3. Development and validation of post-harvest treatments for Alphonso Mango and Robusta Banana for delayed ripening/increased longevity with acceptable organoleptic properties

3.1 INTRODUCTION

3.1.1 Mango

Alphonso Mango the most wanted among the variety of Indian mangoes and is rated the best in the world. The variety is thin skinned, soft fleshed with low fiber content and sweet aroma (Knight, 1997). The high perishable nature of the fruit of quick softening and extensive ripening and the short harvest season limit utilization of the variety, for commercial purposes. Being a major fruit crop of great economic importance, the king of fruits mango has been extensively studied for post harvest and storage. In general, depending on the variety and environmental conditions, mangoes take 6-12 days for normal ripening under ambient conditions and become over ripe and get spoiled within 15 days after harvest (Krishnamurthy et al. 1971). As a climacteric fruit, the period of ripening is characterized by a series of biochemical changes initiated by the autocatalytic production of ethylene and increase in respiration. Ripening results in the characteristic color, taste and aroma with desirable acid sugar ratio and softening. The post harvest physiology of mango fruit though extensively studied was mostly confined to the biochemical changes were most of them deal with biochemical changes that occur during ripening. The process of ripening involves the onset of number of metabolic process in which new proteins are synthesized and many enzymatic activities hasten their pace, like rise in respiration increase in polygalacturonase (PG) activity (Hobson, 1965) and ethylene production (Pratt et al., 1969).
Mango has a short shelf life when held at ambient temperature and is sensitive to low temperatures resulting in chilling injury. Many studies have been done on increasing the shelf life of mango using controlled atmospheres and low temperatures. (Chaplin et al., 1991; Yahia, 1998; Acosta et al., 2000; Bender et al., 2000). Pre storage treatments such as high temperature, temperature conditioning, exposure to methyl jasmonate and nitrogenic gas at stages of harvest have been reported (Burdon et al. 1994).

3.1.2 Banana

Banana another important fruit of wide consumption is rendered unfit to the extent of > 60% on account of outdated post harvest practices. Decay is the greatest cause of spoilage during marketing. Deteriorative changes in texture, flavor and color affects the quality of banana fruit. These changes often are accompanied by decrease in the nutritive value. The post harvest changes in banana are principally related to the process of ripening and senescence.

Several biochemical changes have been reported in banana during its ripening process. Starch degradation appears to be a rapid process, which offered necessary sugar fuel for respiration, which in turn generate ATP for a metabolic energy source (Tucker, 1993). Antioxidants such as polyphenols tannins as well as antioxidant enzymes such as peroxidase, catalase and superoxide dismutase (Masia, 1998) were found to be modulated resulting in softening of the fruit.

As a measure of post harvest management, mangoes and bananas are transported green at about 13 - 20° C depending on the variety. Although storing at <13° C is warranted (Kader 1986) it could not be adopted, since banana and mango are susceptible to chilling injury at
<12.5° C. Alternatively integrated storage system including precooling, pretreatments followed by modified and CA storage will be useful to reduce chilling injury and extended storage life. Nevertheless, understanding of the effect of post harvest treatments on regulation of ripening, retention of storage life quality, compositional changes like colour, flavour, texture, acceptability etc., need to be evaluated, in order to promote the enhanced marketability and consumption of these fruits in earning foreign exchange. Therefore studies were carried out on these various post harvest treatment and method of storage. The methodology adopted in executing the work is presented under the following heads.

3.2. MATERIALS AND METHODS

3.2.1 Procurement of fruits

Freshly harvested matured mango fruits (*Mangifera indica* L.) variety, Alphonso were selected for the all the experiments. The harvesting was done manually by hand picking in the morning hours (8:00 to 9:00 am), latex was removed from the fruit stalk and the then they were immediately transported in plastic crates cushioned with newspapers to the laboratory.

3.2.2 Sorting, grading and washing of fruits

Fruits were sorted out for mechanical injuries like abrasions, punctures, bruises, etc. Both mango and banana fruits were graded to maintain uniformity in the experiment. Mango fruits were washed in running water to remove the adhering latex, dust, dirt, and surface moisture was allowed to drain off and dry off.
3.2.3 Effect of different pre-cooling temperatures on chilling injury

The mango fruits were divided into five groups and each group comprised of 100 fruits. Initial fruit field temperature was recorded using thermometer.

3.2.3.1 Pre-cooling at different temperatures

Pre-cooling was done by using forced air pre-cooler (Rinac India Ltd). Ninety percent relative humidity (RH) was maintained for all the treatments.

Treatments

T₁ : 8 °C pre-cooled air to pre-cool fruits to 8 °C.
T₂ : 13 °C pre-cooled air to pre-cool fruits to 13 °C.

3.2.3.2 Hot water dip followed by cooling

By using hot water bath and forced air pre-cooler (Rinac India Ltd)

T₃ : Fruits were exposed at 52 °C to 55 °C heat shock for 5 min followed by cooling to 8 °C using 8 °C pre-cooled air.
T₄ : Fruits were exposed to 52 to 55°C heat shock for 5 min followed by cooling to 13 °C by using 13 °C pre-cooled air.
T₅ – Control.

Mangoes in the groups of 1-5 were subjected to the treatments T₁-T₅ respectively. The temperature of the fruits was monitored by thermometer. The fruits were removed from the pre-cooler after the set temperature was attained. Fruits were observed for morphological injuries and were immediately cut into small pieces for analysis. The cut pieces of fruits were dipped in liquid nitrogen and stored at -80 °C for biochemical analysis.
3.2.4 Effect of fungicide, Prochloraz and hot water treatment in mango stored at ambient conditions (26-33° C and 60-70 % RH)

3.2.4.1 Prochloraz treatment

The fruits (50 Nos.) were dipped in Prochloraz, 45 %EC (250ppm) (Indofil Chemicals Co., Thane) for 10 min. were taken out and kept at ambient conditions (26-33 °C and 60-70 % RH) for 7 days. During the storage at RT (ambient temperature) fruits were observed for per cent disease incidence, longevity and organoleptic quality parameters (appearance fruits, pulp color, texture, taste and flavor).

3.2.4.2 Hot water treatment

The fruits (50 Nos.) were dipped in hot water tank maintained at 52° C – 55 °C for 5 min. The hot water tank for mango treatment was fabricated by the Division of Agricultural Engineering, Indian Institute Horticultural Research (IIHR), Bangalore. The fruits were kept at ambient conditions (26-33 °C and 60-70 %RH) for 7 days. Percent disease incidence was recorded. Longevity and organoleptic quality were recorded.

3.2.4.3 Untreated Control fruits

Mango fruits (50 Nos.) were kept at ambient conditions (26-33 °C and 60-70 %RH) for 7 days without any treatment.

3.2.5 Determination of longevity, disease severity and organoleptic quality of the fruits stored at 26-33 °C and 60-70 % RH

3.2.5.1 Longevity

The fruit longevity was determined by recording duration of the fruits (days) that is taken to reach the best edible stage of ripeness i.e.
when the surface color had fully changed to orange yellow and when fruits had become conveniently soft for slicing, and; the longevity was calculated from the day of storage.

\[ \text{3.2.5.2 Disease severity} \]

The degree of disease severity was categorized into three groups based on the intensity rating as

- **Severe (++++)**: > 25 % of the total stored fruits spoiled
- **Moderate (++)**: 10 to 25 % of the fruit surface affected
- **Mild (+)**: <10 % of the total fruit surface occupied by the lesions
- **Nil (-)**: Completely disease free

\[ \text{3.2.5.3 Organoleptic quality} \]

The ripe fruits were tasted for organoleptic qualities by a panel of eight judges following hedonic rating system (Amerine et al., 1965). Organoleptic quality such as fruit appearance, pulp color, texture, taste and flavor were judged by scoring as follows:

- Very good : 5
- Good : 4
- Acceptable : 3
- Bad : 2
- Very bad : 1

\[ \text{3.2.6 Combined effect of Prochloraz and hot water dip on longevity} \]

The fruits (50 Nos.) were dipped in hot water (maintained at 52 °C – 55 °C) containing 250 ppm Prochloraz. The fruits were taken out and kept at ambient conditions (26-33 °C and 60-70 %RH) for 7 days. Observations were taken as quarter ripened (QR), half ripened (HR) and Optimum ripened (OR) fruits. The fruits after storage were subjected to
biochemical analysis to determine the antioxidant levels, total sugars, starch etc. The physiological parameters such as total soluble solids (TSS), respiration rate and ethylene production were also recorded.

3.2.7 Determination of physiological parameters of mango stored at ambient conditions (26-33 °C and 60-70 %RH)

3.2.7.1 Respiration rate

The individual fruit was enclosed in a hermetic container of known volume for one hour or less and 0.5 ml of the headspace gas from the container was withdrawn and injected into gas chromatograph (Model: Hewlett Packard 6890, USA) having porapak Q column with a thermal conductivity detector (TCD) using nitrogen as the carrier gas at a flow rate of 30 ml min⁻¹. The percentage of CO₂ was calculated by simultaneous running of the standard CO₂ gas. The respiration rate was calculated as mg/kg/h by using the formula:

\[
\text{CO}_2 (\text{mg/kg/h}) = \frac{\text{Density of CO}_2 \times \% \text{ CO}_2 \times (\text{container volume-fruits volume}) \times 60}{\text{Weight of the fruit (Kg) \times Enclosure period (min) \times 100}}
\]

3.2.7.2 Ethylene production rate

The production rate was determined following the methodology adopted for determination of respiration rate using gas chromatography (Model: Hewlett Packard 5890, USA) having porapak Q column with a flame ionization detector (FID) using nitrogen as the carrier gas at a flow rate of 30 ml/min. The production of ethylene was measured in μl/kg/h by using the formula:

\[
\text{C}_2\text{H}_4 (\mu\text{l/kg/h}) = \frac{\text{ppm of } C_2H_4 \times (\text{container volume-fruits volume}) \times 60}{\text{Weight of the sample (Kg) \times Enclosure period (min) \times 100}}
\]
3.2.7.3 Firmness

The firmness of fruit, at equatorial region, was measured using an Instron-Universal testing machine (Model 4201, USA) (Plate 1). A plunger of 8 mm diameter was used for puncturing, set at a speed of 100 per min. with 50 Kg load using a 500 Kg load cell. The firmness was expressed as Kg of force required for puncturing.

3.2.7.4 Total Soluble Solids (TSS)

The TSS (°Brix) was recorded with a hand refractometer (Model: Erma, Japan).

3.2.7.5 Estimation of total sugar (alcohol soluble sugar) and starch (alcohol insoluble sugar)

A known weight of fruit pulp tissue was blended in 80 % ethanol, filtered and the residue was re-extracted (x3) in 80 % ethanol. The combined extracts were pooled and evaporated and re-dissolved in water and made up to known volume with distilled water. Phenol-Sulphuric acid (Dubois et al., 1956) method was employed for the estimation of total sugars. A known weight (10 mg) of ethanol insoluble residue (starch) was hydrolysed using 2.5 N Hydrochloric acid followed by glucose determination employing Dinitrosalicylic acid method.

3.2.8 Effect of 13 °C storage on ripening behavior of mango

Prochloraz treated fruits (100 Nos.) were allowed to pre-cool to 13 °C by using 13 °C pre-cooled air. The pre-cooled fruits were stored for 21-25 days in ‘walk-in’ cold room maintained at 13 °C and 85 to 90 % RH. Observations were taken at quarter ripened (QR), half ripened (HR) and Optimum ripened (OR) fruits. Longevity and organoleptic quality was recorded. The physiological parameters such as total soluble solids (TSS),
Plate 1: Instron-Universal testing machine
total sugar, respiration rate and ethylene production was also recorded. The fruits after storage were subjected to biochemical analysis to determine the antioxidant levels.

3.2.9 Effect of 8 °C storage temperature, followed by storage at ambient conditions (26-33 °C and 60-70 % RH) on ripening behavior of mango.

Prochloraz treated fruits (125 Nos.) were pre-cooled to 8 °C by using 8° C pre-cooled air. The pre-cooled fruits were stored in ‘walk-in’ cold room for 21 days maintained at 8°C and 85 to 90%. Effect of chilling injury on stored fruits was recorded, sampled at weekly intervals. After 21 days of storage, fruits were shifted to ambient conditions (26°-33° C and 60-70 % RH) for ripening (one week) sampled at 3 and 7 days of storage. Samples were stored in -80°C for further biochemical analysis.

3.2.10 Effect of MAP on longevity and acceptability of mango stored at 8 °C

Prochloraz treated fruits (125 Nos.) were allowed to pre-cooled to 8° C by using 8° C pre-cooled air. These fruits were kept individually in low-density polyethylene and polypropylene (100 gauge) bags of the dimensions 8 x 8 cm having with and without pinholes on either surface of the bags. Sealing was done in such a way that all four corners of the bags possessed a single pinhole and center of the bag possessed another pinhole. Bags with pin holes were labeled as perforated polypropylene (PPP) and perforated polyethylene bags (PPE). Bags without pinholes were labeled as non-perforated polypropylene (NPPP) and non perforated polyethylene bags (NPPE). Fruits kept in open air were labelled as control and 25 fruits were taken for each treatment. These packed fruits were stored in ‘walk-in’ cold room for one month maintained at 8 °C and 85 to 90 % RH. The fruits were sampled for biochemical analysis after 5 days.
and 30 days after storage. After 30 days of storage, fruits were removed from the bags and were kept at ambient conditions for ripening. After 7 days of storage, fruits were sampled for biochemical analysis. During MAP storage and post MAP ripening, the severity of the chilling injury and CO₂ injury was expressed by the following intensities.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Description</th>
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<tbody>
<tr>
<td>+ + + +</td>
<td>Very Severe</td>
</tr>
<tr>
<td>+ + +</td>
<td>High</td>
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<tr>
<td>+ +</td>
<td>Moderate</td>
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<tr>
<td>+</td>
<td>Non-occurrence</td>
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</tbody>
</table>

### 3.2.11 Effect of 13 °C storage temperature, followed by stored at ambient conditions (26-33 °C and 60-70 % RH) on ripening behavior of Alphonso mango.

