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Effect of Ethrel (ethylene) on Ripening of Mango var. Banganapalli

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Commercial handling of 'Banganapalli' mangoes is burdened by lack of uniformity in ripening of the fruits. A viable approach to overcome this problem could be application of ethylene. Mango (var. Banganapalli) fruits harvested at 75 per cent maturity were exposed to 50, 100 and 150 ppm for 15, 20 and 25 h and subsequently, ripened at 16 ± 2ºC, 23 ± 2ºC and 30 ± 2ºC. Ripening was enhanced in all the treated fruits at all concentrations used. The ripening rate progressively increased with increase in ethylene concentration. Depending on the concentration, ripening was achieved in 4-6 d earlier, when compared to untreated fruits. Untreated control mango fruits remained shriveled, green and failed to ripen uniformly, even after 8 d of storage. Fruits treated with 150 ppm of ethylene for 25 h at 23 ± 2ºC induced uniform ripening without impairing the taste and flavour of mango. The effect on fruit ripening was assessed by change in peel colour, increase in total soluble solids and decrease in flesh firmness and acidity.

Key words: Ethylene, Firmness, Maturity, Quality, Ripening

Mango (*Mangifera indica L.*) is one of the major fruit crops of India and is also known as 'King of Fruits'. It has delicious taste, excellent flavour and attractive fragrance besides, Vitamin A and C. India ranks first among world's mango producing countries with a total production of 11 million tonnes a year. The export of mango rose to 1,04,350 tonnes in 2014-2015 as compared to 90,000 tonnes in 2013-2014 (NHB, 2015). Despite the fast rate of market expansion for mangoes, a problem of heterogeneous ripening among fruits from the same lot has been reported. This postharvest problem affects consumer acceptability, despite its delicious flavour.

Ethylene plays a very important role in regulation of fruit ripening. Ripening reactions controlled by ethylene can be increased by exposure of the fruit to an atmosphere containing exogenous ethylene in order to produce homogeneous external colour . The use of ethylene gas in achieving faster and more uniform ripening of fruits is well documented (Kader, 2002). Many scientists duplicated the effects of ethylene gas by use of aqueous solutions of ethrel (2-chloroethyl phosphonic acid). Ripening is promoted in many harvested fruits by dipping in 500 to 2000 ppm ethrel in aqueous solution (Mohammed and Goukh, 2003). In the presence of alkaline medium ethylene evolves from ethrel. Studies were conducted to evaluate the effect of ethrel in aqueous solution and ethylene gas liberated from ethrel in an alkaline medium on mango fruit ripening.

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Materials and Methods

Mature green mango fruits of variety Banganapalli were collected from the orchard at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The harvest maturity for mangoes was assessed by the following morphological characteristics such as fruit length, diameter, mass, volume, surface area and specific gravity. The selected fruits were uniform in size, colour and found free from blemishes. The fruits were washed, air dried and exposed to different treatments *viz.,* T_1 to T_{27} – ethylene treated fruits, T_{28} – control (untreated fruits) and T_{29} – acetylene treated fruits (commercial practice).

T_1 - 16ºC, 15 h & 50 ppm	T_{10} - 23ºC, 15 h & 50 ppm	T_{19} - 30ºC, 15 h & 50 ppm
T_2 - 16ºC, 20 h & 50 ppm	T_{11} - 23ºC, 20 h & 50 ppm	T_{20} - 30ºC, 20 h & 50 ppm
T_3 - 16ºC, 25 h & 50 ppm	T_{12} - 23ºC, 25 h & 50 ppm	T_{21} - 30ºC, 25 h & 50 ppm
T_4 - 16ºC, 15 h & 100 ppm	T_{13} - 23ºC, 15 h & 100 ppm	T_{22} - 30ºC, 15 h & 100 ppm
T_5 - 16ºC, 20 h & 100 ppm	T_{14} - 23ºC, 20 h & 100 ppm	T_{23} - 30ºC, 20 h & 100 ppm
T_6 - 16ºC, 25 h & 100 ppm	T_{15} - 23ºC, 25 h & 100 ppm	T_{24} - 30ºC, 25 h & 100 ppm
T_7 -16ºC, 15 h & 150 ppm	T_{16} - 23ºC, 15 h & 150 ppm	T_{25} - 30ºC, 15 h & 150 ppm
T_8 - 16ºC, 20 h & 150 ppm	T_{17} - 23ºC, 20 h & 150 ppm	T_{26} - 30ºC, 20 h & 150 ppm
T_9 - 16ºC, 25 h & 150 ppm	T_{18} - 23ºC, 25 h & 150 ppm	T_{27} - 30ºC, 25 h & 150 ppm

