Original Research Article

Effect of ethephon and storage temperature on physico-chemical changes during ripening of mango (*Mangifera indica* L.) Cv. Neelum

Abstract

Mango fruits Cv. Neelum treated with ethephon of different concentrations i.e. 250, 500, 750 and 1000 ppm for five minutes at different temperature conditions *viz*., 16, 20, 24 and 28 °C with 80% RH ripened in ripening chamber and untreated fruits kept at ambient temperature (30-34 °C). Then the mango fruits were analyzed for physico-chemical changes and sensory qualities. It was found that mango Cv. Neelum ethephon dip treatment placed in the ripening chamber triggered the ripening process and showed that the significant increasing trends in L*, a*, b* values of colour, TSS (°Brix), PLW (%), reducing sugars (%), pH and decreasing trends in firmness (N), acidity during ripening in all the treatment combinations during advancement of storage period in ripening chamber. It was observed that mango fruits Cv. Neelum ripened by ethephon dip treatment of 750 ppm for 5 minutes at 20 °C, 80% RH showed better results in respect of a high overall acceptability score of 8.50.

Keywords: Mango, Ethephon, Ripening, Physico-chemical changes

Introduction

Mango (*Mangifera indica* L.) belongs to the family *Anacardiaceae*, is considered as one of the choicest fruits of the world because of its attractive colour, delicious taste, and excellent nutritional value. Mango is the most important tropical fruit in India accounting for 2.29 million ha of an area with a production of 15.19 million tons and a productivity of 6.63 t ha-1. India is estimated to account for about 40 per cent of the world's mango production. (PIB, 2017). One-fifth of the total fruit produced in the country is mango next to Banana. Mango is one of the most extensively exploited fruit because of its flavour, fragrance and juice content. It is a good source of fiber, sugars, vitamins, and minerals along with anti-oxidants.

Fruit ripening is a genetically programmed stage of development overlapping with senescence (Watada *et al.*, 1984). Mango fruits ripen unevenly on the tree and the natural ripening process can be very slow and unpredictable. To overcome this problem, fruits can be ripened artificially by exposing the fruits to certain chemicals, which initiate the ripening process. (Campbell and Malo, 1969) found that the ripening of mature-green mangos was accelerated in response to ethylene released from 2- chloroethylphosphonic acid (Ethephon). Ethephon/ethrel is an ethylene-releasing chemical, which can be used to improve fruit colour development and stimulates ripening process of the fruit.

However, ripening of fruit generally is not completed on the tree because natural ripening is a long process. Ethylene is one of the natural ripening hormones which is responsible for accelerating the normal process of maturation, senescence and ripening. The use of ethylene gas helps in achieving faster and more uniform ripening of fruits (Kader, 2002). Ethylene gas is commercially applied in the form of liquid i.e. Ethephon. In the case of ethephon, the ripening is slightly cumbersome, the fruit sellers have to either dip the fruits in a solution or pass through fumes of this chemical (Siddiqui and Dhua, 2009; Kulkarni *et al*., 2004). In alkaline medium, ethylene is evolved from ethephon (Thompson and Seymour, 1982). The ripening of green mangoes was accelerated by 2-chloroethyl phosphonic acid (ethephon). Early and uniform ripening and colour development can be achieved by dipping of fruits in diluted ethephon (2-Chloroethyl phosphonic acid) solution which is recommended for a number of climacteric fruits including mango (Venkatesan and Tamilmani, 2013, Gupta *et al.,* 2015),

The ripening with ethephon treatment seems to hold promise to get good and uniform quality. In this technique, the fruits are dipped in different concentrations and placed in a ripening chamber for 24 h to induce the fruits to ripen. The most important thing in this technique is temperature and relative humidity control inside the ripening chamber which should range between 16-25 ^{0}C and 90-95% RH, depending upon the fruit type (Mahajan and Ghuman, 2010). And also, the ripening technology can be used at wholesale markets before distribution to retailers. Therefore, the present investigation was carried out to study the effect of different concentrations of ethephon at different temperatures on physico-chemical changes during ripening behaviour of mango Cv. Neelum.

Materials and Methods

The present research entitled "Effect of ethylene on physico-chemical changes during ripening of mango (*Mangifera indica* L.) Cv. Neelum." was carried out in the Process Engineering Laboratory, Department of Processing and Food Engineering, Dr. NTR College of Agricultural Engineering, Bapatla during the year 2018 - 2019. Physiologically mature, healthy green fruits at an optimum maturity of mango Cv. Neelum was collected from Agricultural Research Farm, Bapatla. Manually harvested fruits were washed with chlorinated water for further investigation. The ripening chamber made up of polyurethane foam panels having a thickness of 60 mm with a dimension of 3.6 x 3.0 x 3.6 m having the capacity to hold 3500-4000 kg of mango fruits.