Prochloraz treated fruits (125 Nos.) were pre-cooled to 13 °C by using 13 °C pre-cooled air. The pre-cooled fruits were stored in ‘walk-in’ cold room (21 days) maintained at 13 °C and 85 to 90 %. Effect of chilling injury on stored fruits was recorded, sampled at weekly intervals. After 21 days of storage fruits were shifted to ambient conditions (26 °-33 °C and 60-70 % RH) for ripening (one week) sampled at 3 and 7 days of storage. Samples were stored in -80 °C for further biochemical analysis.

### 3.2.12 Effect of Modified Atmospheric Pressure (MAP) on longevity and acceptability of mango stored at 13° C

The effect of MAP on longevity and acceptability of Alphanso mango stored at 13 °C was assessed in a similar pattern described earlier (3.2.10). The fruits were sampled for biochemical analysis after 5 days and 25 days after storage. After 25 days of storage, fruits were removed from the bags and were kept at ambient conditions for ripening. After 5 days of storage, fruits were sampled for biochemical analysis. During
MAP storage and post MAP ripening, the severity of the chilling injury and CO₂ injury were recorded.

### 3.2.13 Effect of Controlled atmosphere (CA) storage on longevity and acceptability of mango stored at 8 °C

Matured fruits were sorted out for mechanical injuries like abrasions, punctures, bruises, etc. and graded as per size, shape and colour to maintain uniformity in the experiment. These fruits were washed in running water to remove the adhering latex, dust, dirt and excess moisture was allowed to drain off. The mango fruits were divided into three groups. Each group contained 60 fruits.

#### 3.2.13.1 Prochloraz treatment

**Group I**

The fruits were dipped in 500 ppm of prochloraz (45% EC) fungicide (Indofil chemicals Co., Thane) emulsions for 10 min. Treated fruits were taken out and excess fungicide solution was drained off. Fruits were dried to remove the excess surface moisture.

#### 3.2.13.2 Hot water treatment

**Group II** Fruits were dipped in hot water tank (maintained at 55 °C) for 5 min.

**Group III** Fruits were immersed in a water tank containing ordinary water followed by drying to remove the excess surface moisture.

#### 3.2.13.3 Pre-cooling

Prochloraz treated, HW-treated and untreated fruits were pre-cooled to 8 °C by using forced air pre-cooler to remove fruit heat rapidly.
Fruit temperature was monitored by using thermometer. Fruits of each treatment were divided equally into two sub-groups. Thirty fruits of each subgroup were stored in air at 8 °C as control of the pre-treated fruits (untreated stored at air, prochloraz treated stored at air and HW-treated stored at air) whereas other subgroups of each pretreated were subjected to CA storage in the storage chambers at 8 °C (untreated CA storage, prochloraz treated CA storage and HW-treated CA storage).

The treatment schedule comprised of

- Prochloraz treated CA stored (Pro CA STORAGE)
- Hot water treated CA stored (HW CA STORAGE)
- Untreated CA stored (UN CA STORAGE)
- Prochloraz treated air stored (Pro air stored)
- Hot water treated air stored (HW air stored)
- Untreated treated air stored (UN air stored)

CA storage chambers were calibrated to establish the specified gas composition – 5% O₂, 5% CO₂ and 90% N₂ by gas blending flow system. The gas blending system generated CA conditions using external supplies of gases from pressurized gas cylinders fitted with double-stage regulators and outlet controlling devices. Gas (O₂, CO₂ and N₂) flows were restricted through needle-valves. The system was designed in such a way that four different gas combinations could be achieved at any time, with four outlets each passing through gas flow meters wherein the final outlet flow of blended gases could be precisely controlled. These outlets were connected to the inlet flexible (Tygon®) pipes that were inserted into the desiccators in which the mangoes were stored. The CA system was a continuous gas flow, open-ended system without humidification. To achieve uniformity in the final flow, the outlet pressure from the gas cylinders was reduced step-by-step using sensitive pressure regulator.
valves and pressure indicating dials. The inlet flow rate per each desiccator containing 30 mangoes was set at 30 ml min⁻¹.

3.2.14 Application of various post harvest storage methods in Banana to delay ripening and extend the longevity of fruits

3.2.14.1 Procurement of the fruits

Freshly harvested matured banana variety Robusta was selected for the experiments. Fruits were hand separated from the main bunches and were immediately transported to the laboratory.

3.2.14.2 Sorting, grading and washing

Fruits were sorted out for mechanical injuries like abrasions, punctures, bruises, etc. and were graded to maintain uniformity in the experiment. These fruits were washed in running water to remove the adhering latex, dust and dirt. Excess moisture was allowed to drain off.

3.2.14.3 Pre-cooling at different temperatures

Banana fruits were divided into six groups and each group contained five hands. Pre-cooling was done by using forced air pre-cooler (Rinac India Ltd.).

T1 – 5° C pre-cooled air to pre-cool fruits to 8° C
T2 – 8° C pre-cooled air to pre-cool fruits to 8 °C
T3 – 13 °C pre-cooled air to pre-cool fruits to 13° C

3.2.14.4 Heat treatment followed by pre-cooling

Heat treatment was done by immersing the fruits in hot water tank and forced air pre-cooler (Rinac India Ltd).
T4 - fruits were exposed to 45 °C heat treatment for one hour followed by cooling to 8 °C by using 8 °C pre-cooled air

T5 - fruits were exposed to 45 °C heat treatment followed by cooling to 13 °C by using 13 °C pre-cooled air

T6 - Control

Bananas in the groups of 1-6 subjected separately to the treatments T1-T6, respectively. The temperature of the fruits was monitored by thermometer. The fruits were removed from the pre-cooler once the set temperature was reached. Fruits were observed for morphological injuries.

3.2.15 Effect of ambient conditions on longevity and acceptability of banana

Untreated banana hands were kept in ambient conditions (24-32°C and RH 60-65%) for the duration of the experiment. Observations were taken at quarter ripened (QR), half ripened (HR) and Optimum ripened (OR) fruits.

3.2.16 Effect of Ethrel treatment on longevity and acceptability of banana stored at ambient conditions

Fruits were dipped in 500 ppm of Ethrel for 10 min and stored at ambient conditions (24-32 °C and 60-65 % RH) for the duration of the experiment. Observations were taken at quarter ripened (QR), half ripened (HR) and Optimum ripened (OR) fruits.
3.2.17 Effect of 8°C storage on longevity and acceptability of banana

Untreated ‘Banana hands’ were stored in “Walk-in” cold rooms (Rinac, India Ltd) maintained at 8° C ± 1° C for the duration of the experiment with 90 ± 2% RH throughout the experiment (Plate 2 and 3). Observations on ripening behaviour and chilling injury were recorded by sampling at weekly intervals up to 21 days.

3.2.18 Effect of 13 °C storage on longevity and acceptability banana

Untreated ‘Banana hands’ were stored in “Walk-in” cold rooms (Rinac, India Ltd) maintained at 13° C ± 1 °C for the duration of the experiment with 90 ± 2% RH throughout the experiment. Observations were taken at quarter ripened (QR), half ripened (HR) and Optimum ripened (OR) fruits.

3.2.19 Effect of CA storage on longevity and acceptability of banana

Treatment schedule for CA storage

- CA storage 1- 5 % O₂ and 5 % CO₂
- CA storage 2- 5 % O₂ and 10 % CO₂
- Control- kept in air

Sorted, graded and washed fruits were sealed in an airtight container and flushed continuously with a gas mixture separately containing 5% O₂ and 5% CO₂ and 5% O₂ and 10% CO₂ for CA storage 1 and 2 respectively. The containers were stored at 13° C for 75 days. The concentration of gas was regularly measured by gas chromatography.

3.2.19.1 Post CA ripening

After 75 days of CA stored, fruits were divided into two groups for treatments. Group I fruits were treated with Ethral (500 ppm) and group II fruits were not treated. These fruits were stored in “Walk-in” cold
Plate 2: Effect of Low Temperature storage on CI in banana
Plate 3: Effect of Low Temperature storage on CI in banana
rooms (Rinac, India Ltd.) maintained at 25°C ± 1°C for the duration of the experiment with 90 ± 2% RH at all times.

3.2.19.2 Visual observations

The fruits were considered to have reached the best edible stage of ripeness when their surface color had fully changed to yellow color and when fruits had become conveniently soft for cutting. The number of days taken to reach the best edible stage were calculated from the day of storage (longevity). The organoleptic quality like fruit appearance, pulp color, pulp texture, taste and flavor were recorded.

During storage of fruits at 8°C, 13°C and at ambient conditions, respiration rate, ethylene production was measured. Fruits sampled at regular intervals were subjected for biochemical analysis to determine antioxidant enzyme levels, texture, total sugars, starch and Total Soluble Sugars (TSS). The methodologies involved in the determination of these parameters are discussed in mango.

3.3. EXPERIMENTAL RESULTS

3.3.1 Effect of pre-cooling and hot water treatment (52-55 °C) on chilling injury and heat injury in mango

Pre-cooling by using different temperatures (forced air) did not cause any morphological chilling injuries. Similarly, hot water dip did not cause any heat injuries like skin scalding, damaged lenticels and browning of the peel. These fruits appeared fresh hard and green.
3.3.2 Effect of prochloraz and hot water pre-treatments in mango during ripening at RT (26-33 °C and 60-70 % RH)

3.3.2.1 Longevity and acceptability

The fruit reached optimal eating quality after 7 to 9 days of storage. Pre-treatments had a pronounced effect on disease incidence. Prochloraz and hot water treatment prevented 90 to 95 % disease incidence respectively (anthracnose and stem end rot). Untreated fruits spoiled (50-60%) mainly because of anthracnose and stem end rot infections (Table 1).

3.3.2.2 Appearance

Pre-treatments had a significant impact on fruit appearance. HW-treated fruits posed good appearance, which were characterized by the shiny surface of the fruit with golden yellow color and thus were given high score (5) by the panel of sensory judges. The appearance quality of Prochloraz treated fruits (4) was also judged better over the untreated fruits (3.7) (Table 1).

3.3.2.3 Pulp color

All the fruits exhibited the most attractive and characteristic golden yellow color of the pulp and were not influenced significantly by prochloraz or HW pre-treatments. HW, prochloraz and untreated fruits scored 5, 4.7 and 4.6 by the panel of sensory judges respectively (Table 1).

3.3.2.4 Pulp texture

The Prochloraz and HW treated fruits scored 4.9 and 5 by the sensory panelists respectively, which were statistically non-significant
with each other but significantly differed with untreated fruits (4.4) (Table 1).

3.3.2.5 Taste

Prochloraz and HW pretreatments had significant influence on fruit taste. Prochloraz and HW treated fruits scored 4.6 and 5 respectively by the panel judges and were statistically non-significant with each other but significantly far with untreated fruits (4.1) (Table 1).

3.3.2.6 Flavour

Pre-treatments did not have any effect on retaining alphonso flavour during ripening. The entire panelist judged different pre-treatments equally and gave very good score (5) (Table 1).

3.3.2.7 Overall acceptability

Pre-treatments did not affect significantly the overall acceptability of the fruits. Prochloraz and HW treated fruits (4.7- 5) scored relatively high over untreated fruits (4.3) (Table 1).

3.3.3 Respiration production rate of Alphonso mango during ripening at RT (26-33 °C and 60-70 % RH)

Respiration rate of fruits ripened at ambient conditions is shown in Fig 1. The results showed that the respiration rate was ranged between 280 to 625 mg CO₂ mg/kg FW/h. Fruits followed a typical climacteric pattern of respiration. The climacteric peak was observed on the 3rd day of storage and respiration declined there after.
Fig. 1. Respiration rate of mango during ripening at RT (26-33°C and 60-70% RH)

Fig. 2. Ethylene production rate of mango during ripening at RT (26-33°C and 60-70% RH)
3.3.4 Ethylene production rate of Alphonso mango during ripening at RT (26-33 °C and 60-70 % RH)

The ethylene production rate of fruits stored at ambient conditions is shown in Fig 2. The results showed that the ethylene production rate ranged between 0.61 - 2 μl/kg/h C₂H₄. Maximum rate of ethylene production was coincided with the climacteric respiratory peak.

3.3.5 Fruit texture and TSS content of mango during ripening at RT (26-33 °C and 60-70% RH)

3.3.5.1 Texture

At harvest freshly harvested matured green (MG) fruit firmness was 43.6 kg. It decreased significantly during ripening. The QR, HR and optimum ripened fruits recorded 22.00, 14.84 and 5.81 kg respectively (Fig. 3).

3.3.5.2 TSS

At harvest freshly harvested MG fruit TSS was 8.22 % Brix and during ripening TSS content of the fruit was increased. Quarter half and optimum ripened fruits recorded 15.2, 16.4 and 17.8 % Brix respectively (Fig. 4).