Respective concentrations of ethrel solution were prepared in a beaker and NaOH pellets were added. These beakers were kept in an air tight chamber (27 no's) separately and closed immediately to prevent the leakage of ethylene. The chambers were opened after 15, 20 and 25 h of exposure to ethylene gas. After exposure, the fruits were kept at 16 ± 2ºC,

23± 2°C and 30 ± 2°C for further ripening. The experiment was carried out in a completely randomized block design with three replications.

Peel colour changes

Peel colour changes were determined daily in the ripened fruits in each treatment. The colour of mangoes in terms of L*, a*, b* values were determined using colour flex meter (Model: 45°/0°, M/s Hunter Lab, Reston, Virginia, USA). Mango samples were cut longitudinally and the colour was measured in three places in each sample. Average values were recorded.

Physiological loss in weight (PLW)

Fruits were weighed before and after ripening in an electronic balance. Physiological loss in fruit weight was calculated by the formula given below,

$$\text{Physiological loss in weight (\%)} = \frac{W_i - W_f}{W_i} \times 100$$

where, W_i = initial weight and W_f = weight at the final day of ripening.

Fruit flesh firmness

Flesh firmness was determined on three fruits picked at random from each lot, every day during ripening. Flesh firmness was measured by fruit pressure tester (Elixir Technologies, Bangalore). The instrument has one cm long probe with a cylinder (3 mm diameter). A square peel of 2 × 2 cm was removed and placed on the platform, plunger was pressed against the fruit until the tip was penetrated into the pulp, up to the notch present in the probe. Two readings were taken from opposite sides on each fruit after the peel was removed. Flesh firmness was expressed in Newton.

Total soluble solids

Total soluble solids (TSS) percentage was measured using refractometer. TSS were determined daily on the same fruits used for determining flesh firmness. TSS were determined directly from the fruit juice, using a digital hand held refractometer (ATAGO, Co Ltd, Japan). Three readings were taken from each fruit and the mean values were calculated and expressed as °Brix.

Acidity

pH is a measure of active acidity, which influences the flavour or palatability of a product and affects the processing requirements. The pH value was determined in the samples by using a digital pH meter and standardized with double distilled water (pH 7.0) and pH standards (5.0 and 8.5). Three fruits were selected randomly and pulped using a mixer grinder for measuring the pH.

Organoleptic evaluation

The fruits after ripening were given to a panel of semi-trained judges to assess the appearance of pulp, colour, flavour, texture, taste and overall acceptability using 9-point Hedonic scale. The scores marked by the panelists were collected and the average was calculated for each parameter and subjected to statistical analysis.

Statistical analysis

Statistical analysis was carried out to study the effect of different parameters on all the dependent variables by Factorial Completely Randomized Block Design (FCRD) using the statistical software AGRESS. Analysis of variance (ANOVA) was conducted to determine whether significant effect exists among temperature, concentration and exposure time on ripening of fruits.

Results and Discussion

Physical characteristics of mango

The physical characteristics of mango fruits was observed by following non destructive method of measurement such as fruit length, diameter, mass, volume, surface area, mass to surface area ratio and specific gravity. Maturity indices of mango var. Banganapalli are presented in Table 1. It was observed from the table that the average length, diameter, mass, volume, surface area, mass to surface area ratio and specific gravity of the mango fruit were 17.8 cm, 8.35 cm, 357.7 g, 370.7cc, 382.7cm^2, 0.93 g cm^{-2} and 1.02, respectively. Similar results with fruit length of 16.2