The selected mango fruits Cv. Neelum was kept in the ripening chamber at Dr. NTR College of Agricultural Engineering, Bapatla. For the preparation of 250, 500, 750 and 1000 ppm of ethephon solutions, 0.64, 1.28, 1.92 and 2.56 mL of ethrel (2-Chloroethylphosphonic acid 39% aqueous solution under the brand name ethefol) respectively were dissolved in 1litre of distilled water. Uniform sized fruits were dipped in ethephon solution for 5 min and air-dried to remove excess moisture. Fruits treated with different concentrations such as 250, 500, 750 and 1000 ppm at different temperatures of 16, 20, 24 and 28 °C with relative humidity 90% in ripening chamber and control sample under ambient conditions (35 °C, 55-65% RH). Further, physico-chemical analysis of mango fruits was recorded at every two days interval.

Independent Variables

Treatments for mango fruits

- Temperatures – 16, 20, 24, 28 °C

Ripening agent

- Ethephon - 250, 500, 750 & 1000 ppm

Dependent Variables

Physico-Chemical Parameters - Physiological loss in weight, firmness, total soluble solids, pH, titratable acidity, reducing sugars, vitamin C and colour.

Sensory Analysis - 9 point hedonic scale

The physiological loss in weight (PLW) after each interval of storage was calculated by subtracting the final weight from the initial weight of the fruits and expressed in per cent. The fruit firmness was measured with the help of a fruit penetrometer (Model FT- 327, USA) using an 8 mm stainless steel probe. Total soluble solids (TSS) was determined by Hand refractometer and expressed in °brix. Reducing sugars and titratable acidity of fruits were recorded by a method as suggested by Ranganna (2010). Ascorbic acid of mango fruits were estimated by a method as suggested by using 2,6-dichlorophenol indophenol dye titration method of Sadasivam and Manickam, 2009. The pH measurement was determined by using a Digital pH meter (Model HI9810, Hanna Ins.). The colour of mango juice samples was measured using Hunter lab colour flex meter (M/s. Hunter lab, Reston, VA, USA; model

CFLX-45). The measurement was done with an illuminate observer combination of D65/10°. The surface colour was quantified in terms of L^*, a^* and b^* values of CIELAB colour space. Data were recorded after 2, 4, 6 and 8 days of storage. Sensory evaluation was carried out by ten untrained panelists based on acceptability, using the 9-point hedonic scale with a panel of ten judges.

Treatments

T1	Temp. - 16 °C, 250 ppm
T2	Temp. - 20 °C, 250 ppm
T3	Temp. - 24 °C, 250 ppm
T4	Temp. - 28 °C, 250 ppm
T5	Temp. - 16 °C, 500 ppm
T6	Temp. - 20 °C, 500 ppm
T7	Temp. - 24 °C, 500 ppm
T8	Temp. - 28 °C, 500 ppm
T9	Temp. - 16 °C, 750 ppm
T10	Temp. - 20 °C, 750 ppm
T11	Temp. - 24 °C, 750 ppm
T12	Temp. - 28 °C, 750 ppm
T13	Temp. - 16 °C, 1000 ppm
T14	Temp. - 20 °C, 1000 ppm
T15	Temp. - 24 °C, 1000 ppm
T16	Temp. - 28 °C, 1000 ppm

Results and Discussion

Weight loss

It was observed from Fig. 1 that the physiological loss in weight was significantly increased with the increase of ethephon concentrations. The maximum weight loss (19.0%) was observed in T15 on 8th day of storage whereas 10.5% in the control sample on the 11th day of storage. Similarly, the loss in weight of fruit during storage both at ambient and in the ripening chamber increased with the enhancement of storage days and was observed in pear (Dhillon and Mahajan, 2011) and papaya (Singh *et al.*, 2012). Continuous processes of respiration and transpiration have resulted in weight loss. Mangoes kept at higher temperatures showed greater weight loss than those at lower temperatures. Results indicated that the difference in total weight loss between ethephon treated and control sample increased with increase in temperature. The higher weight loss at higher temperatures could be related to the higher evapotranspiration rate and respiration rate at the higher temperatures as previously reported by Lebibet *et al*. (1995).

