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Ripening Behaviour of Banana with Different Sources of Ethylene

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A B S T R A C T

Present experiment laid out in Completely Randomized Design with seven treatments and three replications was carried out at Banana Research Station, Jalgaon (M.S.) during the year 2015-16. Ethylene gas and Ethephon were used as the sources of ethylene. There were three concentration of each ethylene gas and ethephon *viz*. 50, 100 and 150 ppm. Ethylene gas treated fruits were kept in the ripening chamber up to 36 hrs.at20^{0}C and 85-90 % RH. Conspicuous changes were witnessed in fruit colour and green colour changed to yellow colour. Similarly, the chemical parameters namely TSS; reducing and total sugar exhibited an increasing trend with increase in concentration and period after the treatment. There was gradual decrease in titratable acidity as the ripening process progressed and also with the increase in the concentration of ethylene gas and ethephon, as well. Lower acidity was observed in the fruits treated with ethylene gas. The physiological loss in weight (PLW) was found to increase with the advancement of storage period irrespective of treatments up to eight days at ambient conditions. Banana fruits treated with 150 ppm ethylene gas had the maximum PLW as compared to other treatments. It was noticed that more the concentration of ethylene gas, faster the ripening process in banana. Banana fruits treated with ethylene gas recorded significantly higher sensory score indicating that the ripening banana fruits with ethylene gas had good acceptability on 4th day of ripening. Ripening of banana with 150 ppm ethylene gas in low cost ripening chamber at 20^{0}C temperature and 85-90 % RH for 36 hours is found safest way of ripening banana.

Introduction

Banana is the most popular fresh fruit all over the world because of its a nutritious value. Its high Vitamin B6 content helps fight infection and is essential for the synthesis of 'heme', the iron containing pigment of hemoglobin. The fruit is also rich in potassium and a great source of fibre too. The ripe fruit is a rich source of energy. In addition, the fruit is prized for its excellent taste and medicinal value.

India is the largest producer of banana with annual production of banana is 297.79 hundred thousand tonnes from an area of 8.026 hundred thousand hectares spread all over the country (Saxena, 2015). Banana covers 22 per cent of the total area under fruits, contributing nearly one third of total fruit production in the country. However, postharvest losses in India are relatively high and occur mainly during handling and transportation in the supply chain. Transporting and distributing fruits from the farmers' orchard to consumers' basket can take several days, during this transit period, banana being climacteric fruit ripens rapidly. A part of ripe fruits are damaged due to harsh conditions of transportation leading to postharvest losses. Therefore, transporting banana fruits harvested at green mature stage and ripen them artificially before selling to the consumer helps to avoid losses. Various practices and ripening agents are used to stimulate ripening. Either bananas are allowed to ripen at ambient conditions or bunches are artificially ripened by smoke treatment (Ram, *et al.*, 1979) or by the use of calcium carbide. Smoke treatment is crude and ineffective due to evolution of carbon monoxide which is hazardous to health. Improper smoke treatment leads to uneven ripening and also poor external colour (yellow) development since the optimum temperature and relative humidity (RH) are not maintained in the ripening room. The use of the chemical calcium carbide is prohibited as its use is hazardous to human health (FSS Act, 2006).

Ripening is the final phase in fruit development in which the biochemistry and physiology of the organ are developmentally altered to influence the appearance, texture, flavor making fruits tasty and attractive to eat (Seymour, 1993). Since, most of the fruit sensory and nutritional quality traits are elaborated at the ripening stage, the control of fruit ripening is also instrumental to maintain the quality attributes of the fruit during the postharvest shelf life.

Postharvest life and quality of banana is dependent not only its postharvest handling, but also on how bananas are ripened. Under natural conditions, banana ripens slowly, leading to high weight loss, desiccation, uneven ripening and fails to develop good colour and aroma. Hence, there is deterioration of marketable quality. People have now become health conscious and demand high quality fruits with uniformly ripened with safe method. Ripening with ethylene is safe to human health and is a natural gaseous hormone. Consequently, it is commonly used for ripening of tropical and subtropical fruits like banana, mango, sapota, papaya, etc. Generally, ethylene gas or ethylene generating source such as ethephon is used for ripening. Ethephon is often considered as better than other chemical ripening agents (Singh, *et al.,* 2011). Therefore, present investigation was undertaken to study the ripening behaviour of banana treated with different sources of ethylene using low cost technology.