3.3.5.3 Total sugars and starch content of mango ripened at RT

Freshly harvested MG fruit recorded 4.48g 100g-1FW of total sugar. Optimum ripened fruit total sugar was increased to 18.52g 100g⁻¹ FW. At harvest MG fruit starch content was 19 g 100g⁻¹ FW and it decreased to 2.16g 100g⁻¹ in optimum ripened fruit.
Fig. 3. Firmness of mango during ripening at RT (26-33°C and 60-70% RH)

Fig. 4. TSS content of mango during ripening at RT (26-33°C and 60-70% RH)
3.3.6 Effect of low temperature storage on longevity and acceptability of mango stored at 8 ° and 13 °C ± 1 and 90% RH

3.3.6.1 Longevity and acceptability

In comparison to fruits ripened at ambient conditions 13°C storage temperature extended the duration of storage. The fruits reached the optimal eating quality after 21 to 25 days of storage. These fruits appeared firm and had uniform yellow colour and absent from CI. However, fruits stored at 8 °C for a period of 21 days developed a CI symptoms characterized by grayish scald like discoloration of the skin, skin pitting and uneven ripening occurred when these fruits were ripened at ambient conditions for 1 week (Table 2).

3.3.6.2 Appearance

Significant variation occurred in the appearance of the fruits subjected to fruits ripened at 13 °C and fruits stored at 8 °C and followed by ripening at ambient conditions (27-32 °C and RH 60- 65%). Fruits stored at 13 °C were rated high (4.6) for their good color. Fruits stored at 8 °C showed further increased CI symptoms during ripening at ambient conditions, which were rated as just acceptable (3) (Table 2).

3.3.6.3 Pulp color

The pulp color of 13 °C stored/ripened fruits was rated high (4.4) which was significantly higher than 8 °C stored followed by ripening at ambient conditions (3.4) (Table 2).
3.3.6.4 Pulp texture

The texture of 8 °C stored fruits followed by ripening at ambient conditions was disintegrated (3.4), which was significantly lower than 13 °C stored/ripened fruits (4.2) (Table 2).

3.3.6.5 Taste

Storage temperature did not influence significantly on fruit taste. Fruit stored at 13 °C scored had higher score (4.9) than fruit stored in 8 °C and followed by ripening at ambient conditions (3.6) (Table 2).

3.3.6.6 Flavour

Storage temperatures did not significantly influence the development of alphonso flavour judged by the sensory panelists (Table 2).

3.3.6.7 Overall acceptability

The overall acceptability of fruits stored at 8 °C was rated significantly low (3.52) due to the development of poor taste, texture and appearance of the fruits. Because of their better organoleptic qualities, fruits ripened at 13 °C were rated high (4.52) by the sensory panelists (Table 2).

3.3.7 Effect of low temperature storage on respiration rate

The respiration rate of fruits stored at low temperature (8 °C and 13 °C) is shown in the Fig 5. The results showed that the respiration rate ranged between 32.7 and 119.9 mg CO₂ kg⁻¹ h⁻¹ for fruits stored at 13 °C where as it ranged between 14.1 and 34.4 mg CO₂ kg⁻¹ h⁻¹ for those stored at 8 °C. It is evident that typical climacteric pattern was observed on the 15 day of storage at 13 °C and respiration rate declined on 21 day
Fig. 5. Respiration rate in mango during storage at 8° and 13°C (± 1 and 90% RH).

Fig. 6. Ethylene production rate in mango during storage at 13°C (± 1 and 90% RH).
of storage. However, fruits stored at 8 °C failed to produce climacteric pattern of respiration even though the fruits were stored for 41 days.

3.3.8 Effect of low temperature storage on ethylene production rate

Ethylene production rate of fruits stored at 13 °C presented in figure. Results showed that ethylene was not detectable up to 6 days of storage and its production was very low between 0.0 to 0.2 μl kg⁻¹ h⁻¹. Ethylene production rate of 15 day stored fruits was found to be highest (0.2 μl kg⁻¹ h⁻¹) (Fig. 6). Fruits stored at 8 °C fail to produce detectable ethylene entire 41 days of storage.

3.3.9 Effect of low temperature storage on Texture

3.3.9.1 At 8 °C (± 1 and 90% RH)

Increased fruit firmness during storage at 8 °C was statistically non-significant. However, during ripening at ambient conditions fruit firmness was decreased significantly (Fig. 7).

3.3.9.2 At 13 °C

During ripening fruit firmness was significantly decreased. The QR, HR and optimum ripened fruits recorded 21, 14 and 5 kg respectively (Fig. 8).

3.3.10 Effect of low temperature storage on TSS

3.3.10.1 At 8 °C (± 1 and 90% RH)

The refractometric analysis of soluble solid content of mango fruits kept at 8 °C and followed by ripened at ambient conditions showed significantly increased TSS content. During ripening at ambient conditions, after 3 and 7 day of storage fruits recorded 15.40 and 18.08% Brix respectively (Fig. 9).
Fig. 7. Effect of 8° C on firmness of mango (± 1 and 90% RH).

Fig. 8. Effect of 13° C on firmness of mango during ripening (± 1 and 90% RH).
Fig. 9. Effect of 8°C on TSS of mango (± 1 and 90% RH).

Fig. 10. Effect of 13°C on TSS of mango during ripening (± 1 and 90% RH).
3.3.10.2 At 13°C

During ripening fruit TSS content increased significantly. At harvest freshly harvested MG fruit recorded 8.22 % Brix and its TSS content increased to 14.64, 16.24 and 18.48 % Brix respectively for QR, HR and optimum ripened fruits respectively (Fig. 10).

3.3.11 Effect of low temperature storage on total sugars and starch content of mango stored at 8° and 13 °C (± 1 and 90% RH).

During ripening fruit total sugar was increased and starch content was decreased. The results showed that fruits ripened at 13 °C recorded 18.2 and 2.28g 100g-1 total sugar and starch respectively. Similarly, fruits stored at 8 °C and followed by ripened at ambient conditions recorded 16.7 3.42g 100g-1 FW total sugar and starch respectively.

3.3.12 Effect CA storage on longevity and acceptability in mango stored at 8 °C

Storing of fruits or vegetables in controlled atmosphere (CA) enriched with high CO₂ and/or utilizing low O₂ levels could be a very beneficial tool to maintain quality of the produce. In the present investigation, combination of low O₂ (5 %) and high CO₂ (5 %) concentration of gases were used in CA storage and extended the storage life of Alphonso mango (45 days) at 8 °C. Pre-treatments - prochloraz and hot water had prevented disease incidence whereas untreated fruits stored in CA were prone to diseases. Pretreated CA stored fruits were absolutely free from morphological CI and fruits appeared fresh, hard and green after 45 days storage at 8 °C (Plate 4). Irrespective of the treatments (untreated, prochloraz treated and hot water treated) fruits kept in air developed dark scald-like discolorations in the peel, began around lenticels and spread outwards, produced circular lesion and pitting on the fruit peel. CI symptoms were further increased when these
Plate 4: 45 days CA Stored at 8°C
air-stored fruits were shifted to ambient temperature for ripening. Prochloraz and hot water treated fruits stored in CA were free from CI and ripened normally when shifted to ambient conditions (24-29 °C).

3.3.12.1 Appearance

The ripe fruits (at ambient conditions) obtained after CA storage (Prochloraz and HW treated) at 8 °C posed good appearance, which was characterized by shiny surface of the fruit with bright yellow colour and thus were given high score (4) by the panel of sensory judges (Plate 5). However, it was affected badly in control fruits (Prochloraz treated (2.7), HW treated (2.6) and untreated (2.5) fruits kept open in air) (Table 3). The loss of score by control fruits stored in air (Prochloraz, HW treated and untreated fruits) was mainly due to uneven development of yellow colour of the fruit.

3.3.12.2 Pulp color

Sensory panelists rated fruit pulp colour of prochloraz (4.7) and hot water treated (4.2) CA stored fruits significantly high over prochloraz, hot water and untreated air fruits (3) (Table 3).

3.3.12.3 Pulp texture.

Prochloraz and hot water pre-treated CA stored fruits pulp texture (4) was rated significantly high compared to control fruits (3-3.3) kept in air. (Prochloraz, hot water and untreated fruits) (Table 3).

3.3.12.4 Taste

CA stored fruits at 8 °C exhibited characteristic sweet taste and were rated significantly highest (4.2) by the sensory judges. Prochloraz,
Plate 5: 45 days CA Stored at 8°C + 1 week ripening at RT
hot water and untreated fruits kept in air scored 3 by the sensory panelists (Table 3).

3.3.12.5 Flavour

The sensory panelists did not significantly differ flavour of alphonso mango stored in CA or air conditions (Table 3).

3.3.12.6 Overall acceptability

The overall acceptability of CA stored Prochloraz treated CA stored (4.16) and hot water treated CA stored (4.16) fruits stored at 8 °C was rated significantly higher compared to pro-air stored (3.18), hot water-air stored (3.18) and untreated air stored (3.1) fruits. Pre-treatments were not significantly influenced among CA stored or fruits stored in air (Table 3).

3.3.13 Effect CA storage on Respiration

During ripening at ambient conditions, prochloraz treated CA stored and HW-treated CA stored fruits showed a typical climacteric pattern of respiration. It was observed that, number of days to attain the climacteric peak was delayed by different pre-treatments (Prochloraz and HW pre-treatments). HW-treated CA stored and prochloraz treated CA stored fruits showed climacteric peaks on second (370 mg CO₂ kg⁻¹ h⁻¹) and third day (570 mg CO₂ kg⁻¹ h⁻¹) of storage respectively. Thereafter, rate of respiration of these fruits was decreased. Prochloraz, HW and untreated fruits (control fruits) stored in air at 8 °C followed by ripening at ambient conditions failed to respire climacteric pattern of respiration. Results showed that HW-treated air (306.2 mg CO₂ kg⁻¹ h⁻¹) and untreated treated air (364.1 mg CO₂ kg⁻¹ h⁻¹) fruits (stored at 8 °C) respiration was highest on second day of storage (Fig. 11). However,
Fig. 11. Effect of CA storage on respiration rate of mango during ripening

Fig. 12. Effect of CA storage on ethylene production rate of mango during ripening
Prochloraz treated control (308.6 mg CO₂ kg⁻¹ h⁻¹) fruit showed increased rate of respiration on third day of ripening at ambient conditions.

3.3.14 Effect CA storage on ethylene production rate in mango

After 45 days in CA storage at 8 °C followed by ripening at ambient conditions for 5 days the ethylene production rate of fruits is shown in Figure 12. The pre-treatments and storage environment affected the rate of ethylene production. Prochloraz treated CA stored (1.28 μl kg⁻¹ h⁻¹) and HW-treated CA stored (1.34 μl kg⁻¹ h⁻¹) fruits produced a maximum ethylene production on 3 and 4 day of storage respectively. Prochloraz and HW pretreated fruits stored in air (at 8 °C control) during ripening synthesized maximum ethylene on 5 and 4 day of storage respectively. These fruits produced comparatively less ethylene than CA stores fruits. However, untreated control fruit produced (1.12 μl kg⁻¹ h⁻¹) maximum rate of ethylene on very first day of storage and decreased to 0.26 μl kg⁻¹ h⁻¹ on 3 day of storage and again it increased to 1.06 μl kg⁻¹ h⁻¹ on last day of storage (5 day).

3.3.15 Effect CA storage on texture

At harvest fruit texture was 43.6. It decreased significantly during ripening. Pre-treatments and storage conditions (CA storage or kept in open air) were not statistically influenced on changes in texture of the fruits (Fig. 13).

3.3.16 Effect CA storage on TSS

At harvest fruit TSS content was 8.22. CAS stored fruits TSS content was increased significantly during ripening. TSS content of ripe fruits was not affected by the storage conditions (CA storage or kept in open air). The prochloraz treated CA stored, Hot water treated CA stored,
Fig. 13. Effect of CA storage on firmness of mango during ripening

Fig. 14. Effect of CA storage on TSS of mango during ripening
prochloraz treated air stored, hot water treated air stored and untreated
air stored fruits recorded 18, 17.5, 17, 17.2 and 17, respectively (Fig. 14).

### 3.3.17 Effect CA storage on total sugars and starch content

Table 8 displays the variation of total sugar as a function of CA
storage of mango for a period of 45 days and followed by ripened at RT.
Ripened fruit total sugar content was increased. Prochloraz (18.18) and
hot water (18.2) treated total sugar content was significantly higher than
Prochloraz (16.4), hot water (16.48) and untreated (16.32) air fruits.
Starch content of CA stored fruits decreased during ripening. Pre-
treatments and CA storage was not significantly influenced on decreasing
in starch content (Table 4).

### 3.3.18 Effect of 8 °C on gaseous composition of modified
atmosphere package of mango

During storage, fruits packed in perforated poly propylene (PP) and
poly ethylene (PE) packs maintained O₂ concentration significantly lower
to atmospheric O₂ levels and higher to the level of O₂ in non-perforated
bags and it was not affected by nature of film (PE or PP). However, O₂
concentrations in non-perforated packs were affected by nature film used
for packaging. The gas composition of perforated PP (18.7 to 19.8%) and
perforated PE (18.4 to 19.4%) packs were not affected by length of
storage. The in-package O₂ concentration of fruits packed in non-
perforated polypropylene (NPPP) and non-perforated polyethylene (NPPE)
was in the range of 0.07-10.2 % and 0.2 -5.4 % respectively (Fig. 15A). It
was observed that, storage period significantly affected the O₂ levels in
non-perforated bags. Fruits packed in NPPP bags recorded 2 % of O₂ on
fifth day of storage and reached least O₂ concentration on fifteenth day of
storage and again reached maximum on last day (30 day) of MAP storage.
Similarly, fruits packed in NPPE showed 6.2 % of O₂ on 5 day of storage
Fig. 15A. Effect of 8°C storage on oxygen concentration inside MA packs

Fig. 15B. Effect of 8°C storage on carbon dioxide concentration inside MA packs
and reached minimum 0.2% O₂ on 15 day of storage and regained to 0.8% O₂ on last day (30 day) of MAP storage.