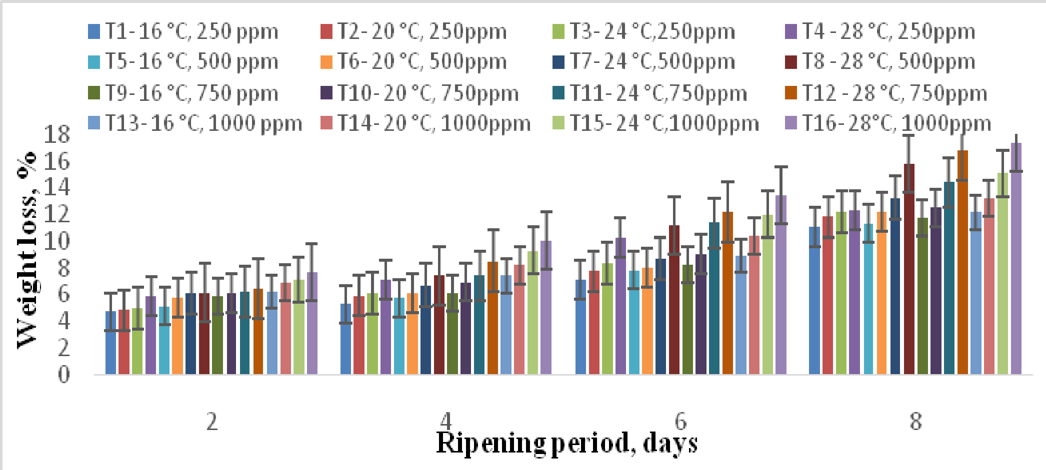

Figure 1. Effect of different concentrations of ethephon at different temperatures on weight loss during ripening of mango Cv. Neelum

Firmness

It was observed from Fig.2 fruit firmness decreases with an increase in temperature and concentration. At the initial stage, the firmness of mango fruit was found to be 15.83 N. Fruit firmness decreased with an increase in ethephon concentration and also decreased with days of storage. The maximum fruit firmness was observed in the control sample and minimum in treatment, T15 ethephon.

The decrease in firmness, during ripening, may be due to the breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability (Brinston *et al.*, 1988). The interaction between temperature and ethephon in firmness showed that differences in firmness between ethephon treated and control mango fruits were less at higher temperatures than at lower temperatures. The reason could be starch hydrolysis or conversion of sugars.

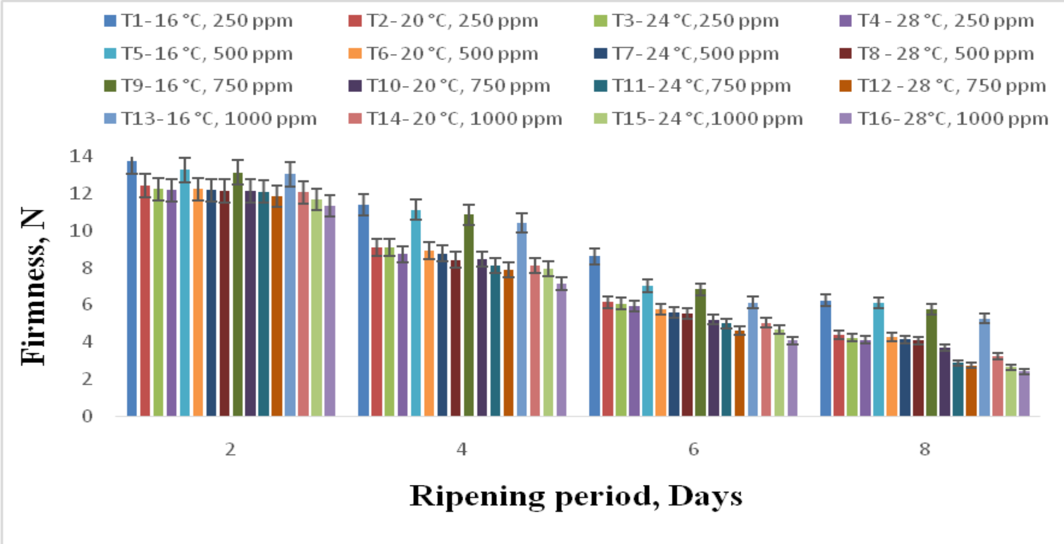

Figure 2. Effect of different concentrations of ethephon at different temperatures on firmness during ripening of mango Cv. Neelum

Total Soluble Solids

It was observed from Fig. 3 the total soluble solids increased with an increase in ethephon concentrations and increased with days of storage. The highest value of TSS was observed in 1000 ppm (20.14 °brix) during 8 days of storage period. Ethephon treated mangoes possessed greater TSS than the control sample. The TSS might be increased due to hydrolysis of starch, cellulose and pectin substances into simpler substances or might be due to a decrease in moisture content. Similar results were also reported by Sakhale *et al.*, (2006).