Materials and Methods

Experiment was laid out in Completely Randomized Design with seven treatments and three replications. Physiologically mature hard green fruits of banana cv. Grand Naine were harvested for the present study. The hands were separated carefully from bunch and delatexed to drain latex from cut portion. Banana hands present in the top and bottom of each bunch were discarded as these were not suitable for ripening studies. Selected banana hands were washed thoroughly with potable water to remove dirt and foreign materials present and these hands were treated with fungicide carbendazim (0.2 %) for five minutes and dried in the shade. The banana hands were treated with different concentrations of ethylene gas (T_1- 50 ppm, T_2-100 ppm, T_3- 150 ppm) and ethephon (T_4- 50 ppm, T_5- 100 ppm and T_6- 150 ppm) and $T_7$was absolute control (untreated fruits). Low cost ripening chamber was used for the treatments.

The low cost ripening chamber of 9.3 m^3 volume made from multilayered UV stabilized plastic tarpaulin and cubical frame of PVC pipes of 2.5 cm diameter having one ton capacity was used for controlled ripening of banana with ethylene. This structure was kept under spacious room provided with 0.8 ton window type air conditioner for maintaining temperature of 20^{0}C. The relative humidity of 90% was maintained by hanging the water drenched cotton sheets inside the chamber. Well prepared bunches were filled into the crates and were kept inside the ripening chamber. After loading the fruits, the flap door was closed by zipping.

The ethylene gas was released in to the chamber from a portable ethylene gas cylinder of 1.6 litre capacity for specified period (4 seconds for 50 ppm; 8 seconds for 100 ppm and 12 seconds for 150 ppm) according to treatment and measured with the help of gas analyser. After the completion of 36 hours exposure to ethylene; the fruit containing crates were maintained at 20°C temperature for further 12 hours and later on exposed to room temperatures. For ethephon treatment, well prepared fruits were dipped in ethephon solution of 50 ppm, 100 ppm and 150 ppm concentrations for 5 min and kept in crates and were allowed to ripen under ambient conditions.

The observations on different physico-chemical and physiological parameters were recorded at an interval of two days 2nd, 4th, 6th and 8th day of treatment.

Physical parameters

Fruits firmness (kg/cm^2)

The firmness of the fruit was tested by a pocket penetrometer (Fruit Tester FT 327) and the firmness was expressed as kg/cm^2 (Desai and Deshpande, 1975). The firmness was recorded at two days interval and each time punctures with the probe were made at two locations on fruit surface and their average was computed.

Colour

As suggested by Venkata Subbaiah *et al.*, 2013, external colour was divided into eight stages 1. Green 2. Green trace of yellow 3. More green than yellow 4. More yellow than green 5. Yellow trace of green 6. Yellow 7. Yellow with brown spots 8. Yellow with increasing black areas.

Bio-chemical parameters

Total Soluble Solids ($^{\circ}$Brix)

Total Soluble Solids content was measured with the help of a pocket refractometer (Atago, Japan) having the range of 0-32^{0}Brix by diluting pulp with deionized water.

Reducing, non-reducing and total sugars(%)

The reducing, non-reducing and total sugars were determined as per the method of suggested by Ranganna (1986) and were worked out by using following formulae-

$$\text{1. Reducing sugars (\%)} = \frac{\text{Factor x volume made x 100}}{\text{*B.R. X wt. of sample}}$$

$$\text{2. Total sugars(\%)} = \frac{\text{Factor x volume made x 100}}{\text{*B.R .xwt. ofsample}}$$

Non reducing sugars = (Total sugar - Reducing sugar) x 0.95

* B.R. means burette reading.

Titratable acidity (%)

Titratable acidity was determined by titrating a known quantity of blended sample diluted with water against standard sodium hydroxide (0.1 N) solution, using phenolphthalein as an indicator and was expressed as malic acid

(AOAC, 2012).Titrable acidity was calculated as given below.

$$\text{Titratable acidity (\%)} = \frac{\text{B.R. x N of alkali x Volume made x Eq. wt. of acid x 100}}{\text{wt. of sample x Vol. of sample taken for estimation x 1000}}$$

Physiological loss in weight (%)

The changes in physiological loss in weight (PLW) in both treated and control fruits were recorded during storage every alternate day and were expressed in percentage. To workout following formula was used.

$$\text{PLW (\%)} = \frac{\text{Initial Wt.(g)} - \text{Final Wt. (g)}}{\text{Initial Wt. (g)}} \times 100$$

Organoleptic taste

The organoleptic evaluation for assessing the flavour, taste (sweetness), texture (palatability) and overall acceptability of ripe banana fruits was carried out by the panels of ten judges by using 9 points Hedonic scale (Amerine,1965).