It was observed that, Fruits packed in perforated and non-perforated bags showed varied levels of CO₂. Nature of packed film and duration of storage significantly influenced the CO₂ concentration. Fruits packed in PPP and PPE showed lower level CO₂ than fruits packed in NPPP and NPPE and higher levels compared to atmospheric CO₂ level. During storage, perforated PP and perforated PE bags maintained 1.9 to 2.3 and 2 to 2.6% CO₂ concentration respectively (Fig 15B). However, storage duration did not affect the CO₂ concentration. The in-package CO₂ concentration in case of non-perforated packed fruits was affected by both nature of packed film and storage duration. After 5 days of storage, fruits packed in NPPP and NPPE recorded 36.13 and 26.2 % of CO₂ respectively. Decrease in CO₂ levels was observed during subsequent storage. Fruits packed in NPPP and NPPE bags showed 29.7 and 16.6% CO₂ on 15 day of storage respectively and after 30 days of storage CO₂ further decreased in non-perforated PP (5.6%) and non-perforated PE (8.8%).

3.3.19 Effect of MAP on longevity and acceptability

3.3.19.1 Stored at 8 °C

Increased longevity was observed in fruits packed in perforated packs (pole ethylene and polypropylene). In this conditions fruits can be stored for one month without CI and CO₂ injuries in addition one week ripening period at ambient conditions. However, fruits packed non-perforated (poly ethylene and poly propylene) packs were failed to ripe because of high CO₂ injuries characterized by browning of the fruit peel and internal break down of the fruit pulp. Fruits kept in air showed CI during storage and CI symptoms increased during ripening (Table 5).
3.3.19.2 Appearance

The sensory evaluation panel rated the appearance quality of fruits packed in perforated PP and perforated PE as high over fruits packed in non-perforated PP and non-perforated PE packs. Fruits packed in perforated in PP and packed in perforated PE had 3.8 rating, with regard to appearance quality, which were significantly higher than fruits packed in NPPP, NPPE and fruits stored in air (Table 5).

3.3.19.3 Pulp color

The pulp color of fruits packed in perforated (PP and PE) film and fruits stored in air were rated good (4) because of their yellow in colour and were significantly higher than fruits packed in NPPP (1) and NPPE (2) packs (Table 5).

3.3.19.4 Pulp texture

The texture of fruits packed in perforated PP (4.1) and PE (4.3) films were rated significantly higher than fruits packed in non-perforated packs (1) Due to uneven ripening fruits kept in air rated 3.6 by sensory panelists (Table 5).

3.3.19.5 Taste

Manually made perforation in fruits packed PPP and PPE film results in sweetness of the fruits and non-perforation flavor the bitterness. Fruits packed in non-perforated packs rated significantly very low (1) score than fruits packed in perforated PP (4.2) and PE (4.3) (Table 5).
3.3.19.6 Flavour

Alphonso flavour quality of fruits packed in perforated packs and fruits were stored in air were rated good (4). However, fruits packed in non-perforated packs were rated as very bad (1) (Table 5).

3.3.19.7 Overall acceptability

The overall acceptability of fruits packed in PPP (4.02) and PPE (4.18) were significantly higher than NPPP (1) and NPPE (1.38). Fruits kept in air rated as acceptable score (3.32) (Table 5).

3.3.20 Effect of MAP on respiration and ethylene production rate at 8 °C

3.3.20.1 Respiration rate

The MA packaging and their interaction during storage at 8 °C had pronounced effect on respiration during ripening at ambient conditions. Fruits were packed in perforated packs followed the climacteric pattern of respiration while fruits were packed in non-perforated packs fail to respire climacteric pattern of respiration. Fruits packed in PPP and PPE film showed the highest rate of respiration on the day (second day of storage at ambient conditions) of climacteric with CO₂ production of 341 and 350 mg CO₂ kg⁻¹ h⁻¹ respectively, but those stored in NPPE and NPPP packs liberated only 287.3 and 145.2 mg CO₂ kg⁻¹ h⁻¹ respectively (Fig. 16). During ripening at ambient conditions respiration rate of fruits stored in air (control) was highest (381 mg CO₂ kg⁻¹ h⁻¹). After appearance of climacteric peak declined rate of respiration was observed in fruits packed in PPP and PPE films.
Fig. 16. Effect of MAP on respiration rate of mango during ripening

Fig. 17. Effect of MAP on ethylene production of mango during ripening
3.3.20.2 Ethylene production rate

The interaction effect of MA packaging on the ethylene production during post MAP ripening showed erratic results. During ripening at ambient conditions, fruits packed in PPP (0.65μl kg⁻¹ h⁻¹) and PPE (0.55 μl kg⁻¹ h⁻¹) produced highest rate of ethylene on second day of storage and decreased to 0.48 and 0.5μl kg⁻¹ h⁻¹ on 5 day of storage respectively. Fruits packed in NPPP and NPPE showed 0.5 and 0.6μl kg⁻¹ h⁻¹ ethylene respectively on very first day of storage and increased to 0.75 and 0.81μl kg⁻¹ h⁻¹ of ethylene on 5 day of storage respectively. Ethylene production rate of control (kept in air) fruits was more on first day of storage (0.57μl kg⁻¹ h⁻¹) and it decreased to 0.35μl kg⁻¹ h⁻¹ on 5 day of storage (Fig. 17).

3.3.21 Effect of MAP on Firmness and TSS content at 8 °C

3.3.21.1 Firmness

The results showed that MAP significantly affected on fruits firmness during storage at 8 °C and followed by ripening at ambient conditions. At harvest MG fruit firmness was 43.6 and it decreased to 40.0, 40.8, 42.0 and 40.0 kg in PPP, PPE, NPPE and control air fruit respectively and firmness increased to 51.2 kg in fruits packed NPPP film. The results showed that during ripening fruits firmness decreased drastically. Fruits packed in non-perforated packs significantly higher firmer than fruits packed in perforated packs and fruits kept in air (Fig. 18).

3.3.21.2 TSS

The effect of MAP on changes on TSS content of fruits stored at 8 °C (one month) and followed by ripened at ambient conditions are presented in Fig. 19. During storage TSS content was increased. Significant differences were observed among the treatments. Nature of
Fig. 18. Effect of MAP on firmness of mango

Fig. 19. Effect of MAP on TSS of mango
packed film used in fruits packed in non-perforated packs significantly affected. However, it was not affected in fruits packed in perforated packs. It was noticed that, fruits packed in PPP (12.9 brix) and PPE (13 brix) and fruits kept openly in air (13.16 Brix) maintained significantly higher level of TSS than fruits packed in NPPP (8.2 brix) and NPPE (10.5 brix) films. Effect of MAP during storage at 8 C was directly influenced on increase in TSS content during ripening. Except, fruits packed in NPPP (8.4 brix ) all other fruits TSS content was increased and significantly lower with PPP (17.8 brix),PPE (18 brix), NPPE (12.4 brix) and air fruit (18.0 brix).

3.3.22 Effect of MAP on total sugars and starch content at 8 °C

3.3.22.1 Total sugar

At harvest MG fruit total sugar content was 4.48 % and it increased during ripening. Fruits kept in perforated bags had significantly higher level of total sugar than fruits kept in non-perforated bags. Fruits kept openly in air recorded 15.68 % total sugars, which was statistically non-significant with fruits kept in PPP (16.86 %) and PPE (16.96 %) films and significantly higher with fruits kept in NPPP (8.24 %) and NPPE (10.24 %) films (Table 6).

3.3.22.2 Starch

Fruits packed in non-perforated packs retained significantly higher level of starch content than fruits packed in perforated packs. Fruits packed in PPP, NPPP, PPE, NPPE packs and fruit kept in air recorded 3.4,12, 3.5, 10.1 and 4.6 g100⁻¹FW of starch respectively (Table 6).
Fig. 20 A. Effect of 13°C storage on oxygen composition inside MA packs

Fig. 20 B. Effect of 13°C storage on carbon dioxide composition inside MA packs
3.3.23 Effect of 13 °C on gaseous composition of modified atmosphere packed mango

The results proved that measured in-package O₂ and CO₂ were significantly affected by type of package, duration of storage and their interaction.

Fruits packed in non-perforated bags showed significantly lower level of O₂ than fruits packed in perforated bags. Fruits packed in PPP and PPE bags recorded 16.4 to 18.2 and 16.6 to 18.1 % O₂, respectively. Similarly, fruits packed in NPPP and NPPE bags showed 0.2 to 0.35% and 0.23 to 0.51 % O₂, respectively (Fig. 20A). However, storage duration had no influence on changes in-package O₂ concentration of fruits packed in perforated and non-perforated films. The results showed that fruits packed in non-perforated packs recorded significantly higher CO₂ levels than perforated bags. The data represents that after 5 days of storage fruits packed in NPPP and NPPE bags recorded 35.6 and 19.8 % CO₂ and during subsequent storage CO₂ decreased gradually to 22.4 and 11.5 on last day of storage respectively (Fig. 20B).

3.3.24 Effect of MAP on longevity and acceptability at 13° C

3.3.24.1 Longevity and acceptability

Increased longevity was observed in fruits packed in perforated packs (PPP and PPE). In this conditions fruits can be stored for 25 days without any CI and CO₂ injuries in addition 5 days ripening period at ambient conditions. However, fruits packed in non-perforated (NPPP and NPPE) packs were not ripened. These fruits showed strong CO₂ injuries characterized by browning of the fruit peel and internal break down of the fruit pulp. Fruits kept in air are over ripened. (shriveling of the fruit peel) (Table 7).
3.3.24.2 Appearance

The fruits packed in different films stored at 13 °C and followed by ripening at ambient conditions rated significantly different by sensory evaluation panelists. Fruits packed in PPP (3.3) and PPE (3) film rated high over fruits packed in NPPP (2.2) and NPPE (2.9) film. Control fruits had highest rate, which was characterized by yellow in colour (Table 7).

3.3.24.3 Pulp color

The pulp color of fruits packed in perforated packs (3) and fruit kept in air (4.4) were judged better over those packed in non-perforated packs. Fruits packed in NPPP (1) and NPPE (2) were rated bad because of their pale brown yellow coloured pulp and also internal break down of the pulp tissue (Table 7).

3.3.24.4 Pulp texture

The texture of fruits of PPP (4.1) and PPE (4.3) packs were adjudged to be good because of their crispy. Fruit packed in NPPP (1) and NPPE (2) packs were fail to ripe hence rated as very bad and bad respectively. Fruits stored in air judged to 4.2 (Table 7).

3.3.24.5 Taste

Perforation results in acceptable sweetness of the fruits and non-perforation favors the bitterness. Fruits packed in NPPP (1) and NPPE (1) packs rated significantly very lower score than PPP (3), PPE (3) and because of their sweetness fruits kept in air fruits rated highest (4.9) among other treatments (Table 7).
3.3.24.6 Flavour

Alphonso flavour quality of fruits packed in perforated packs and fruits stored in air were rated good (4). However, fruits packed in non-perforated packs had off flavour and were rated as bad (2). Fruits kept in air at 13 °C ripened early and retained Alphonso flavour during storage at ambient conditions and rated significantly higher (4.6) than other fruits (Table 7).

3.3.24.7 Overall acceptability

The overall acceptability of MA packed fruits stored at 13 °C was significantly affected. Fruits packed in perforated bags were adjudged to just acceptable (3.2). However, fruits packed in non-perforated packs were not acceptable (1.48-1.78). Control fruits kept in air were rated as acceptable (4.54) (Table 7).

3.3.25 Effect of MAP on respiration and ethylene production rate at 13 °C

3.3.25.1 Respiration rate

The results showed that, during ripening at ambient condition the rate of respiration was affected by MA packaging. Fruits packed in PPP and PPE showed the highest rate of respiration on the day (third day of storage) of climacteric with CO₂ production of 269 and 308 mg CO₂ kg⁻¹ h⁻¹, but fruits packed in NPPP and NPPE packs fail to produce climacteric peak and liberated only 160.3 and 169 mg CO₂ kg⁻¹ h⁻¹ respectively on third day of storage. Control fruit recorded highest rate of respiration on very first day of storage (282 mg CO₂ kg⁻¹ h⁻¹) and declined thereafter (Fig. 21).
Fig. 21. Effect of MAP on respiration rate of mango during ripening

Fig. 22. Effect of MAP on ethylene production rate of mango during ripening at 13°C
3.3.25.2 Ethylene production rate

The ethylene production behavior of fruits during ripening at ambient conditions is shown in Fig. 22. The effect of MAP had a great influence on ethylene production. Fruits packed in PPP (0.6 μl kg⁻¹ h⁻¹) and PPE (0.5 μl kg⁻¹ h⁻¹) packs showed highest rate of ethylene production on fourth day of storage. Similarly, fruits packed in NPPP (0.38 μl kg⁻¹ h⁻¹) and NPPE (0.77 μl kg⁻¹ h⁻¹) packs exhibited highest rate of ethylene on 3 day of storage. Control fruit recorded 0.44 μl kg⁻¹ h⁻¹ ethylene on 4 day of storage.