Mangoes kept at higher temperatures showed greater TSS than those at lower temperatures. The increase in TSS was the outcome of the conversion of carbohydrates into simple sugars through a complex mechanism during the storage and the conversion rate was increased with the increase in temperature. This conversion is also considered to be one of the important indexes of the ripening process in mango and other climacteric fruit (Doreyappy-Gowda and Huddar, 2001; Kays, 1991; Kittur *et al.*, 2001).

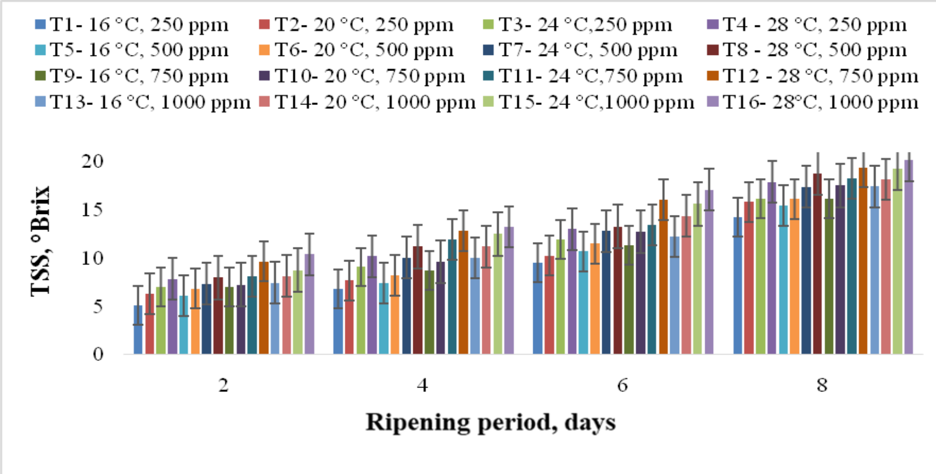

Figure 3. Effect of different concentrations of ethephon at different temperatures on total soluble solids during ripening of mango Cv. Neelum

Titratable acidity

It is observed from the Fig.4 that acidity of the mango fruit was decreased by post harvest application of ethephon and the response varied within the concentrations. A maximum decrease (0.18%) in total acidity was found in T16 on 8th day of the storage treatment. The result indicates that the acidity content declined significantly with the increase in days of storage. Riberau-Gayon (1968) suggested that the transformation of organic acids into sugars may be the reason for decreasing organic acids during fruit ripening. The titratable acidity was also decreased with the increase in storage temperature. The decrease in acidity was attributed to the conversion of citric acid into sugars and their further utilization in the metabolic process of the fruit (Doreyappy-Gowda and Huddar, 2001; Mizrach *et al.*, 1997; Rathore *et al.*, 2007; Srinivasa *et al.*, 2002).

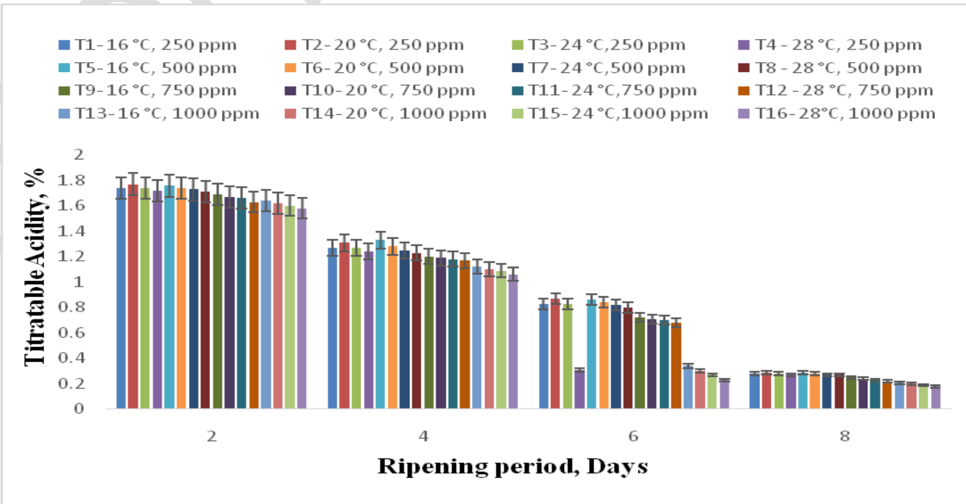

Figure 4. Effect of different concentrations of ethephon at different temperatures on titratable acidity during ripening of mango Cv. Neelum

Reducing sugars

The results revealed that the sugar content increased with increasing ethephon concentration and storage temperatures as shown in Fig. 5. The maximum reducing sugar content (6.26%) was observed in T16 on 8th day of storage. The values of sugar content increased up to 8 days. In the present experiment, ethephon enhanced the rate of accumulation of reducing sugars in mango fruits. Similarly, a high percentage of sugar with ethephon application was observed by Singh *et al*., 2012 in mango. It was due to the faster rate of respiration and the formation of sugar content with the oxidation of carbohydrates.