Table 1. Physical characteristics of mango *var.* Banganapalli

S.No	Length (cm)	Diameter (cm)	Mass (g)	Volume (cc)	Surface area(cm^2)	Mass to Surface ratio	Specific gravity
1	16.0	8.1	350	363	375	0.93	1.02
2	17.5	8.3	352	364	377	0.93	1.01
3	16.5	8.2	352	365	378	0.93	1.03
4	17.0	8.2	354	367	380	0.93	1.00
5	19.0	8.5	358	372	382	0.94	1.02
6	18.5	8.5	359	371	384	0.93	1.01
7	18.7	8.6	361	374	385	0.94	1.00
8	18.3	8.3	363	376	387	0.94	1.01
9	18.0	8.4	364	377	389	0.94	1.02
10	18.5	8.4	364	378	390	0.93	1.03
Mean ± S.E	17.8 ± 0.11	8.35 ± 0.08	357.7 ± 0.59	370.7 ± 0.62	382.7 ± 0.57	0.93 ± 0.01	1.02 ± 0.05

cm, diameter of 7.5 cm, fruit mass of 363.4 g, fruit volume of 375.8 cc, fruit surface area of 381.4 cm^2, mass to surface area ratio of 0.91 g cm^{-2} and specific gravity of 1.02 were reported for the Kesar variety of mangoes by Kapse and Katrodia (1997).

Ripening of mango

Ethylene released from ethrel triggered fruit ripening at all concentration used; the higher the concentration, the faster was the ripening. The

Table 2. Organoleptic evaluation of mango fruits

Parameters	Treatments										
	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	T_{18}	T_{28}	T_{29}
Appearance	7.8	8.4	8.0	8.3	8.3	8.2	8.2	8.0	8.5	6.9	8.1
Colour	8.0	8.3	8.3	8.4	8.4	8.3	8.5	8.4	8.4	6.7	8.0
Texture	7.8	8.5	8.0	8.1	8.1	8.0	8.3	8.2	8.5	7.1	8.1
Flavour	8.0	8.0	8.0	8.3	8.3	8.0	8.1	8.1	8.4	7.1	8.0
Taste	8.0	8.1	8.0	8.2	8.2	8.0	8.4	8.3	8.4	7.2	7.8
Overall acceptability	8.1	8.3	7.8	8.3	8.3	8.1	8.3	8.2	8.4	7.0	8.0

optimization parameters for ripening mango fruits using ethylene treatment was based on the appearance, firmness, overall acceptability and the number of days to attain the bright yellow colour. The treatments T_{10} to T_{18} took 5 d to attain the bright yellow colour. The firmness value for these treatments ranged between 8.8 and 18.6 N and the overall acceptability was in the range of 7.8 to 8.4.

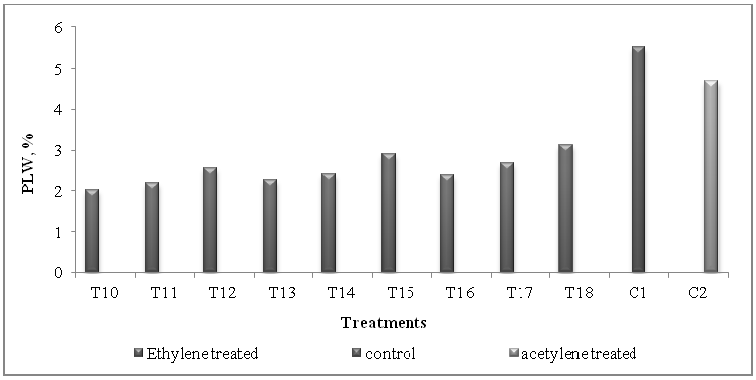

Fig. 1. Effect of ethylene on physiological loss in weight of mango fruits

The treatments T_{10} to T_{18} satisfied all the factors such as appearance, firmness, overall acceptability and the number of days to attain the bright yellow colour. Hence, these treatments have been adjudged to have the optimum process parameters for ripening mango fruits using ethylene. For these optimized treatments, the physicochemical changes were compared with that of control (T_{28}) and acetylene