3.3.26 Effect of MAP on firmness of Alphonso mango stored at 13°C

The data on the effect of MAP on changes in firmness of fruits held at 13 °C for period of 25 days and followed by ripened at ambient conditions are represented in the Fig. 23. The results obtained after MAP storage showed that the storage temperature, MAP and their interaction had a great impact on the retention of firmness during storage. At harvest MG fruit recorded firmness of 43.6 Kg/cm², which significantly decreased during storage. After MAP storage, fruits packed in non-perforated bags were significantly firmer than fruits packed in perforated bags and fruits kept in air. Fruits packed in NPPP bags had significantly higher firmness than NPPE, PPP, PPE and fruits kept in air. Fruits stored in PPP, NPPP, PPE, NPPE and air recorded 2.32, 21.28, 2.24, 16.08 and 3.28 Kg/cm² firmness respectively.

The interaction effect of storage temperature and MAP revealed that the firmness of the fruits differs significantly in post MAP ripened fruits. Firmness was reduced significantly during post MAP ripening. Like during MAP storage, fruits packed in non-perforated bags recorded the highest firmness compared to fruits packed in perforated bags and
Fig. 23. Effect of MAP on firmness of mango stored at 13° C (± 1 and 90% RH).

Fig. 24. Effect of MAP on TSS of mango stored at 13° C (± 1 and 90% RH).
fruits kept in air. The PPP, NPPP, PPE, NPPE and fruits kept in air recorded 1.72, 16.0, 1.52, 12.48 and 1.28 Kg/cm² firmness respectively.

3.3.27 Effect of MAP on TTS content of mango stored at 13 °C.

Effect of MAP on changes in TSS content of fruits stored at 13 °C for a period of 25 days and followed by ripened at ambient conditions recorded in Fig.24. Significant difference was observed among the treatment. Increased TSS content was observed during storage. Fruits packed in perforated packs recorded higher TSS than fruits packed in non-perforated packs. Fruits packed in NPPP showed significantly higher TSS than fruits packed in NPPE film. The fruits kept openly in air (control) recorded increase in the total soluble solids content to 17 brix compared to 8.22 brix at its harvest and significantly higher than fruits packed in NPPP (9.72 brix), PPE (15.4 brix) and NPPE (12.0 brix) films. The data on the TSS of post MAP ripe fruits after storage asserted that MAP had a significant impact on the final TSS content of fruits. The fruits stored in air and perforated packs had maximum (16.2 to 16.8) final TSS, which were significantly higher than fruits packed in NPPP (1.72 brix) and NPPE (12.48 brix) films.

3.3.28 Effect of MAP on total sugar and starch of mango stored at 13 °C.

3.3.28.1 Total sugar

The results represents that fruits kept openly in air (17.46 %) had significantly more total sugar than MAP fruits. The effect of MAP at 13 °C asserted that the fruits packed in NPPP (7.82 %) and NPPE (8.3 %) packs had significantly lower level of total sugars than fruits packed in PPP (14.68 %) and PPE (14.32 %) packs (Table 8).
3.3.28.2 Starch

A significant decrease in the level of starch was observed during ripening. At harvest, total starch content recorded in MG fruit was 19.04 g100g⁻¹. It was observed that the level of starch decreased drastically during storage. The retention of starch was more in non-perforated packs (10.6 to 12.72 g100g⁻¹) than perforated packs (4.2 to 4.5 g100g⁻¹) (Table 8).

3.3.29 Effect of Ethrel treatment on longevity of banana stored at RT

Ethrel treated fruits ripened normally. At this condition, fruits can be stored for 6-7 days. Untreated fruits failed normal ripening though fruits were kept for 18 days.

3.3.30 Effect of low temperature storage on ripening of banana

3.3.30.1 Longevity

In comparison to fruits ripened at ambient conditions, 13 °C storage temperatures extended the duration of storage. The fruits reached the optimal eating quality after 40 to 45 days of storage. These fruits appeared firm and had uniform yellow colour and absent from CI. However, fruits stored at 8 °C for a period of 40 days developed a CI symptoms characterized by grayish scald like discoloration of the skin, skin pitting (6).

3.3.31 Effect of various post harvest storage methods on organoleptic quality of banana

3.3.31.1 Appearance

The sensory evaluation panelists rated the appearance quality of fruits ripened at 13 °C highest (5) and on par with CA stored fruits (4.6,
to 4.8) and significantly differed with fruit treated with ethrel and ripened at ambient conditions (3.6), untreated fruits ripened at ambient conditions (control) (2) and fruits stored at 8 °C (1) (Table 9).

### 3.3.3.1.2 Pulp colour

Significant variation occurred in the pulp colour of ripe fruits subjected to different treatment combinations. The fruits stored in CA conditions (4.5 to 4.6) fruits ripened at 13 °C (kept in air) (4.5) and ethrel treated RT ripened (4) fruits were rated significantly higher than untreated (2) fruits ripened at RT. However, fruits stored at 8 °C were not ripened and scored significantly least score (1) (Table 9).

### 3.3.3.1.3 Pulp texture

Fruits ripened at 13 °C (5), and fruits stored under CA conditions (at 13 °C) followed by ripened (4.8 to 4.9) at 25 °C scored more with regards to their firm and crisp texture. Ethrel treated RT ripened (4) and untreated RT ripened (2) fruits scored more than fruits stored at 8 °C (1) (Table 9).

### 3.3.3.1.4 Taste

Fruits stored at 13 °C had very good taste and were rated highest (5) by the sensory panelists. Ethrel treated RT ripened fruits and fruits stored in CA conditions were also rated to 4.7 to 4.8 rating, with regard to sweetness quality, which were significantly higher than untreated fruits ripened at RT (2) and fruits stored at 8 °C (1) (Table 9).

### 3.3.3.1.5 Flavor

Ethrel treated RT stored fruits had superior flavour and on par with fruits ripened at 13 °C (4.5) and fruits stored in CA conditions
followed by ripened at 25 °C (4.5 to 4.6). Untreated fruits stored at RT were rated bad (2). Fruits stored at 8 °C were not ripened and scored significantly least score (1) (Table 9).

3.3.3.6 Overall acceptability

Fruits ripened at 13 °C (Plate 6) and fruits stored in CA conditions (followed by ripened at 25 °C) (Plate 7) outscored the others, when judged for their overall acceptability, with 4.8 and 4.6 to 4.7 rating respectively. The overall acceptability rating of ethrel treated and RT stored was also good. Untreated fruits stored at RT or 8 °C suffered a setback in their overall acceptability due to uneven and failure of ripening respectively (Table 9).

3.3.3.2 Respiration rate of banana during storage at RT

The number of days to attain the climacteric peak was delayed by ethrel treatments. Untreated fruits stored at RT failed normal behavior of ripening and showed respiratory climacteric on terminal phase of its storage life (Fig 25B). After 4 days of storage the rate of respiration was 38 and increased 67 on 6th day of storage and followed gradually till the appearance of climacteric peak (255) on 16 day of storage. Ethrel treatment had a pronounced effect on rate of respiration. It hastened rate of respiration and the climacteric peak was attained on the third day itself recording a respiration rate of 275 mg CO₂ kg⁻¹ h⁻¹ and was found to decrease from the 4th day onwards up to day six, thus bringing about the characteristic climacteric curve (Fig 25A).

3.3.3.3 Respiration rate of banana during storage at 8 °C and 13 °C

The respiration rate of 8 ° and 13 °C stored fruits is shown in Figure 26. The results showed that respiration rate ranged between 9.9 to 11.9 mg kg⁻¹h⁻¹ for fruits stored at 8 °C where as it ranged
Fig. 25A. Respiration rate of banana during storage at RT (Ethrel treated)

Fig. 25 B. Respiration rate of banana during storage at RT (Untreated)
Fig. 26. Respiration rate of banana during storage at 8°C and 13°C

Fig. 27A. Ethylene production rate of banana during storage at RT (Ethrel treated)
Plate 6: Effect of Low Temperature storage on ripening in banana
Plate 7: 75 days CA Stored at 13°C +1 week ripened at 25°C
between 11.6 and 60.64 mg kg\(^{-1}\)h\(^{-1}\) for those stored at 13 °C. It is evident that the respiration rate of 13 °C stored fruits followed a climacteric pattern. The climacteric peak was observed on the 35 day of storage and respiration rate declined further. Fruits stored at 8 °C were not ripened and failed to produce climacteric peak.

3.3.34 Ethylene production rate of banana during storage at RT

The results show that ethylene was not detectable up to 14\(^{th}\) day of storage at room temperature. From 15\(^{th}\) day onwards ethylene production triggered, recording ethylene levels of 3.0, 4.0 and 4.0 µl kg\(^{-1}\) h\(^{-1}\) on 15\(^{th}\), 16\(^{th}\) and 17\(^{th}\) days respectively. In contrast to the ethereal untreated fruits, ethylene production was detected from day one onwards. Ethereal treated fruits. Maximum ethylene production was documented on 3\(^{rd}\) of storage (5 µl kg\(^{-1}\) h\(^{-1}\)) and from day four onwards ethylene levels were seen fluctuating at a decreasing pace Fig. 27A and Fig. 27B.

3.3.35 Ethylene production rate of banana during storage 13 °C

The ethylene production rate 13 °C stored fruits is shown in Figure 28. The results showed that ethylene production rate ranged between 0.48 to 0.78 µl kg\(^{-1}\)h\(^{-1}\) for fruits stored at 13 °C whereas ethylene production was not detected in fruits stored at 8 °C.

3.3.36 Effect of CA storage on respiration rate and ethylene production rate of banana during ripening at 25 °C

3.3.36.1 Respiration rate

The respiratory behaviour of the fruits with respect to ethrel untreated under CA storage conditions is given (Fig. 29). The respiration rate increased as the days passed by and the climacteric peak was
Fig. 27B. Ethylene production rate of banana during storage at RT (untreated)

Fig. 28. Ethylene production rate of banana during storage at 13°C
observed on 3rd day (175 mgCO2 kg⁻¹ h⁻¹). From 4th day onwards fluctuations in respiration rates was observed and started declining upto the 6th day. In ethral treated the climacteric peak was observed one day earlier i.e. on the 2nd day compared to that of the untreated ones indicating the influence of ethereal on the respiration rate of the fruits. And declined from day three onwards. Under the CA II storage ethrel untreated conditions maximum respiration rate was delayed as compared to CA I conditions. The climacteric peak was observed on 5th day recording a respiration rate of 205.93 mg CO₂ kg⁻¹ h⁻¹. The climacteric peak in this case was observed on the second day (237 mg CO₂ kg⁻¹ h⁻¹) itself which is similar to that of those recorded at CA I ethrel treated conditions

3.3.3.6.2 Ethylene production rate

On day one ethylene levels were not perceived and from day two onwards the ethylene production started increasing and attained a maximum of 4.88 on the fifth day. Ethylene production levels ranged from 0 to 2.86 µl kg⁻¹ h⁻¹ (Fig. 30). Under ethrel treated conditions peak ethylene production was obtained on day four (3.77 µl kg⁻¹ h⁻¹) and the production range recorded was 2.45 to 3.77 µl kg⁻¹ h⁻¹. Ethylene production levels recorded maximum under this condition on the third day (5.99 µl kg⁻¹ h⁻¹) and decreased rapidly on subsequent days. The ethylene production levels ranged from 0 to 5.99 µl kg⁻¹ h⁻¹. As against all the treatments, this treatment produced the highest ethylene levels ranging from 4.2 to 5.85 µl kg⁻¹ h⁻¹. The maximum levels was produced on the second day (5.85 µl kg⁻¹ h⁻¹).
**Fig. 29.** Respiration rate CA stored banana during ripening at 25°C

**Fig. 30.** Ethylene production rate CA stored banana during ripening at 25°C
3.3.37 Application of various postharvest treatments/methods on Firmness, total sugars and starch

3.3.37.1 Firmness

The data regarding fruit pulp firmness is presented in Table 10. Significant differences were found among the storage method. Ethrel treatment had a significant impact on fruit pulp firmness. Fruits (control) stored at RT recorded 1 Kg/cm² which was highest among the treatments. Storage temperature also had significant influence. Fruits ripened at 13 °C (0.7) recorded significantly higher firmness than CA stored fruits. Type of CA storage or ethrel treatment was not affected significantly on pulp firmness.

3.3.37.2 Total sugars

Application of various postharvest storage treatments on changes in the percent of total sugars of banana are presented in Table 11. Storage temperature and atmosphere had significant impact on increasing in total sugar. Fruits stored at 8°C were not ripened and showed significantly least total sugar (1.4 g/100 FW) than other fruits ripened at different conditions. Fruits ripened at RT, 13°C and fruits stored in CA conditions at 13°C followed by ripened at 25°C showed increased total sugar content. Total sugar content of banana fruits ripened at RT (14 to 18.4) or 13°C (18.2) were on par with CA stored (18 to 18.5) fruits at 13°C followed by ripened at 25°C. Type of CA storage was not effected significantly on total sugar.

3.3.37.3 Starch

In matured green fruit, starch content was 18.5 g/100g FW. During ripening starch content decreased. Fruits stored at 8°C and fruits ripened at RT (untreated) significantly retained higher level of
starch than fruits treated with ethrel and ripened at RT (0.4g/100g FW), fruits ripened at 13 °C (0.5g /100g FW) and fruits stored under CA conditions at 13° C followed by ripened at 25 °C (0.4 to 0.46g/100g FW). Type CA storage was not significantly affected on disappearances of starch (Table 11).