From the Fig. 5, it was also observed that the reducing sugar content was lowest for samples stored at 16 °C and highest for samples stored at 28 °C. The increasing trend may be the polysaccharides were converted into soluble sugar through a hydrolytic conversion process, which was sensitive to temperature and/or to sunlight exposure for climacteric fruits during the ripening process (Campestre *et al.*, 2002; Kays, 1991; Martinez *et al.*, 1997).

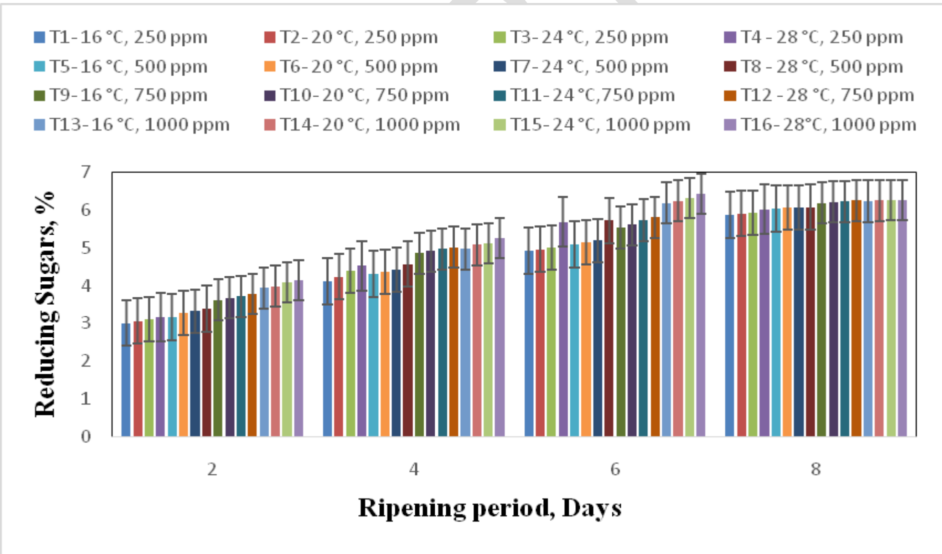

Figure 5. Effect of different concentrations of ethephon at different temperatures on reducing sugars during ripening of mango Cv. Neelum

Ascorbic acid

It was observed from Fig. 6 that the ascorbic acid increased with an increase in ethephon concentrations and decreased with days of storage. The minimum value of ascorbic acid content (40.08 mg/100 g) was observed in T1 on 8th day of storage. The values of ascorbic acid content decreased up to 8 days. A decline in the ascorbic acid content of the mango fruits might be due to the utilization of ascorbic acid in the respiration process during ripening at ambient conditions. A similar trend was also observed by Sakhale *et al.*, (2006), William *et al.*, (2009), Pandarinathan and Sivakumar (2010), in mango fruits.

Further, it is also observed that the ascorbic acid was decreased with the ripening of the fruit or with the increase in storage temperature. This trend was due to conversion of acid into sugars and their further utilization in metabolic process of the fruit and that the chemical and biological process was increased with the increase in storage temperature (Doreyappy-Gowda and Huddar, 2001; Mizrach *et al*., 1997; Rathore *et al*., 2007; Srinivasa *et al*., 2002).