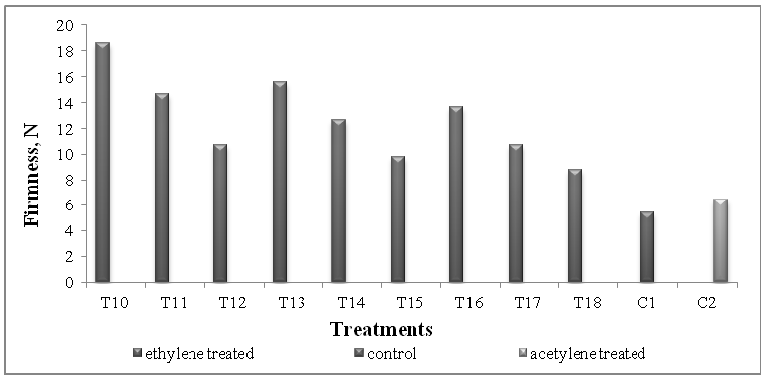

Fig. 2 Effect of ethylene on firmness of mango fruits

treated (T_{29}) fruits in terms of physiological loss in weight, firmness, colour, pH and TSS and organoleptic evaluation.

Effect on physiological loss in weight

Weight loss during ripening is an important factor which adversely affects the appearance, flavour and marketability of fruits. Physiological loss in weight is due to water loss through cuticle. Evaporation of water from outer surface causes drawing of water from the epidermal cells by mass flow through the liquid water phase of cuticular membrane to the air

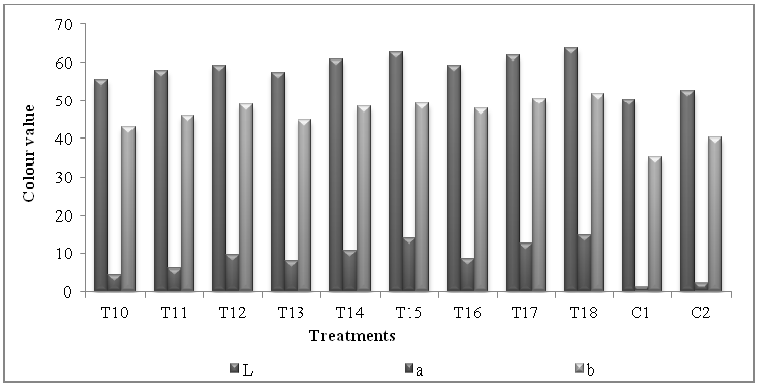

Fig. 3. Effect of ethylene on colour value of mango fruits

water interface at the surface. It is observed from the table that the mango fruits ripened with ethylene recorded the lowest weight loss than the mangoes ripened commercially. The treatments *viz.,* T_{10} to T_{18} recorded the weight loss which ranged from 2.01 to 3.13 per cent, respectively (Fig. 1). Mahajan *et al.* 2008 reported an increased weight loss in guava fruits during ripening process caused by ethylene application. The control and acetylene ripened mango fruits recorded the highest weight loss of 5.50 and 4.78 per cent. This higher loss in control sample might be due to the higher rate of