Statistical analysis

As the experiment was designed Completely Randomized Design, the analysis of the datagenerated on changes physicochemical and physiological parameters of banana was carried out as per the method described by Panse and Sukhatme (1995).

Results and Discussion

Effect of ethylene gas and ethephon on physical parameters of banana during ripening

Peel colour

The banana fingers were greenish at harvest, but subsequently during ripening green colour turned to trace of yellow, more green than yellow, more yellow than green, yellow trace of green, uniform yellow, yellow with brown spots and dark black during storage period (Table 1).

It was evident that the fruits treated with 150 ppm ethylene gas (T_3) and 100 ppm ethylene gas (T_2) developed yellow colour on 4th day after treatment. The striking change in peel colour in banana was observed in the treatment T_3 (150 ppm ethylene gas) and score was 5.00, 6.00, 7.67 and 8 on 2nd, 4th, 6th and 8th day of observation. In case of the fruits treated with ethephon, exhibited almost same trend in both the treatments i.e. T_5 (100 ppm ethephon) and T_6 (150 ppm ethephon). However, maximum score was registered by the Treatment T_3 (150 ppm ethylene gas).

The colour of banana fruit is an important consideration to the consumer. The change in colour of the peel from green to yellow is the most apparent change that occurs during ripening and serves as a rough gauge to the stage of ripeness (Palmer, 1971). All treatments with ethylene gas and ethephon showed significant change in the colour and as the concentration increased; the colour change was faster. Further, improvement in colour was faster in case of banana fruits exposed to ethylene gas as compared to ethephon treated fruits. Moreover, there was uniform colour development in this treatment,

In the present investigation, improvement in colour was much faster in the treatment T_3 (150 ppm ethylene gas) which recorded the score of 5.00, 6.00, 7.67 and 7.67 on 2nd, 4th, 6th and 8th of the treatment. Most acceptable and uniform yellow colour was observed in the treatment T_3 (150 ppm ethylene gas) on 4th day of treatment. On the 6th and 8th day of treatment, black specks appeared on the peel which progressed rapidly losing their marketable quality. Means fruits had saleable quality up to 4^{th} after treatment.

Colour development induced by applying ethylene gas and ethylene releasing compounds has been well documented in banana by Rao, *et al.*,1971; Patil, 2003; Mahajan, *et al.*, 2010; Tapre and Jain, 2012; Mebratie *et al.*, 2015. The change in colour during ripening may be due to the synthesis of carotenoids accompanied by the simultaneous loss of chlorophyll (Reyes and Paul, 1995).

Fruit firmness (kg/cm^2)

There was sharp decline in firmness of banana fruits in all the treatments with the advancement of ripening (Table 1).The treatment T_3 i.e. 150 ppm ethylene gas recorded significant loss in fruit firmness and recorded 3.50, 2.60, 1.90 and 1.20 kg/cm^2 fruit firmness on 2^{nd}, 4^{th}, 6^{th} and 8^{th} days of treatment respectively. Treatment T_3 (150 ppm ethylene gas) and treatment T_2 (100 ppm ethylene gas) were at par with each other on 4^{th}, 6^{th} and 8^{th} day of treatment, respectively. The maximum fruit firmness was observed in untreated fruits i.e. T_7 which was recorded 12.53, 10.70, 8.17 and 5.97 (kg/cm^2) on 2^{nd}, 4^{th}, 6^{th} and 8^{th} days of treatment, respectively. It is revealed from the data that the firmness loss proceeded faster after fruits were exposed to both the sources of ethylene and there is linear decrease in fruit firmness in all the treatments. Moreover, loss of firmness was more in case of banana fruits exposed to ethylene gas as compared to ethephon treated fruits.

The results are in conformity with findings of Sane *et al.,* (2005); Imsabai *et al.,* (2006); Mahajan *et al.,* (2010); Kulkarni, *et al.*, (2011); Mebratie, *et al.*, (2015); Patil and Shanmugasundaram (2015). Similar results were also reported by Montalvo *et al.*, (2007); Laguneset *al.,* (2007), William *et al.*, (2009) in mango.