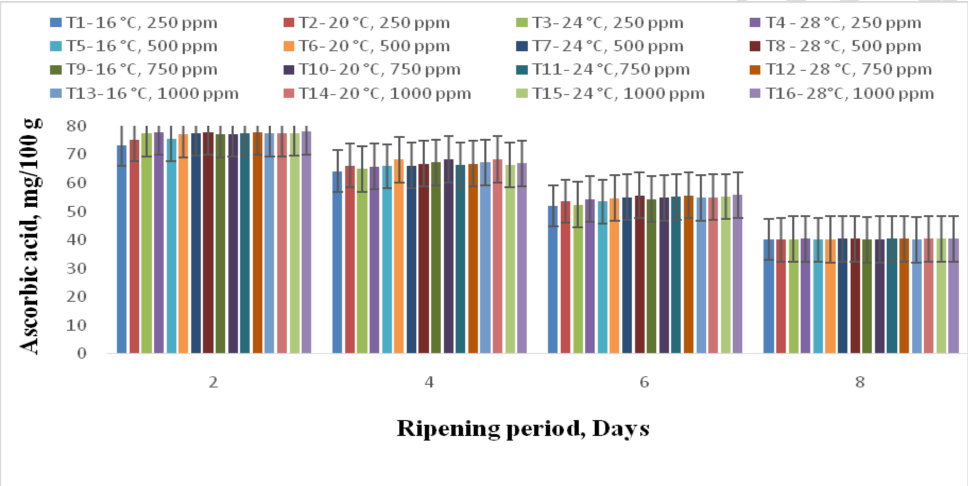

Figure 6. Effect of different concentrations of ethephon at different temperatures on ascorbic acid during ripening of mango Cv. Neelum

pH

The results revealed that the pH increased during ripening and decreased with an increase in ethephon concentrations. as shown in Fig.7. The pH value of the control sample is 4.1. The pH value of mango Cv. Neelum fruits are in the range of 4.3-7.3. Also, results indicated that the pH increased with an increase in storage temperatures during the ripening of mango fruits. These observations were attributed to the conversion of citric acid and ascorbic acid into sugar and other products with the ripening process and whose rate of conversion was increased with the temperature (Absar *et al.*, 1993; Kumar and Singh, 1993; Rathore *et al.*, 2007; Yuniarti, 1980).

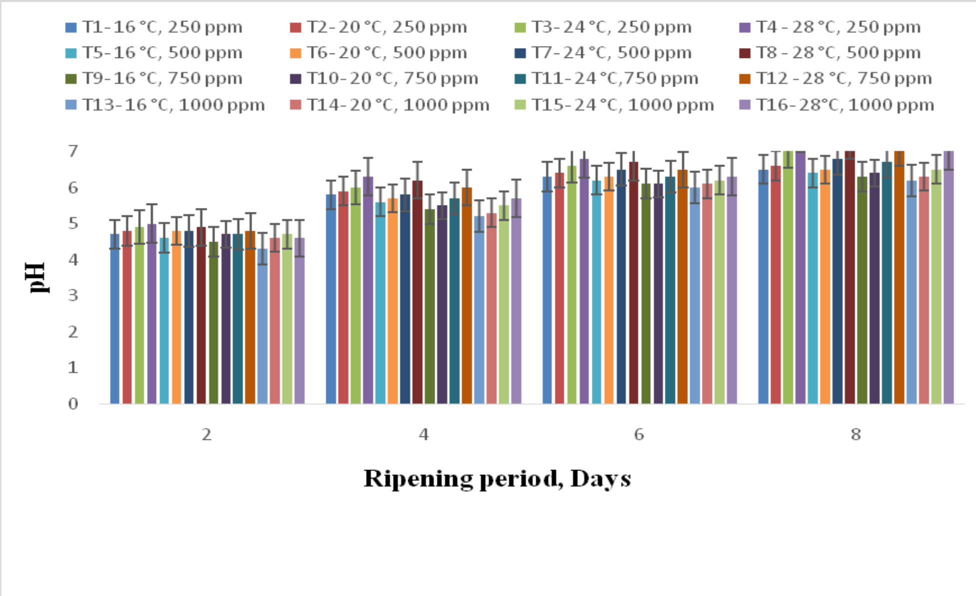

Figure 7. Effect of different concentrations of ethephon at different temperatures on pH during ripening of mango Cv. Neelum

L* value for colour (Lightness)

It was observed from Fig. 8 that the L* value for colour (Lightness) increases with increase in ethephon concentration as well as storage temperature during the enhancement of storage period in mango fruits. At the initial stage, the L* value of mango fruit was found to be 36.43. At the end of the 2^{nd}, 4^{th}, 6^{th} and 8^{th} day of storage, treatment T15 recorded the highest L* value (51.47, 52.72, 56.04). This is because of the fact that ethylene effects on the tissue and degreening of fruits. As the ethylene or ethephon triggered the ripening process, there is a rapid change in the colour from dark (green) to lightness (yellow) and it increased during the period of storage. Similar findings were reported by Daware (2012), Deepa and Preetha (2014) and Gill *et al.* (2015) in Dusehari mango fruits. Mangoes ripened at higher temperatures were significantly less green than those at lower temperatures.