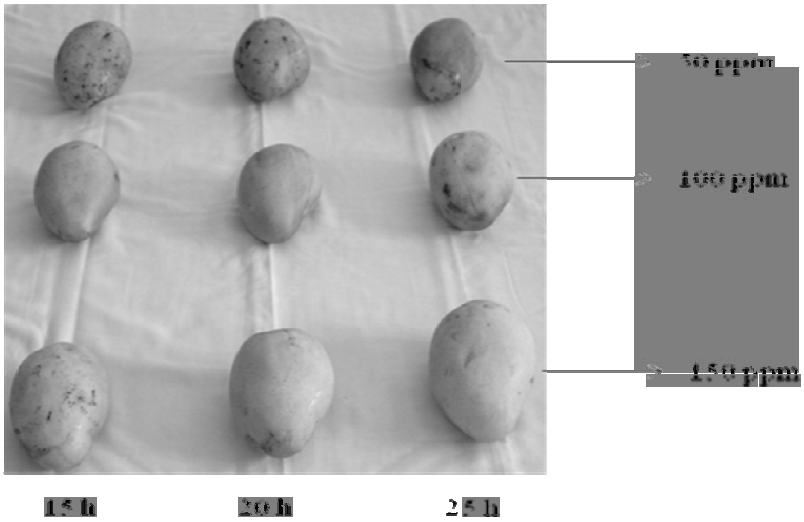

Fig. 4. Ethylene treated mango fruits

metabolism at higher temperatures. Similar studies showed the increase in physiological loss in weight during ripening of tomato fruits with ethephon and ethylene, may be due to upsurge in respiration rate of the fruits. An increase in weight loss in banana fruits during ripening process was caused by ethephon (Mahajan *et al.,* 2010).

Effect on fruit flesh firmness

Texture is one of the important quality parameter in sensory evaluation, which plays an important role at the time of selection of fruit by consumer. Pectic substances are structural polysaccharides responsible for the firmness of fruits and softening of the fruit occurs when these pectin polymers become less tightly bound in the cell walls during ripening (Kudachikar *et al*., 2001). The loss of pectin substance in the middle lamella of the cell wall is perhaps the key steps in the ripening process that leads to the loss of cell wall integrity thus, cause loss of firmness and softening. From the Fig 2, it is observed that the highest firmness value (18.6 N) was recorded in T_{10} and the lowest value in control (5.40 N). The acetylene ripened mango fruits showed a firmness value of 6.40 N. The decrease in firmness during ripening might be due to breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability. The softening of mango fruit under the commercially ripened method was higher and therefore, recorded the lowest firmness value when compared to the treated samples. Further, softening of fruits is related to a change in cell wall component and starch degradation. The starch granules, packed in the tissue of mango flesh give rise to the toughness of the unripe fruit and are

hydrolyzed to sugar during ripening. Similar result was reported by Sudhakar and Gopalakrishna (2009) for the ripening of mango.

Effect on peel colour

Changes in 'L' value

The major quality characteristic that create attraction towards the fruit is its colour (Fig. 3). The colour of mango changed from green to yellow as the ripening progressed with increased level of ethylene exposure. An uneven colour change was observed in the mango fruits ripened under commercial method. The change in lightness (L) value was more in the ethylene treated mango fruits than in control. The treatments T_{10} to T_{18} registered the 'L' value in the range of 55.47 to 63.87, respectively, while in control it was 50.20 and acetylene ripened mango fruits showed 52.71.

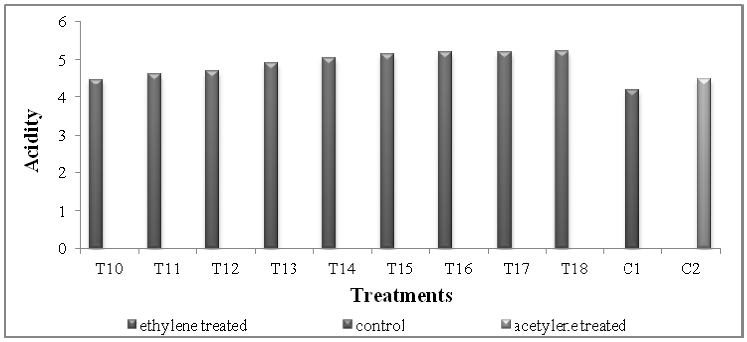

Fig. 5. Effect of ethylene on acidity of mango fruits

Changes in 'a' value

Mango skin colour is important for its role in perception of overall quality (Aguilar *et al.,* 2001), also important for determining appropriate maturity for harvesting, processing and consumption. This loss of green colour is an obvious sign of fruit ripening in mango cultivars. Colour changes are due to the disappearance of chlorophyll and the appearance of other pigments. The ethylene gas and ethephon treatments are known to accelerate the chlorophyll degradation or synthesis of carotenoids by stimulating the synthesis of chlorophyllase enzyme in calamondin tissue, which is responsible for chlorophyll degradation and expression of • carotene pigments that induces yellowness in green tissue of many fruits (Reyes and Paull, 1995 and Mahajan *et al.,* 2008). The highest 'a' value of 14.74 was observed in T_{18} and it was the lowest in control (1.13).