The decrease in firmness during ripening may be due to breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability (Brinstone *et al.,* 1988). The loss of pectin substances 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 (Watada, 1986; Mahajan, *et al.*, 2010 and Chauhan *et al.*, 2012). According to Patil and Shanmugasundaram (2015) degradation of nutrients and increase in moisture content of pulp may also contribute to the softening of fruits. The fruits from the treatment T_3 on 4^{th} day of treatment had good consumer acceptability.

Effect of ethylene gas and ethephon on Physico chemical parameters of banana during ripening

Total Soluble Solids (^{0}Brix)

It is apparent from the Table 2, that there was increase in TSS of banana up to 4^{th} day of treatment and later on from 6^{th} day treatment, there was decrease in TSS in the source of ethylene gas treatments. Whereas, there was increase in TSS of banana up to 6^{th} day of treatment and later on 8^{th} day treatment, there was decrease in TSS in the source of ethephon treatments. It was further observed that, the treatment T_3 i.e. banana treated with 150 ppm ethylene recorded highest, TSS of 17.9 ˚B and 22.8 ^{0}Brix on 2^{nd} and 4^{th} day of treatment followed by the treatment T_2 i.e. banana fruit treated with 100 ppm ethylene gas i.e. 17.6 ˚B and 21.7 ˚B on 2^{nd} and 4^{th} day, respectively. On 6^{th} day of treatment the significantly highest TSS was observed in the treatment T_5 i.e. banana fruits treated with 100 ppm ethephon which recorded 22.1 ˚B TSS followed by T_6 i.e. 150 ppm ethephon recorded 21.6^{0}Brix. But, it was noteworthy that on 8^{th} day of treatment, the treatment 50 ppm ethephon recorded significantly highest TSS of 20.6^0Brix.

In the present study, the treatment T_3 i.e. banana treated with 150 ppm ethylene recorded highest TSS of 17.9^0Brix and 22.8 ^{0}Brix on 2nd and 4th day of treatment followed by the treatment T_2 i.e. banana fruit treated with 100 ppm ethylene gas i.e. 17.6 ^{00}Brixand 21.7 ^{0}Brix on 2nd and 4th day, respectively. The TSS was higher in the fruits treated with ethylene gas up to 4th day of treatment.

Although highest TSS on 8th of the treatment was observed in the Treatment T_4 (Ethephon 50 ppm) followed by the Treatment T_5 (Ethephon 100 ppm), fruit had no marketable quality. Increase in TSS with increase in ripening in banana has been reported by Patil (2003); Saiprasad *et al.,* (2008) and Kulkarni, *et al.,* (2011) and Hailu *et al.,* (2013).

The increase in TSS may be attributed beak down of starch into simple sugars during ripening process (Dadzie and Orchard, 1997) and also to an increase in concentration of organic solutes as a consequence of water loss (Ryall and Pentzer, 1982). The decrease in TSS in later stage i.e. on 6th and 8th day of ripening may be due to interconversion of some of the sugars into volatile organic acids and utilization for respiration.

Reducing sugars (%)

As revealed from the data (Table2), both the sources of ethylene influenced the reducing sugar content significantly. It was observed that there was increasing trend in reducing sugar content as the process of ripening progressed. The treatment T_3 (150 ppm ethylene gas) recorded highest reducing sugar 8.84%, 14.81%, 19.89% and 20.93% on 2nd, 4th, 6th and 8th day of treatment, respectively. The treatment T_2 (100 ppm ethylene gas) was at par with the treatment T_3 (150 ppm ethylene gas) which recorded reducing sugar i.e. 14.56% and 20.60 % on 4th and 8th day of treatment. The reducing sugar content was the lowest (1.07%, 1.22%, 4.36% and 6.36%) on 2nd, 4th, 6th and 8th day in the treatment T_7 (Control), respectively.

Reducing sugar content was higher in the ethylene treatment as compared to ethephon treated fruits. Increase in reducing sugars during ripening in banana has also been reported by Nair and Singh (2003); Deepak *et al.,* (2008); and Tapre and Jain (2012).

Increase in reducing sugars during ripening could be ascribed to hydrolysis of starch into soluble sugars in the presence of ripening enzymes (Venkata Subbaiah *et al.,* 2013).