3.4 DISCUSSION

Fruits serve as a source of energy, vitamins, minerals, dietary fibers and antioxidants. Availability of these nutrients depends on the quality of fruits. Fruit quality is dependent on the many pre and post harvest practices like mineral, water, canopy and pest and disease management before harvest and also on time of harvest, handling and storage practices. Fruit quality is controlled by the colour, taste, texture, aroma, and food value. Textural quality factors include firmness, crispness, juiciness and mealiness. Taste depends on type and concentration of sugars and acidity, astringency (phenolic compounds) and aroma (concentration of odor active volatile compounds). Off flavors may result from fermentative metabolites.

Pigments undergo many changes during the maturation and ripening of fruits. These include loss of chlorophyll, which is influenced by post harvest handling and storage. Astringency is related to fruit phenolics, which usually decrease during ripening because of conversion of astringent phenolic compounds from soluble to insoluble non-astringent compounds. Loss of astringency occurs via polymerization of phenolics, change in molecular size of phenolics and change in hydroxylation pattern of phenolics.

Volatile are responsible for the characteristic aroma of fruits. They are present in extremely small quantities (Lewensohn et al., 2005).
Volatile compounds are largely esters, alcohols, acids, aldehydes, terpenes and ketones. Relative importance of aroma volatiles depends upon the threshold concentration of odour. Keeping fruits within their optimal ranges of temperature and relative humidity is the most important factor in maintaining their quality and minimizing postharvest losses. Responses to atmosphere modification vary greatly among species developmental stage and duration and temperature of exposure. Maintaining the optimum range of oxygen, carbon dioxide and ethylene concentrations around the fruit extends the post harvest shelf life relative to air control.

According to Shewfelt (1993), firmness is the primary textural attribute measured in fruits and vegetables. Terms such as firmness, crispness, mealiness, juiciness and hardiness are all related to the texture of fruits and is controlled by the wall to wall adhesion of cells. This is the primary factor influencing the perception of fruit texture and controlled by the strength of the middle lamella, the area of cell to cell contact and the extent of plasmodesmatal connections. If the cell to cell adhesion poor and the tissue can separate with minimal force the fruits are soft and melt considerably when eat. On the other hand if the cell to cell adhesion is strong the fruit does not melt easily and are called crisp. (Bourne, 1982).

Flavour is complex trait determined by genetics, environment, cultural practices, maturity at harvest, and post harvest handling. Flavour is composed of sweetness, sourness, bitterness, saltiness and aroma. Sweetness is related mainly to sugars and sometimes to sorbitol. Fructose is more sweet than sucrose followed by glucose. Acidity is composed of organic acids like malic acid in mangoes and oxalic acids in bananas (Almeida and Huber, 1999). Aroma derived from volatile components in fruits and those that are present in concentrations that
can be perceived by human nose are assumed to contribute to the aroma of the fruit.

Alphonso mango stored at RT (26-33 °C and 60-70 %RH) could be stored for 7 days. HWT is the most preferred quarantine treatment because it is easily adoptable by growers and produce distributors, uses short treatment times, is reliable and accurate in the monitoring of fruit temperatures, is efficient in killing surface decay organisms and cleanses fruit surface during treatment (Jacobi et al., 2001; Shellie and Mangon, 2000). In the present study, application of 52-55°C (generally adopted as quarantine measures) for 5 minutes to mango has not shown any fruit damage due to heat injuries (HI) like skin scalding, damaged lenticels which could be due to very short exposure period and tolerant of this fruit at this temperature. HW-treated fruits ripened at ambient conditions posed good appearance, which were characterized by the shiny surface of the fruit with golden yellow color. Similarly, several fungicides are presently used as postharvest treatments for control of wide spectrum of decay causing microorganisms. In the present report, Prochloraz completely prevented disease incidence including anthracnose. Untreated fruits presents disease incidence mainly because of anthracnose and stem end rot hence these fruits scored relatively low scores than prochloraz and HW treated fruits. Development of yellow colour of the fruit (peel and pulp) was slightly more in HW treated fruits mainly because of HW induced carotenoid synthesis.

Mangoes were reported to ripe satisfactorily (i.e. with acceptabile eating quality) between at 21 and 24 °C. Temperature 12-13 °C generally considered as optimum for storage of mango (Kader, 1986). Storage of mangoes below 10 °C resulted in chilling injury (CI) manifested by grayish scald like discoloration of the skin, skin fitting, uneven ripening,
reduction in the levels of carotenoids, aroma and flavour during ripening and susceptibility to fungal decay (Thomas, 1983).

The longevity and acceptability of the 13°C stored fruits was very good. According to observed results the longevity of these fruits was three weeks. Storage at 13°C is regarded as the ideal for mango (Kader, 1986). In general 13°C storage temperature is very much suitable for Alphonso mango. During visual assessment of mango fruits after stored at 13°C were confirmed that these fruits were free from chilling injury (CI) symptoms.

Increases in the degree of sensitivity to the development of visual symptoms of chilling injury can occur as mango fruits stored at 8 °C. As far as deterioration of the visual appearance of the fruit is concerned, relatively prolonged storage at 8 °C is not possible, (González-Aguilar et al., 2000; Nair et al., 2003). Based on the changes in the visible appearance of the fruits, the present report showed that Alphonso is more chilling sensitive at 8°C (21 days + one week) at ambient conditions. These fruits showed further increased CI symptoms (uneven ripening, bleaching of chlorophyll pigment, darkening of the peel color etc.) when they were ripened at ambient conditions ((21 days at 8 °C + one week at ambient conditions). Because of normal ripening at 13 °C and failure of normal ripening of fruits stored at 8°C, followed by ripened at ambient conditions sensory panelist gave very good score to 13°C stored fruits and given just acceptable score to 8°C stored (followed by ripened at ambient conditions) fruits.

The enclosure of Alphonso mango in different polymeric films led to the development of modified atmosphere due to its continuous respiration and permeable nature of packed film. The percent gas compositions inside the packs were affected by nature of packed film (PE...
or PP), perforation/non-perforation, storage temperature and duration of storage.

The expected gas composition was successfully obtained in PPP and PPE packed fruits during storage and the levels obtained were less than expected CO₂ 3-5%. The results showed that the concentration of CO₂ inside PPP (1.9-2.3%) and PEP (2-2.68%) packs at 8°C was maintained more or less similar and the duration of storage was not affected significantly, which could be attributed to the reduced rate of respiration and easy permeability of the gases through manually made micro perforations. In-package concentration of O₂ in fruits packed in PPP and PEP packs almost near to the level of atmospheric O₂ level mainly because micro perforations. The maintained level CO₂ level in these fruits results in extension of storage life for one month.

The high in-package concentration of CO₂ in PPNP and PENP packs presented in the results (table) which might be due to the less permeability of this film to CO₂. The fruits consumed the oxygen present inside the package as these respired and CO₂ was produced. The reduction in O₂ concentration and increase in CO₂ concentration created a gradient causing O₂ to enter and CO₂ to exit the package. Because of low permeability of these films to CO₂ results in elevated level of O₂ and CO₂ was observed. The results showed that in build high CO₂ concentration was more during early days of MAP storage affected the normal physiology of these fruits during subsequent storage results in fall in rate of respiration and decrease in CO₂ concentration. This was also supported by visual appearance of these fruits. Fruits packed in non-perforated packs developed strong CO₂ injuries, results in reduced rate of respiration.
The high in-package concentration of CO₂ in MA packed fruits (stored at 13°C) documented in the results, which might be due to increased rate of respiration of these fruits. It was evident from the results that the concentration of CO₂ was significantly very high in fruits packed in PPNP and PENP films than PPP and PEP films.

The variability in the gas composition might have resulted from variation in respiration rates of fruits affected by MA packaging (micro perforation, non-perforation, type of packaging film) and their interaction. Because of manually made perforation, fruits packed in PPP and PEP packs showed significantly lower level of O₂ and CO₂ than fruits packed in PPNP and PENP packs. However, the maintained level of O₂ and CO₂ concentrations of these gases in PPP and PEP packs were more than the fruits packed in PPP and PEP packs and stored in 8° C. This is mainly because of increased rate of respiration and manually made micro perforation were not enough to easy permeability of these gases. Decrease in CO₂ concentrations inside PPNP and PENP packs during terminal phase of storage may be due to respiration rates started to fall in response to the MA (high CO₂ and low O₂), resulting in elevation of the O₂ content and reduction in CO₂ content.

Modified atmosphere/controlled atmosphere storage of fresh horticultural crops using 2 to 3 % O₂ and < 5% CO₂ effectively reduce or inhibit C₂H₂ induced senescence reduces respiratory metabolism maintains flesh firmness and color and controls physiological disorders in harvested fruits and vegetables. Even though several workers has attempted to evaluate the beneficial and detrimental effects of Controlled and Modified atmosphere on fresh fruits and vegetables, the mode of action of Oxygen and CO₂ on these commodities still remains to be understood.
The ripening of mango after one month MA storage at 8° C followed by ripening at ambient conditions resulted in normal ripening of the fruit observed in fruits packed in PPP and PEP film. However, fruits packed in PPNP and PENP film failed ripe at all. The results showed that when ripening was carried out at ambient conditions, resulted in overall acceptability was good.

Availability of O₂ and maintained CO₂ concentrations were within the tolerable limit present in the fruits packed in PPP and PEP film resulted in normal ripening, and these fruits could be extended longevity of these fruits for period of one month followed by ripening period of one week. However, the maintained CO₂ were extremely high and during storage in PPNP and PENP packs at 8° C fail to ripe and were seriously suffered with CO₂ injury hence these fruits should not stored as MA condition in PPNP or PENP packs.

Rate of respiration was high at 13° C, fruits packed in PPP and PEP showed relatively high concentration CO₂ and influenced on normal ripening of the fruits. The results showed that when ripening was carried out at ambient conditions (26-33° C and 60-70%) the development of fruit (peel) colour was not matched the level of fruits stored in air or fruits ripened in air at ambient conditions. The sensory panelist overall quality recommendation was just acceptable. So fruits cannot be stored under these conditions. Increased rate of respiration of the fruit, (at 13°C) and low permeability of the film towards O₂ and CO₂ results in decreased O₂ and increased accumulation of CO₂ resulted in failure of fruit ripening. These fruits suffered with severe CO₂ injury characterized by brown coloured peel and internal breakdown of the fruit pulp. However fruits ripened in air at 13° C (95% RH) ripened normally on 21 days of storage, later, showed shriveling (over ripening) during shifted to ambient conditions.
CA regimes were beneficial in extending storage life of fruits and reduced the chilling injuries during storage and late ripening. Effectiveness of chilling injury reduction, maintaining product quality and extension of storage life in CA storage often depends on the type of commodity, concentrations O$_2$ and CO$_2$, temperature and duration of storage (Wang 1993). In the present investigation, combination of low O$_2$ (5 %) and high CO$_2$ (3 %) concentration of gases used in CAS had extended storage life of mango to 45 days and would ripened normally when transferred to ambient conditions. Noomhorm and Tiasuwan (1995) in their study with Red mango has extended storage life for 25 days at 13° C. The CAS fruits were absolutely free from CI injuries. All control air fruits developed visible CI. In the present CA experiments applied pre-treatments are effectively controlled the disease incidents. However untreated CA stored fruits were completely spoiled mainly because anthracnose and stem end rot. However, Prochloraz and hot water pretreatment prevent the disease incidence. Previously Jacobi et al. (2001) reported that hot water treatment can effectively kill surface decay organisms and cleanses fruit surface during treatment.

Horticultural crops can be classified according to their respiration rates and mango fruits are classified as moderate respiration (Kader, 2002). Several studies have reported that ethylene activates respiratory enzymes in different processes in different fruits. For example, ethylene treatment increases the activity of malic enzymes in climacteric fruits (pome fruits) and the respiration of avocado and banana in the pre-climacteric stage, as reviewed by Noodén and Leopold (1988).

Respiration is the process by which stored organic materials (Carbohydrates, proteins and fats) are broken down into simple products such as carbon dioxide and water vapour and accompanied by evolution of energy (Kader, 2002; Noodén and Leopold, 1988). The loss of stored
food reserves in the fruit through respiration means the hastening of senescence. The rate of deterioration of harvest commodities is generally proportion to the respiration rate. Mango is a climacteric fruit. Measurements of the Alphonso mango showed a typical climacteric respiration peak and decreased steadily thereafter. On the other hand, McCollum (1993) found that for the variety ‘Kent’ C2H4 production reached a maximum after the climacteric of respiration. Other climacteric respiratory patterns have been observed in the varieties ‘Tommy Atkins’ by Mitcham and McDonald (1992), and ‘Kent’ by Trinidad et al. (1997). The maximum of C2H4 evolution occurred simultaneously with the increase of respiration in the variety ‘Haden’ (Trinidad et al., 1997). These results indicated that the degree of synchronization of C2H4 evolution with the respiratory climacteric depends upon the mango variety.