Changes in 'b' value

The increase in the yellowness value ('b') in the treatments T_{10} to T_{18} ranged from 42.87 to 51.92, respectively, whereas it was 35.16 in control and 40.23 in acetylene ripened mango fruits. Similarly, ethrel treated 'Neelam' mangoes developed yellow, colour in the peel portion on 6th d and colour change increased faster during ripening as compared to control, which took 8 d to turn yellow on peel (Kulkarni *et al.,* 2004). Ripening of mango using ethylene changed the peel colour from green to yellow which was related to increase in the 'a' and 'b' values. These 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 (Fig.4). Similar results were reported by Sergent *et al.,* (1993) for mango, where the high ethylene concentration of 1000 ppm accelerated colour development in the peel to a maximum of 88 per cent compared to those ripened with a concentration of 500 ppm, which was 79 per cent.

Effect on acidity

The treatment T_{10} to T_{18} registered the pH value in the range of 4.47 to 5.21, respectively is presented in Fig.5. A little change in pH was recorded in control (4.17) and acetylene ripened (4.50) mango fruits during ripening. Increase in ripening period degraded the citric acid content of the fruits ultimately, increasing the pH (Lalel *et al.,* 2003).

Effect on TSS

The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss. Increase in TSS during fruit ripening is due to the hydrolysis of starch to sugars. This increase in TSS might be due to the alteration in cell wall structure and break down of complex carbohydrates into simple sugars during storage and ripening (Kittur *et al.,* 2001). Fig.6 shows that the treatment T_{18} attained the maximum TSS value of 20^{o}B followed by T_{17}, with a value of 19.8^{o}B. While, the untreated mango fruits showed a minimum value of 15.1^{o}B. Kulkarni *et al.* (2004) reported an increase in TSS in mango fruits treated with ethrel. This increase may also be due to numerous anabolic and catabolic processes taking place in the fruit, preparing it for senescence.

Organoleptic evaluation

The panel of semi trained judges perceived differences between mangoes ripened using

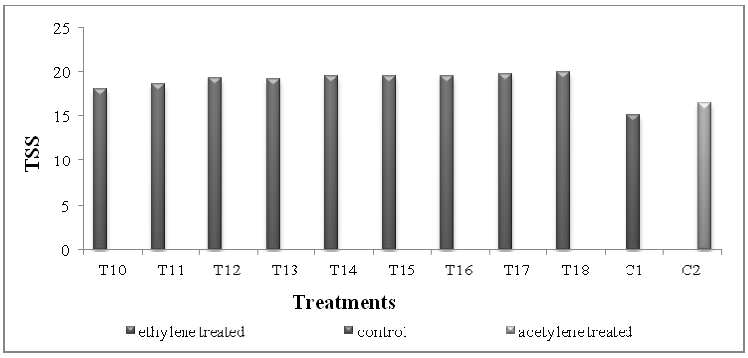

Fig. 6. Effect of ethylene on TSS of mango fruits

ethylene and mango ripened under commercial method and the scores are presented in the Table 2. The descriptive sensory evaluation revealed that the fruits treated with ethrel solution recorded the overall acceptability score in the range of 8.1 to 8.4. However, the control fruits remained partially ripe with an overall acceptability score of 7.0. The improvement in sensory quality with ethylene gas or ethephon treatments may be due to the role of ethylene or ethephon in promoting changes, which are important to flavour quality and formation of aroma volatile in climacteric fruit (Kulkarni *et al.,* 2004). There was also a significant increase in the aroma and juice of passion fruit during ripening due to increase in certain volatile compounds, which act as precursors for aroma in the fruit cells (Kishore *et al.,* 2006).

Conclusion

Ethylene released from ethrel in alkaline medium triggered fruit ripening in mango fruits at different concentrations used. The technique of using ethylene released from ethrel in an alkaline medium, recommended in this study is simple, easy, safe, less expensive and more effective than dipping fruits in aqueous solution of ethrel. From this study, it can also be concluded that mango fruits exposed with 150 ppm ethylene for 25 h and subsequently ripened at 23°C could be the best among different treatment combinations.

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