Total sugars (%)

All treatments with ethylene gas and ethephon exhibited increase in the total sugars and the increase was in linear fashion. Total sugars of 10.84%, 16.93%, 21.49 % at 2nd, 4th, 6th day of treatment was noticed in T_3 (150 ppm ethylene gas), which was significantly highest than rest of the treatments. However, the treatment T_2 i.e. 100 ppm ethylene gas (22.05%) was at par with T_3 i.e.150 ppm ethylene gas (22.21%) on 8th day of treatment. While, lowest total sugar was observed in the treatment T_7 (Control) which were 2.63 %, 3.13 %, 6.44 % and 8.22% on 2nd, 4th,6th and 8th day of treatment during storage at ambient condition.

However, the treatment T_2 i.e. 100 ppm ethylene gas was at par with T_3 on 8th day of treatment which recorded 22.05 % total sugars. In case of fruits treated with different concentration of ethephon, maximum total sugar content was observed in the treatment T_6 i.e. 150 ppm ethephon which were 5.40%, 10.52%, 14.51% and 16.74 % on 2nd, 4th, 6th and 8th day of treatment.

Total sugar content was higher in the ethylene treatment as compared to ethephon treated fruits. Increase in reducing sugars during ripening in banana has also been reported by Nair and Singh (2003); Deepak *et al.*, (2008); and Tapre and Jain (2012). Increase in total sugars during ripening could be ascribed to hydrolysis of starch into soluble sugars in the presence of ripening enzymes (Sarode and Tayade, 2009; Venkatasubbaiah *et al.*, 2013).

Non-reducing sugars (%)

As revealed from the data presented in the Table 2, in general there was increasing trend of non-reducing sugar content up to 6th day of treatment in treatment T_4 (50 ppm ethephon) and T_5 (100 ppm ethephon) and then there was decrease in non-reducing sugar content on 8th day of treatment in all the treatment. In the treatments T_6, T_2 and T_3 showing continuous decrease in the non-reducing sugar content. In brief, there was no definite pattern of increase or decrease. Significantly highest non-reducing sugar was recorded in the treatment T_6 i.e. banana fruits treated with 150 ppm ethephon and it was 2.27 % on 2nd and 4th day of treatment. However, non-reducing sugar content was higher in the treatment T_7 (Control) at the 6th and 8th day of the treatment. Treatments T_4 (50 ppm ethephon), T_1 (50 ppm ethylene gas) and T_5 (100 ppm ethephon) were at par with the treatment T_7 (Control) on 6th day. This might be due use of non-reducing sugars for triggered respiration because of accelerated ripening due ethylene gas and ethephon. Similar findings were reported Nair and Singh (2003).

Titrable acidity (%)

As revealed from the Table2,gradual decrease in titrable acidity was noted with the progress of ripening process in all treatments from 2nd to 8th day of treatments. The titrable acidity was maximum in T_7 (Control) which was 0.54, 0.51, 0.40 and 0.33 per cent on 2nd, 4th,6th and 8th day of treatment and lowest acidity was registered in the treatment T_3 treatment (150 ppm ethylene gas) and it was 0.46, 0.33, 0.26 and 0.21 per cent on 2nd, 4th,6th and 8th day of treatment, respectively.

Data also showed that the acidity decreased with the increase in the concentration of ethylene gas and ethephon. Even, lower acidity was observed in the fruits treated with ethylene gas. Present findings are in confirmation with Patil (2003), Mebratie *et al.*, (2015) and Mahajan *et al.*, (2008) in guava. Dhillon and Mahajan (2011) while studying ethylene and ethephon induced fruit ripening in pear observed decrease in acidity and they ascribed this decrease in acidity to the utilization of available organic acids at a faster rate in the respiration during the ripening triggered by sources of ethylene and also to the conversion of organic acids into soluble sugars and long chain polysaccharides.