Fruits during ripening at 13° C showed a climacteric rise in respiratory peak on 15 day of storage and it coincides with the ripening process. It shows that fruits stored at 13 °C are metabolically active. Fruits stored at 8 °C resulted in very low respiration rate throughout the storage and failed to respire climacteric pattern of respiration. The rate of respiration of fresh produce is a temperature dependent process and is regulated by many enzymes. The fruits stored at 8°C results in the reduced enzyme activity, thus lowering the rate of respiration. The low temperature was reported to induce in the physical properties of membrane lipids and resulted in dissociation of enzymes and other proteins resulting in alteration of the kinetics of enzyme and thus impaired ion movement through membranes and metabolic process like respiration and protein synthesis (Lyons, 1973, Wills et. al., 1989)

During ripening at ambient conditions, climacteric peak of fruits packed in PPP and PEP (stored at (8° C or 13° C) had the minimum rate
of respiration on the day of climacteric and fruits packed in PPNP and PENP fruits fail to produce climacteric peak at all. The differential responses of fruits packed in perforated or non-perforated packs in different films were related to their magnitude of stress caused by the low $O_2$ and high $CO_2$ as recorded in the table. Fruits packed in perforated packs (PE and PP) and stored at $13^\circ C$ and $8^\circ C$ showed increased rate of respiration on 2 and 3 day of their ripening respectively and decreased thereafter. Similarly, fruit kept openly during storage at $8^\circ C$ showed increased rate of respiration on 3 day of storage These results concordance with mango variety 'Manila' showed that a typical climacteric respiration peak develop by the 6th day of storage and decreased steadily thereafter (Dinora et al., 1997). However, $13^\circ C$ stored/ripened control air fruit rate of respiration was decreased after 2 day of storage it indicates the senescence of the fruit.

The climacteric peak of prochloraz treated CA stored fruits was comparatively high and one day delayed compared with HW treated CA stored fruits. Pretreatment prevented the disease incidence in CA stored fruits and elevated the CI symptoms results in typical climacteric pattern of respiration. However, HW pretreatment might have enhanced induction of ethylene synthesis at the time of CA storage results in early ripening, hence appearance of one day advanced climacteric peak than prochloraz treated CA stored fruits. Fruits kept in air (Prochloraz treated, HW treated and untreated and stored at $8^\circ C$) suffered with CI and affected the metabolic activity results in fail to produce climacteric pattern of respiration during ripening. One day advance increased rate of respiration by HW treated and untreated fruits kept in air (control fruits) than prochloraz treated control air fruits may be due to temperature and disease induced ethylene synthesis might have triggered in the synthesis respiratory enzymes during ripening at ambient conditions. However, prochloraz prevented diseases (Prochloraz treated fruits kept in air)
results in delayed synthesis of ethylene hence one delayed increased rate of respiration than HW treated and untreated control air fruits during ripening.

Ethylene is a naturally occurring plant growth hormone that has numerous effects on the growth, development and storage life of many fruits, vegetables and ornamental crops. Plant tissues of all ages can be induced to produce ethylene in response to various challenges, and plant tissues will respond to ethylene in a range of ways. The evolution of ethylene and the response of tissues to applied ethylene are, however, under developmental control. Ethylene synthesis occurs at specific times in the developmental trajectory of certain tissues, for example during fruit ripening, leaf and flower senescence and abscission. A wide range of stresses will also provoke ethylene production, for example mechanical trauma such as bruising and cutting, temperature stresses, and chemical stress (Heun-Hong and Kenneth, 2000).

Ethylene sets in motion a series of events leading to senescence. In ripening fruit, these events involve breakdown of cell walls, change in pigments and formation of certain flavor compounds (Brady, 1990). In leaves and fruits it can lead to senescence of specific cell layers in the petiole, resulting in abscission and thus shedding of the organ (Morgan, 1984). Ethylene production in climacteric tissues is higher than in non-climacteric tissues. Climacteric tissues are characterized by a low rate in ethylene production during the pre-climacteric stage. However, in these tissues ethylene production rises sharply during the climacteric stage (Sisler and Yang, 1984). The longevity of climacteric tissues is decreased when exposed to ethylene, while the longevity of non-climacteric tissues is not affected by the hormone.
Fruits (kept openly in air) during ripening at 13° C exhibited a peak in ethylene production rate, which coincide with the respiratory peak on the same day. This could be attributed to the normal ripening behavior of the fruits. Fruits stored at 8° C did not produce detectable quantity of ethylene during storage, which might be due to detrimental effect of 8° C storage temperature. Ethylene production behavior of MA packed fruits was varied differently. The irregularities in the ethylene production behavior might be due to MA packaging and their interaction during storage had a direct impact on ethylene production during ripening. Perforated fruits (PPP and PEP) stored at 8° C showed increased ethylene synthesis on second day of storage and thereafter it was decreased. It follows the similar pattern of ethylene production of fruit (kept in air) during ripening at 13° C and this temperature is also recommended for storage of mango (Kader, 1986). However, fruits packed in non-perforated packs during ripening showed irregular pattern of ethylene synthesis. This may be due to MA stress developed by increased accumulation CO₂ and decreased availability of O₂ during storage. Fruits kept in air recorded increased synthesis of ethylene on very first day of storage it may be due CI induced oxidative stress induced the early induction of ethylene. MA packed fruits stored at 13° C, followed by ripening at ambient conditions showed irregular pattern of ethylene synthesis. Fruits packed in PPP and PEP packed fruits showed an increased rate of ethylene production on 4 day of storage and decreased thereafter. The high ethylene synthesis in fruits packed in non-perforated fruits promoted to one day early than perforated is an indication CO₂ induced stress during MAP storage. Kader (1986) asserted that elevated CO₂ atmosphere could reduce, promote or no effect on ethylene production or action in fruits, depending upon commodity, variety, physiological age, initial quality, CO₂ concentration, temperature and duration of exposure to such conditions.
Ethylene production is rapidly arrested when tissues are placed under anaerobic conditions (Imaseki, 1999; Bleecker and Kende, 2000). When such tissues are returned to air, ethylene production starts at a significantly higher rate than that in the control tissues, which have not been placed under such anaerobic conditions. However, this increased rate is transient and returns to control levels in a few hours. This phenomenon was interpreted as indicating that an intermediate has accumulated during anaerobiosis but was rapidly converted to ethylene on returning tissues to air (Imaseki, 1999).

Prochloraz and HW treated CA stored fruits followed by ripening at ambient conditions showed a highest rate of ethylene synthesis on 3 and 2 day of storage/ripening respectively and decreased thereafter. Increased rate of ethylene synthesis also coincide with climacteric respiratory peak. Similar pattern was also observed in fruits during ripening (kept in air) at ambient and 13°C. It shows that the storage environment (CA storage at 8°C) was not showed any detrimental effected on these fruits. One day promotion in increased ethylene synthesis in HW treated CA stored and HW treated fruits stored in air (control) may be due to temperature induced ethylene synthesis at the time of heat treatment might have carried and triggered in early induction of ethylene during ripening. Untreated, Prochloraz and HW treated fruits fail to ripe normally and exhibited different pattern of ethylene synthesis. Untreated control fruits stored in air infected by anthracnose and stem end rot results in early induction in synthesis of ethylene and it was delayed in Prochloraz treated control fruits mainly because of fruits were free from disease incidence.

Firmness is the primary textural attribute measured in fruits and vegetables. Fruit firmness is an important tool to determine ripeness and quality (Kagan-Zur et al., 1995). Fruit ripening is associated with textural
alterations, which is dramatic in climacteric fruits. Textural change is the major event in fruit softening and is the integral part of ripening, which is the result of enzymatic degradation of structural as well as storage polysaccharides (Tucker and Grierson 1987; Hulme, 1971).

As the fruit proceeds towards ripening, there will be a progressive decrease in the firmness of the fruit. In some fruits like mango and banana, the ripe fruits are so soft that often it becomes extremely difficult to handle them. Softening is brought about by changes in cell wall constituents among which pectin substances play a major role. Depending upon their inherent composition and mature, different fruits soften at different rates and to varying degrees (Tucker and Grierson, 1987). Fruits like mango, banana, sapota, papaya, avocado undergo drastic and extensive textural softening from 'stone hard' stage to 'soft' pulpy stage. During ripening, softening fruit is caused by the conversion of protopectic, the insoluble, high molecular weight. Parent pectin into soluble polyurorides (John and Dey, 1986). This tightly bound protopectin is degraded into soluble pectins, which are found loosely bound to the cell walls. This phenomenon is attributed to the textural softening during ripening (Doreyappa and Huddar, 2001). Starch is the bulk polysaccharide propend in some fruits like mango and banana, and its enzymatic hydrolysis results in pronounced loosening of cell structure and sweetness development, which is mainly due to sugar accumulation (Tucker and Grierson 1987). The changes in the cell wall composition, which accompany fruit softening during ripening are due to the action and carbohydrate hydrolases. These hydrolapses acts on cell wall polymers, resulting in their degradation. Most of these enzymes are present in low levels and are constitutive throughout fruit development and ripening (Tucker 1993; Tucker and Grierson, 1987; Fischer and Bennett, 1991).
The mechanical nature of firmness has lead to attention being directed towards cell wall changes. (Ketsa et al., 1999; Watada et al., 1984). The breakdown or modification of cell wall polysaccharides during the ripening of mango fruits is associated with changes in firmness, and these changes are the result of the increased activity of polygalacturonases, cellulase and α-galactosidase (Ali et al., 1995; Huber, 1983, Ketsa et al., 1999). Based on these, an explanation could be suggested for the rapid decrease in firmness of fruits were stored at ambient conditions (stored in air) and fruits stored/ripened at 13 °C, fruits stored under MAP or CA storage followed by ripened at ambient conditions. During this period, hydrolase enzymes may act on the cell wall resulting in the rapid decrease of fruit firmness (as shown in Figure 3). In connection, these chemical changes can be associated with increased C2H4 and respiration during storage of fruits at ambient conditions, ripening at 13° C and fruits stored under MAP (fruits packed in perforated packs) or CA followed by ripening at ambient conditions, by which the cell wall hydrolysis might have enhanced. It is clear that, the metabolic interaction between ethylene synthesis, respiration and decrease in fruit firmness may be attributed to increased activity of polygalactouronase (PG), pectin methylesterase (PME), and beta Galactosidase as well as depolymerization of cell wall pectins. The MA storage retarded ripening in fruits packed in non-perforated packs that is why softening of fruits was also retarded (Smock, 1979). The extent of maintenance of fruit firmness varied with the film. The retardation of firmness losses might be due to reduced activity of cell wall degrading enzymes like polygalacturonases, cellulase and α-galactosidase.

The largest qualitative change associated with ripening is usually the breakdown of carbohydrate polymers, particularly to total conversion of starch to sugars. The percentage of total soluble solids (TSS) increases in fruits as sugar content increases. (Mukherjee and Dutta, 1967). From
the present results it is evident that during ripening, there was a large
degradation of starch leading to increase in soluble sugars and total
soluble solids observed in fruits ripened at ambient conditions (kept in
air), fruits packed in PPP and PEP (stored at 8° C and 13° C) and CA
stored fruits. In most ripe fruits, including mango, sugar forms the main
component of soluble solids. Since the amount of sugar in fruits usually
increases as the fruit ripens, the soluble solids content of the fruit can be
a useful index of stage of ripeness. It shows that normal ripening process
was not affected by pre-treatments. Fruits stored at 8° C followed by
ripened at ambient conditions TSS content was increased with increased
ripeness. This may be due to accumulated soluble sugars in the ripe
pulp of mango is probably due to starch hydrolysis as also corroborated
by the concomitant disappearance of starch in the ripe fruits.
Krishnamurthy et al. (1960) reported sucrose to be a major constituent of
sugars during ripening. A decline in starch content and increase in
sucrose was reported by Tandon et al. (1988).

The restricted increase in TSS could be attributed to the effect of
reduced/altered metabolic rate in fruits packed in NPPP and NPPE (MA
packed stored at 8° C or 13° C) fruits. Storage environment effected the
normal ripening of fruits packed in non-perforated packs (PPNP and
PENP) showed lower level TSS and soluble sugars and retained higher
starch content. Fruits stored at 8° C (kept openly in air) suffered with CI
leads to abnormal ripening process, during ripening at ambient
conditions resulted in relatively lower level of TSS and higher level of
starch.

Effect of temperature – 8 0C and 13 0C in Air and controlled
atmospheric conditions were also examined on delaying of ripening,
acceptability and longevity parameters of another important fruit Banana
–Robusta. Acceptability of fruits was also determined during artificial
ripening condition via induction of ethylene by ethrel. Results indicated that ethrel treatment offered 2 fold higher acceptability (4.8) when compared to those allowed to ripe at control air at ambient condition (2.0). However longevity was only 7 days in the former when compared to 18 days in the later - control fruits. Storage of Banana at 8° C offered very poor quality of fruit with an acceptability parameter of ~1; while those stored at 13° C offered better property with a value of ~ 4.8.

Storage of Banana at 13° C was improved under controlled atmospheric condition either at 5%O₂ + 5%CO₂ or 5%O₂ + 10% CO₂ levels with an acceptability parameter of ~ 4.7 when ripened at 25° C., even after storage up to 75 days suggesting the effect of CA treatment on Banana acceptability and longevity.

3.5 SUMMARY AND CONCLUSION

- Hot water treatments and prochloraz treatments prevented ~95 % of disease incidence as apposed to untreated mangoes which got spoiled up to ~ 60 % by anthracnose and stem end rot infections.

- Prochloraz and hot water treatments affected less significantly the organoleptic and acceptability parameters of mango as evaluated by measuring fruit appearance, pulp colour/texture and taste/flavor. Properties pertaining to the quality and acceptability resemble with those of fresh fruits.

- Overall acceptibility parameters (AP) indicated that Mangoes stored at 13° C had better acceptability value of ~ 4.5 when compared to that of untreated fresh fruits which had a value of ~ 5.0. At 8° C however AP were less significant with a value of ~ 3.5.
• Results were substantiated by ethylene production rate where 0.6-2 μl/kg/L in untreated fresh fruits were reduced to 0.2 μl/kg/L and negligible level even after storing for 15–41 days at lower – 8°C temperature. Total soluble solids (TSS) and sugar (TS) observed at higher levels such as ~18% was reduced to insignificant levels during the storage condition revealing the compactness of the fruit and intactness of biochemicals in the fruit during optimized storage condition – 13°C envisaging the delay in the ripening process and the increase of longevity.