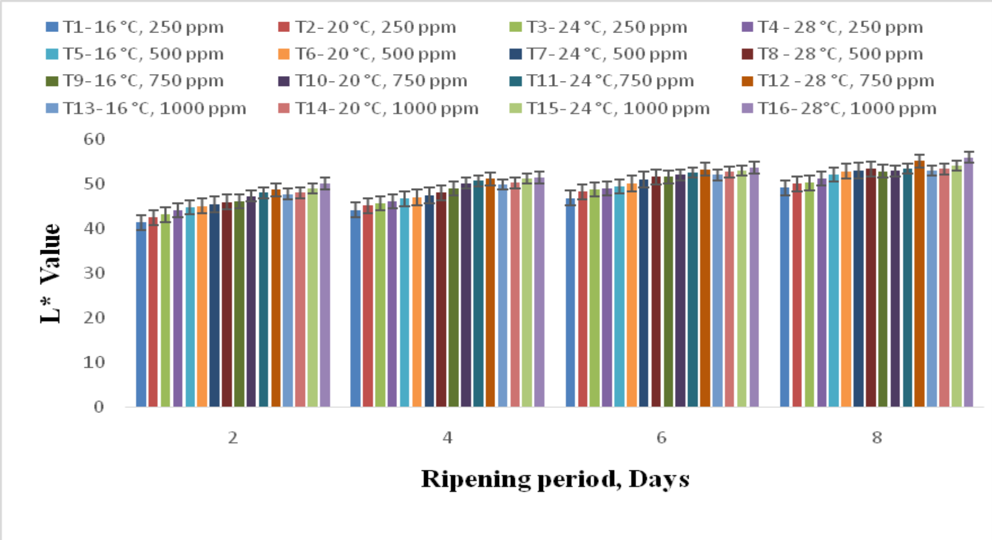

Figure 8. Effect of different concentrations of ethephon at different temperatures on L* during ripening of mango Cv. Neelum

a* and b* value (Redness/Greenness and Yellowness)

The results revealed that the a* and b* value increased during ripening with the increase in ethephon concentrations and storage temperatures as shown in Fig. 9 & 10. At the initial stage, a* and b* value of mango fruit was found to be -11.12 and 25.51. It was also observed that a* values for colour were less in untreated fruits in all days. This might be due to the breakdown of chlorophyll leading to the disappearance of green colour. During ripening, the peel colour changed from dark green to bright yellow and this is due to the change in chlorophyll which gradually unmasked the carotenoid pigments present in unripe mango fruits. As the ethylene triggered the ripening process, there was a rapid change in the colour from dark (green) to redness and it increased during the period of storage. Similarly, the b* values for colour were lower in untreated fruits i.e. control sample at all days. This might be due to changes during ripening period (loss of greenness, increase in redness and yellowness) occurred as a result of the breakdown of the chlorophyll in the peel. Similar findings were also reported by Daware (2012), Deepa and Preetha (2014), Gill *et al*. (2015) in mango fruit.

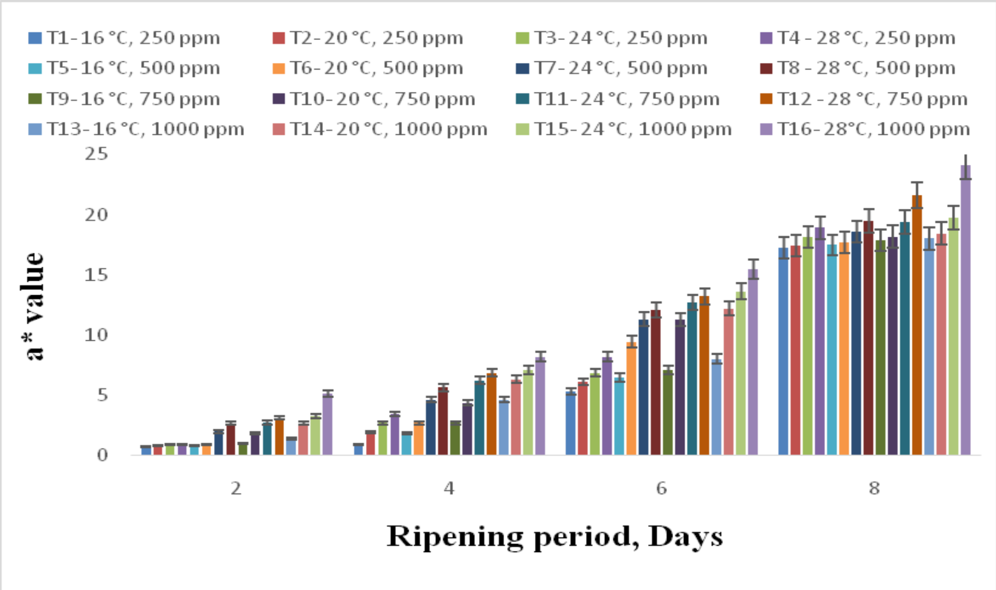

Figure 9. Effect of different concentrations of ethephon at different temperatures on a* value during ripening of mango Cv. Neelum