Shelf life studies

Physiological Loss in Weight (PLW) (%)

Results showed that all the sources of ethylene significantly influenced this parameter (Table 3). It was also observed that there was rapid loss in weight with the progression of ripening of fruit. The PLW was highest in the treatment T_3 (150 ppm ethylene gas) and it was 7.67%, 14.65%, 22.08% and 31.05 % on 2nd, 4th, 6th and 8th day of treatment. The treatment T_3(150 ppm ethylene gas) was followed by the treatment T_2(100 ppm ethylene gas) and it recorded 6.22%, 14.05%, 20.90% and 28.22% on 2nd, 4th,6th and 8th day of treatment. In fact, the treatments T_3 and T_2 were at par with each other. The minimum physiological loss in weight (%) of 2.43%, 5.22%, 9.10% and 13.25% on 2nd, 4th, 6th and 8th day, was observed in the T_7 (Control) i.e. untreated fruits, respectively. It was also evident from the data that the PLW increased with the increase in the concentration of ethylene gas. Further it was also observed that PLW was more in case of the fruits treated with the ethylene gas as compared to the fruits treated with ethephon.

This is very important parameter because weight loss adversely affects the appearance, flavour and weight of fruit. PLW also affects nutritional composition of the fruit. It was observed that there was rapid loss in weight with the increase ripening of fruit and with the increase in the concentration of ethylene gas. Further it was also observed that PLW was more in case of the fruits treated with the ethylene gas as compared to the fruits treated with ethephon.

As the ethylene gas and ethephon concentration increased, the ripening process occurred at the faster rate due to the rise in the respiratory climacteric triggered by ethylene and ethephon treatments (Kulkarni, *et al.*, 2011). This would have increased in the loss of moisture from the fruits resulting into loss of weight of fruits as compared to control.

The significant increase in the PLW may be due to the continuous processes of respiration and transpiration during ripening. The results are in accordance with Patil (2003); Mahajan *et al.*, (2010) and Mebratie *et al.*, (2015). Similar findings were also reported in other fruit crops by Medicott *et al.*, (1990); Montalvo *et al.*, (2007) and Lagune s*et al.*, (2007) in mango fruit; Dhillon and Mahajan (2011) in pear.

Table.1 Effect of ethylene gas and ethephon on peel colour and fruit firmness during ripening of banana

Treatment Number	Treatments	Fruit peel colour				Fruit firmness (kg/cm^2)			
		Days after treatment				Days after treatment			
		2	**4**	**6**	**8**	**2**	**4**	**6**	**8**
T_1	50 ppm ethylene gas	3.00	5.00	7.00	8.00	5.40	4.90	3.53	2.20
T_2	100 ppm ethylene gas	4.00	5.67	7.00	7.67	4.57	2.67	2.23	1.77
T_3	150 ppm ethylene gas	5.00	6.00	7.67	8.00	3.50	2.60	1.90	1.20
T_4	50 ppm ethephon	1.00	3.00	5.00	7.00	10.70	8.70	7.33	5.97
T_5	100 ppm ethephon	2.00	5.00	7.00	8.00	9.00	8.27	7.00	5.80
T_6	150 ppm ethephon	3.00	5.67	7.00	8.00	8.17	6.47	5.40	3.73
T_7	Control	1.00	2.00	3.00	4.00	12.53	10.70	8.17	5.93
	S.E.±	0.21	0.21	0.21	0.12	0.28	0.21	0.16	0.18
	C.D. at 5 %	0.66	0.66	0.66	0.33	0.85	0.66	0.50	0.57

Table2 Effect of ethylene gas and ethephon on different physicochemical parameters during ripening of banana

Treatment Number	Treatments	TSS (˚Brix)				Reducing sugars (%)				Total sugars (%)				Non-Reducing Sugar (%)				Titrable acidity (%)			
		Days after treatment				Days after treatment				Days after treatment				Days after treatment				Days after treatment			
		2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
T_1	50 ppm ethylene gas	15.9	20.5	18.3	16.0	7.14	13.3	17.4	19.3	9.2	15.2	19.4	21.1	1.99	1.85	1.91	1.66	0.52	0.38	0.33	0.30
T_2	100 ppm ethylene gas	17.6	21.7	19.2	18.9	8.22	14.5	19.3	20.6	10.1	16.4	21.1	22.0	1.87	1.80	1.69	1.50	0.48	0.37	0.31	0.27
T_3	150 ppm ethylene gas	17.9	22.8	20.1	18.1	8.84	14.8	19.8	20.9	10.8	16.9	21.4	22.2	1.77	1.57	1.51	1.30	0.46	0.33	0.26	0.21
T_4	50 ppm ethephon	7.1	19.7	21.0	20.6	2.13	3.9	5.4	11.6	2.6	3.3	7.4	13.5	0.47	0.50	1.93	1.76	0.52	0.46	0.39	0.32
T_5	100 ppm ethephon	10.9	20.2	22.0	19.7	2.63	6.0	7.9	12.6	3.1	8.3	9.9	14.5	0.46	1.18	1.90	1.77	0.50	0.43	0.34	0.31
T_6	150 ppm ethephon	16.7	20.8	21.6	19.3	3.00	8.8	12.6	14.9	5.4	10.5	14.5	16.7	2.27	1.93	1.75	1.71	0.48	0.39	0.33	0.30
T_7	Control	4.07	4.53	16.1	16.5	1.07	1.2	4.3	6.3	2.6	3.1	6.44	8.22	1.49	1.82	1.98	1.77	0.54	0.51	0.40	0.33
	S.E.±	0.16	0.15	0.09	0.13	0.10	0.16	0.08	0.14	0.05	0.10	0.06	0.14	0.024	0.06	0.046	0.05	0.015	0.014	0.007	0.009
	C.D. at 5 %	0.50	0.47	0.27	0.41	0.30	0.48	0.24	0.44	0.17	0.31	0.19	0.43	0.075	0.18	0.14	0.15	0.048	0.044	0.024	0.029