• Storing of fruits and vegetables in controlled atmosphere (CA) enriched with 5% CO₂ and low O₂ were found to be useful in general storage of fruits and vegetables. In mango, CA would protect fruits up to 45 days without changing the organoleptic and acceptability parameter in prochloraz and hot – water pretreatment condition. This was attributed to inhibition of disease incidence and protection against chilling injury.

• Results were further substantiated by inhibition of ethylene production rate and reduction in the accumulation of TSS and Total sugars. In addition climacteric surge of respiration was observed during the Post-CA ripening at ambient conditions, indicating the retention of quality assurance for natural type ripening process. Prochloraz and heat treated fruits without CA suffered from chilling injuries resulting in abnormal ripening.

• Effects of modified atmospheric package were studied on acceptability and longevity of Mango. Perforated and Non Perforated (NP) polypropylene (PP) and polyethylene (PE) bags were considered for packing. Tolerable CO₂ and O₂ concentrations were maintained nearest to the atmospheric gas – AIR in the perforated
PP and PE packs. PP and PE offered protection to fruits against chilling and CO₂ injury. Extent of protection offered was validated employing fruit acceptability and longevity parameters. Better protection was observed by PP and PE compared to that of NPPP and NPPE at 8°C than 13°C.

- Effect of temperature – 8°C and 13°C in Air and controlled atmospheric conditions were also examined on delaying of ripening, acceptability and longevity parameters of another important fruit Banana – Robusta. Acceptibility of fruits was also determined during artificial ripening condition via induction of ethylene by ethrel. Results indicated that ethrel treatment offered 2 fold higher acceptability (4.8) when compared to those allowed to ripe at control air at ambient condition (2.0). However longevity was only 7 days in the former when compared to 18 days in the later – control fruits. Storage of Banana at 8°C offered very poor quality of fruit with an acceptability parameter of ~1; while those stored at 13°C offered better property with a value of ~ 4.8.

- Storage of Banana at 13°C was improved under controlled atmospheric condition either at 5%O₂ + 5%CO₂ or 5%O₂ + 10% CO₂ levels with an acceptability parameter of ~ 4.7 when ripened at 25°C, even after storage up to 75 days suggesting the effect of CA treatment on Banana acceptability and longevity.
Table 1. Effect of prochloraz and hot water pre-treatments on organoleptic quality in mango during ripening at RT (26-33°C and 60-70% RH)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Organoleptic qualities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appearance</td>
</tr>
<tr>
<td>Prochloraz</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>HW treated</td>
<td>5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Un treated</td>
<td>3.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td>0.1</td>
</tr>
<tr>
<td>C.V %</td>
<td>5</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.3</td>
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</table>

Table 2. Effect of low temperature on organoleptic quality in mango during ripening at 8°C and 13°C

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Organoleptic qualities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appearance</td>
</tr>
<tr>
<td>8°C</td>
<td>3.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>13°C</td>
<td>4.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td>0.2</td>
</tr>
<tr>
<td>C.V %</td>
<td>12.1</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Table 3. Effect of CA storage on organoleptic quality in mango stored at 8°C

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Organoletic quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit app</td>
</tr>
<tr>
<td>Pro treated CA stored</td>
<td>4</td>
</tr>
<tr>
<td>HW treated CAS</td>
<td>4</td>
</tr>
<tr>
<td>Prochloraz treated air stored</td>
<td>2.7</td>
</tr>
<tr>
<td>HW treated air stored</td>
<td>2.6</td>
</tr>
<tr>
<td>UN treated air stored</td>
<td>2.5</td>
</tr>
<tr>
<td>SEM</td>
<td>0.14</td>
</tr>
<tr>
<td>C.V %</td>
<td>10.13</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.43</td>
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</table>

Table 4. Effect of CA storage on Total sugar and Starch content in mango

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total sugar (g/100g fresh weight)</th>
<th>Starch (g/100g fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matured Green at Harvest</td>
<td>4.48 (12.20) ^d</td>
<td>19.04 (25.86) ^a</td>
</tr>
<tr>
<td>Prochloraj treated post CA ripened</td>
<td>18.18 (24.21) ^a</td>
<td>3.1 (10.61) ^d</td>
</tr>
<tr>
<td>Hot water treated post CA ripened</td>
<td>18.2 (16.63) ^c</td>
<td>3.1 (10.61) ^d</td>
</tr>
<tr>
<td>Prochloraz treated air stored</td>
<td>16.4 (24.31) ^a</td>
<td>4.76 (10.72) ^c</td>
</tr>
<tr>
<td>Hot water treated air stored</td>
<td>16.48 (18.83) ^b</td>
<td>4.62 (18.52) ^b</td>
</tr>
<tr>
<td>Untreated air stored</td>
<td>16.32 (23.31) ^a</td>
<td>4.18 (12.34) ^c</td>
</tr>
<tr>
<td>SEM</td>
<td>0.52</td>
<td>0.56</td>
</tr>
<tr>
<td>C.V %</td>
<td>5.9</td>
<td>7.7</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>1.56</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Table 5. Effect of MAP on organoleptic quality in mango stored at 8°C

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Organoleptic quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appearance</td>
</tr>
<tr>
<td>PPP</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>NPPP</td>
<td>1.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>PPE</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>NPPE</td>
<td>1.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Open air</td>
<td>3.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td>0.08</td>
</tr>
<tr>
<td>C.V %</td>
<td>7.1</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 6. Effect of MAP on total sugar and starch in mango stored at 8°C

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total sugar (g/100g fresh weight)</th>
<th>Starch (g/100g fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M.G at Harvest</td>
<td>4.48 (12.20)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>19.00 (25.86)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PPP</td>
<td>16.86 (24.21)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.4 (10.61)&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>PPNP</td>
<td>8.24 (16.63)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.00 (20.21)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>PEP</td>
<td>16.96 (24.31)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.5 (10.72)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>PENP</td>
<td>10.44 (18.83)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.1 (18.52)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>CONTROL</td>
<td>15.68 (23.31)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.6 (12.34)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td>0.52</td>
<td>0.56</td>
</tr>
<tr>
<td>C.V %</td>
<td>5.94</td>
<td>7.7</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>1.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Table 7. Effect of MAP on organoleptic quality in mango stored at 13°C

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Appearance</th>
<th>Pulp color</th>
<th>Pulp texture</th>
<th>Taste</th>
<th>Flavour</th>
<th>Over all acceptability</th>
<th>CO₂</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP</td>
<td>3.3ᵇ</td>
<td>3.0ᵇ</td>
<td>3.0ᵇ</td>
<td>3.0ᵇ</td>
<td>4.0ᵇ</td>
<td>3.20ᵇ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPPP</td>
<td>2.20ᵈ</td>
<td>3.0ᵇ</td>
<td>1.0ᵈ</td>
<td>1.0ᶜ</td>
<td>2.0ᶜ</td>
<td>1.48ᶜ</td>
<td>++</td>
<td>Bitter</td>
</tr>
<tr>
<td>PPE</td>
<td>3ᶜ</td>
<td>1.0ᵈ</td>
<td>3.0ᵇ</td>
<td>3.0ᵇ</td>
<td>4.0ᵇ</td>
<td>3.20ᵇ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPPE</td>
<td>2.9ᶜ</td>
<td>2.0ᶜ</td>
<td>2.0ᶜ</td>
<td>1.0ᶜ</td>
<td>2.0ᶜ</td>
<td>1.78ᶜ</td>
<td>++</td>
<td>Bitter</td>
</tr>
<tr>
<td>Open air</td>
<td>4.6ᵃ</td>
<td>4.4ᵃ</td>
<td>4.4ᵃ</td>
<td>4.9ᵃ</td>
<td>4.60ᵃ</td>
<td>4.54ᵃ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEM</td>
<td>0.08</td>
<td>0.19</td>
<td>0.13</td>
<td>0.05</td>
<td>0.15</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.V %</td>
<td>7.1</td>
<td>16.0</td>
<td>12.7</td>
<td>3.87</td>
<td>10.54</td>
<td>15.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.25</td>
<td>0.57</td>
<td>0.4</td>
<td>0.13</td>
<td>0.5</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Total sugar (g/100g fresh weight)</td>
<td>Starch (g/100g fresh weight)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M.G. at Harvest</td>
<td>4.52 (12.26) d</td>
<td>19.04 (25.86) a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPP</td>
<td>14.68 (22.49) b</td>
<td>4.52 (12.24) d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPPP</td>
<td>7.82 (16.14) c</td>
<td>12.72 (20.88) b</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPE</td>
<td>14.32 (22.22) b</td>
<td>4.24 (11.78) d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPPE</td>
<td>8.3 (16.78) c</td>
<td>10.6 (19.00) c</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CONTROL</td>
<td>17.46 (24.7) a</td>
<td>1.96 (7.94) e</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEM</td>
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<td>8.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA @ 5 %</td>
<td>1.65</td>
<td>1.7</td>
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<td></td>
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</tbody>
</table>
Table 9. Effect of various post harvest treatments on organoleptic quality of banana

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Appearance</th>
<th>Pulp colour</th>
<th>Pulp texture</th>
<th>Taste</th>
<th>Flavour</th>
<th>Over all acceptability</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored at RT (untreated)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Starchy</td>
</tr>
<tr>
<td>Stored at RT (Ethrel treated)</td>
<td>3.6</td>
<td>4</td>
<td>4</td>
<td>4.7</td>
<td>5</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Stored at 13°C</td>
<td>5</td>
<td>4.5</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Stored at 8 °C</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Bitter and starchy</td>
</tr>
<tr>
<td>CAI 75 + 6 days RT</td>
<td>4.7</td>
<td>4.6</td>
<td>4.8</td>
<td>4.8</td>
<td>4.5</td>
<td>4.68</td>
<td></td>
</tr>
<tr>
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<td>4.6</td>
<td>4.6</td>
<td>4.9</td>
<td>4.7</td>
<td>4.6</td>
<td>4.66</td>
<td></td>
</tr>
<tr>
<td>CAI 75 + 5 days eth RT</td>
<td>4.5</td>
<td>4.7</td>
<td>4.8</td>
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<td>4.5</td>
<td>4.64</td>
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<tr>
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<td>4.8</td>
<td>4.5</td>
<td>4.8</td>
<td>4.8</td>
<td>4.6</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>SEM</td>
<td>0.16</td>
<td>0.23</td>
<td>0.15</td>
<td>0.17</td>
<td>0.26</td>
<td>0.11</td>
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</tr>
<tr>
<td>CD @ 5 %</td>
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<td>0.67</td>
<td>0.45</td>
<td>0.48</td>
<td>0.75</td>
<td>0.31</td>
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</tbody>
</table>

Table 10. Effect of various post harvest treatments on fruit pulp texture quality of banana

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fruit pulp texture (Kg/cm2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored at RT (untreated)</td>
<td>0.6</td>
</tr>
<tr>
<td>Stored at RT (untreated)</td>
<td>0.4</td>
</tr>
<tr>
<td>Stored at 13°C</td>
<td>0.7</td>
</tr>
<tr>
<td>CAI 75 + 6 days RT</td>
<td>0.54</td>
</tr>
<tr>
<td>CAII 75 + 6 days RT</td>
<td>0.52</td>
</tr>
<tr>
<td>CAI 75 + 5 days eth RT</td>
<td>0.52</td>
</tr>
<tr>
<td>CAII 75 + 5 days eth RT</td>
<td>0.54</td>
</tr>
<tr>
<td>SEM</td>
<td>0.05</td>
</tr>
<tr>
<td>C.V %</td>
<td>21.0</td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Table 11. Effect of various post harvest treatments on fruit pulp texture quality of banana

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total Sugar (g/100g fresh weight)</th>
<th>Starch (g/100g fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At harvest</td>
<td>18.5(25.5)</td>
<td>1.9(10.82)</td>
</tr>
<tr>
<td>Stored at RT (untreated)</td>
<td>3(9.88)</td>
<td>14(22.76)</td>
</tr>
<tr>
<td>Stored at RT (Ethrel treated)</td>
<td>0.4(3.84)</td>
<td>18.4(25.26)</td>
</tr>
<tr>
<td>Stored at 13°C</td>
<td>0.5(4.24)</td>
<td>18.2(25.24)</td>
</tr>
<tr>
<td>Stored at 8°C</td>
<td>18.48(25.5)</td>
<td>1.4(6.6)</td>
</tr>
<tr>
<td>CAI 75 + 6 days RT</td>
<td>0.4(3.91)</td>
<td>18.1(24.91)</td>
</tr>
<tr>
<td>CAII 75 + 6 days RT</td>
<td>0.46(4.12)</td>
<td>18.5(25.5)</td>
</tr>
<tr>
<td>CAI 75 + 5 days eth RT</td>
<td>0.41(3.94)</td>
<td>18.0(25.1)</td>
</tr>
<tr>
<td>CAII 75 + 5 days eth RT</td>
<td>0.42(3.98)</td>
<td>18.12(24.9)</td>
</tr>
<tr>
<td>SEM</td>
<td>0.4</td>
<td><strong>1.75</strong></td>
</tr>
<tr>
<td>C.V %</td>
<td><strong>10.3</strong></td>
<td><strong>18.8</strong></td>
</tr>
<tr>
<td>CD @ 5 %</td>
<td><strong>1.25</strong></td>
<td>5</td>
</tr>
</tbody>
</table>