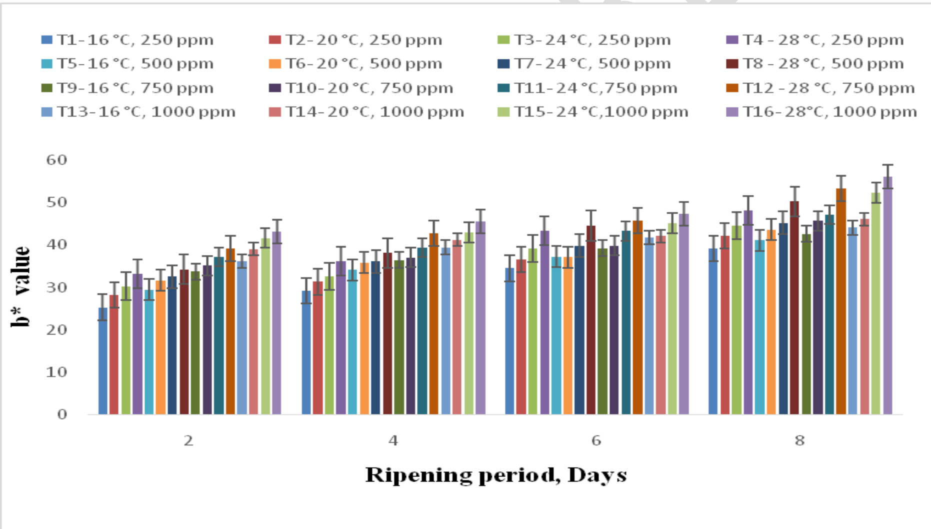

Figure 10. Effect of different concentrations of ethephon at different temperatures on b* value during ripening of mango Cv. Neelum

Organoleptic evaluation at ripening

The data (scores) on the organoleptic evaluation of Neelum mango fruits are presented in Table 1. It could be revealed from the data that fruits ripened at ethephon, 750 ppm, 20 °C temperature, 80% RH (T10) recorded maximum (8.50) sensory score in overall acceptability. The mango fruits ripened at ambient temperature (control) recorded the lowest 6.25 as overall acceptability.

Table 1 Effect of various treatments on organoleptic evaluation during ripening of mango Cv. Neelum fruits

Treatments	Colour	Flavour	Taste	Texture	Overall acceptability
Control	6.00	7.00	6.00	6.00	6.25
T1	7.50	7.50	7.25	8.00	7.56
T2	7.50	7.50	8.00	8.00	7.75
T3	8.00	7.50	7.50	8.00	7.75
T4	8.00	8.00	7.50	8.00	7.88
T5	7.50	8.00	7.50	8.00	7.75
T6	7.50	7.50	7.50	8.00	7.63
T7	8.25	8.00	7.50	7.65	7.85
T8	7.65	8.25	8.00	8.00	7.98
T9	8.50	8.25	8.00	8.25	8.25
T10	8.50	8.75	8.50	8.25	8.50
T11	8.50	8.00	8.50	8.25	8.31
T12	8.50	8.75	8.50	8.25	8.50
T13	8.45	8.00	8.00	8.00	8.11
T14	7.65	8.25	8.00	8.00	7.98
T15	8.50	8.00	8.50	8.25	8.31
T16	8.50	8.25	8.00	8.25	8.25

Conclusion

It was found that mango Cv. Neelum ethephon dip treatment triggered the ripening process. It was also noticed that more the concentration of ethephon, faster was the ripening process and showed the significant increasing trends in L*, a*, b* values of colour and PLW (%) and decreasing trends in firmness (N) in all the treatments during advancement of the storage period in ripening chamber. It was observed that mango fruits Cv. Neelum ripened in ripening chamber in 8 days whereas fruits ripened at ambient conditions in 12 days. Similarly, mango fruits Cv. Neelum ripened by ethephon dip treatment of 750 ppm at 20 °C, 80% RH for 5 minutes showed better results in respect of high overall acceptability score of 8.50.

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