Table.3 Effect of ethylene gas and ethephon on PLW (%) and organoleptic evaluation during ripening of banana

Treatment Number	Treatments	Physiological loss in weight (%)				Organoleptic evaluation			
		Days after treatment				Days after treatment			
		2	4	6	8	2	4	6	8
T_1	50 ppm ethylene gas	5.85	9.81	14.71	19.42	5.00	6.00	7.00	3.25
T_2	100 ppm ethylene gas	6.22	14.05	20.90	28.22	6.00	7.75	7.25	2.00
T_3	150 ppm ethylene gas	7.67	14.65	22.08	31.05	6.00	8.00	7.00	2.00
T_4	50 ppm ethephon	2.84	6.41	10.13	14.35	5.00	5.33	6.25	4.00
T_5	100 ppm ethephon	2.75	6.44	10.62	14.79	5.00	5.38	6.88	4.00
T_6	150 ppm ethephon	3.93	8.38	13.13	18.54	5.88	6.38	6.88	3.00
T_7	Control	2.43	5.22	9.10	13.25	5.00	5.00	5.00	6.00
	S.E.±	0.515	1.029	1.330	2.018	--	--	--	--
	C.D. at 5 %	1.564	3.123	4.035	6.123	--	--	--	--

Organoleptic evaluation

The organoleptic taste means the acceptability of the fruits or edible quality of the fruits. In general the fruits had acceptability of the fruit up to 4th day of the treatment and then there was decrease in the acceptability of fruit (Table 3).

The treatment T_3 (150 ppm ethylene gas) recorded maximum score of 8.0 on 4th day of treatment followed by the treatment T_2 (100 ppm ethylene gas). On 6th day of treatment, maximum score was recorded in treatment T_2 (100 ppm ethylene gas).

In general, the organoleptic rating increased up to 6th day after treatment and there after the rating declined. This means that fruits had acceptability of the fruit up to 4th day of the treatment. In case of organoleptic score, the treatment T_3 (150 ppm ethylene gas) recorded maximum score of 8.0 on 4th day of treatment followed by the treatment T_2 (100 ppm ethylene gas). On 6th day of treatment, maximum score was recorded in treatment T_2 (100 ppm ethylene gas). Although, both sources of ethylene improved the sensory quality of the banana fruit, but fruits ripened with ethylene gas had more rating than ethephon suggesting superiority of ethylene gas for ripening of banana. This is also evident from the colour change of banana fruit. Similar results are reported by Nair and Singh (2003) in mango cv. Kensington and Kulkarni *et al*., (2004) in mango cv. Kesar; and Mahajan *et al*., (2010).

In conclusion the overall data, considering physical, biochemical and PLW studies indicates that the treatment T_3 i.e. treating banana fruits with 150 ppm ethylene gas recorded its superiority for most of the characters studied. Moreover, the uniform yellow colour and highest edible quality was observed on 4th day of ripening in this treatment (T_3). Further, use of ethylene for artificial ripening of fruits is permitted under FSSA (Anon. 2006). Therefore, ripening banana with 150 ppm ethylene gas in low cost ripening chamber at 20^{0}C temperature and 85-90 % relative humidity for 36 hours is innocuous way of ripening banana.

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