83
20.06.06	32.0	29.9	86
21.06.06	31.9	28.1	81
22.06.06	31.1	28.4	83
23.06.06	31.9	27.0	81
24.06.06	31.9	28.2	83
25.06.06	31.1	27.3	86
26.06.06	30.1	28.4	81
27.06.06	30.5	28.7	83
28.06.06	31.5	29.0	86
29.06.06	30.5	27.9	81
30.06.06	31.6	28.6	83

Appendix II. Analysis of variance of data on color development (days) of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of ripening
Factor A	1	9.500**
Factor B	3	13.500**
AxB	3	0.400*
Error	16	0.125

Appendix III. Analysis of variance of data on % weight loss of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % weight loss of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	1.153**	10.587**	0.920**	6.752**
Factor B	3	0.313**	1.193**	0.077**	0.569**
AxB	3	0.106**	0.242**	0.015NS	1.380**
Error	16	0.013	0.017	0.006	0.003

Appendix IV. Analysis of variance of data on % rottening of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % rottening of mango at different days of storage		
		4th day	6th day	8th day
Factor A	1	58.625**	1660.339**	3612**
Factor B	3	334.704**	510.302**	681.116**
AxB	3	6.390**	107.900**	158.796**
Error	16	0.235	1.596	4.461

Factor A : Types of solution

Factor B : Ethrel concentrations

** : Significant at 1% level of probability

* : Significant at 5% level of probability

Appendix V. Analysis of variance of data on shelf life of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of shelf life
Factor A	1	9.627**
Factor B	3	12.943**
AxB	3	0.377**
Error	16	0.077

Appendix VI. Analysis of variance of data on % moisture content of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % moisture content of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	6.070^{NS}	2.633^{NS}	10.049^{NS}	3.168^{NS}
Factor B	3	1.214^{NS}	1.317^{NS}	1.000^{NS}	1.764^{NS}
AxB	3	0.289^{NS}	0.087^{NS}	0.090^{NS}	0.016^{NS}
Error	16	3.851	6.678	6.007	5.583

Appendix VII. Analysis of variance of data on ascorbic acid content of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of ascobic acid of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	12.227**	0.046^{NS}	24.970**	98.459**
Factor B	3	1.306**	1.53**	2.878**	10.916**
AxB	3	1.104**	0.593**	1.329**	3.207**
Error	16	0.001	0.012	0.038	0.194

Factor A : Types of solution

Factor B : Ethrel concentrations

** : Significant at 1% level of probability

* : Significant at 5% level of probability

Appendix VIII. Analysis of variance of data on P^H of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of P^H of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	0.033**	0.064**	0.076**	0.138**
Factor B	3	0.007*	0.059**	0.094**	0.232**
AxB	3	0.005NS	0.009**	0.009**	0.008**
Error	16	0.002	0.002	0.0001	0.0001

Appendix IX. Analysis of variance of data on titrable acidity of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % titrable acidity of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	0.870**	0.132**	0.111**	0.023**
Factor B	3	0.614**	0.099**	0.103**	0.020**
AxB	3	0.045**	0.005**	0.003**	0.068NS
Error	16	0.003	0.0001	0.0002	0.0001

Appendix X. Analysis of variance of data on % reducing sugar of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % reducing sugar of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	0.078**	0.238**	0.196**	0.077**
Factor B	3	0.141**	0.244**	0.030**	0.038**
AxB	3	0.011NS	0.003NS	0.003**	0.006**
Error	16	0.01	0.013	0.0001	0.0001

Factor A : Types of solution

Factor B : Ethrel concentrations

** : Significant at 1% level of probability

* : Significant at 5% level of probability

Appendix XI. Analysis of variance of data on % non-reducing sugar of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of %non-reducing sugar of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	0.859**	0.088**	1.283NS	2.338NS
Factor B	3	1.170**	0.103**	1.754**	0.503NS
AxB	3	0.272**	0.079**	1.459*	0.534NS
Error	16	0.043	0.009	0.383	0.039

Appendix XII. Analysis of variance of data on % total sugar of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % total sugar of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	2.464**	6.294**	2.464**	3.278**
Factor B	3	2.491**	1.856**	3.893**	4.032**
AxB	3	0.275*	0.138**	0.628*	0.625**
Error	16	0.040	0.008	0.043	0.011

Appendix XIII. Analysis of variance of data on % total soluble solids of mango as influenced by types of solution and ethrel

Source of variation	Degrees of freedom	Mean square of % total soluble solids of mango at different days of storage			
		2nd day	4th day	6th day	8th day
Factor A	1	17.733**	8.074**	6.283**	29.548**
Factor B	3	10.273**	4.946**	0.754**	0.784**
AxB	3	0.601**	0.079**	0.647**	0.661**
Error	16	0.002	0.004	0.043	0.042

Factor A : Types of solution

Factor B : Ethrel concentrations

** : Significant at 1% level of probability

* : Significant at 5% level of probability