Ripening behaviour of banana treated with different ethylene sources

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ABSTRACT

Banana var Grand Naine fruits harvested at 75-80 per cent maturity were treated with different concentrations and different sources of ethylene. Ethylene gas and ethephon were used as sources of ethylene with three concentrations of each ethylene gas and ethephon viz 50, 100 and 150 ppm and ethylene gas-treated fruits were kept in the ripening chamber up to 36 h at constant 20°C temperature and 85-90 per cent relative humidity. The fruit colour as well as the chemical parameters namely TSS, reducing and total sugars exhibited an increasing trend with increase in concentration and period after the treatment. It was noticed that more the concentration of ethylene gas, faster was the ripening process in banana. The fruits treated with ethylene gas recorded significantly higher sensory score indicating that the fruits treated with ethylene gas have good overall acceptability on 4th day of ripening. It can be safely concluded that ripening of banana with 150 ppm ethylene gas in low cost ripening chamber at 20°C temperature and 85-90 per cent relative humidity for 36 h is safe way of ripening banana.

Keywords: Banana; ripening; ethylene gas; ethephon; quality

INTRODUCTION

Banana is a rich source of carbohydrates, vitamin A and fair source of vitamins C, B_1 and minerals, mainly potassium and phosphorus with calorific value of 116 calories per 100 g (Gopalan et al 2004). India is the largest producer and consumer of banana in the world contributing about 25.6 per cent of the total world production. In India the production of banana was 30,460 thousand MT from an area of 866 thousand hectares in 2019 (Anon 2019).Though banana is produced in large quantities in Maharashtra there are huge postharvest losses. Several factors are responsible for postharvest losses in banana and unscientific ripening is one of the causes. It is a climacteric fruit and is ripened after harvest. But the methods used for ripening of banana are inappropriate. Ripening is the final phase in fruit development which involves a complex series of events such as a change in colour, softening of the pericarp and changes in sweetness and flavour that make fruits both tasty and attractive to eat. Postharvest life and quality of banana are dependent not only on 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 which are uniformly ripened with safe method. To meet the domestic demand normally banana is artificially ripened either by smoke or by using calcium carbide. The Food Safety and Standards Authority of India (FSSAI) has banned calcium carbide under the Prevention of Food Adulteration (PFA) Act, 1954 (Agrawal 2019). Ripening with ethylene is safe to human health. Therefore it is commonly used for ripening of tropical and subtropical fruits like banana, mango, sapota, papaya etc. Generally ethylene gas or ethylene-generating sources such as ethephon is used for ripening.

MATERIAL and METHODS

Present investigations were done in completely randomized design (CRD) with seven treatments and three replications and were carried out at Banana Research Station, Jalgaon, Maharashtra during the year 2015-16.

Total soluble solids content of the pulp was measured by using a pocket refractometer (Atago, Japan) having the range of 0-53°Brix. Reducing sugarsand total sugars were determined by using Fehling reagent as per the method suggested by Ranganna (1976).The non-reducing sugars were estimated by the formula:

$$\text{Non-reducing sugars} = \text{Total sugar} - \text{Reducing sugar} \times 0.95$$

Titratable acidity was determined by titrating a known quantity of blended sample diluted with water against standard sodium hydroxide (0.1N) solution using phenolphthalein as an indicator and was expressed as malic acid. A known quantity (0.2 g) of samples was digested in binary mixture of concentrated H_2SO_4 (30%) in the ratio of 1:1 and this acid extract was used for determination of total phosphorus. For calculating physiological loss in weight (PLW), the banana fruits were weighed on weighing balance on the first day of the treatment and their mean weight was expressed in grams (g). Subsequently every alternate day they were weighed and the loss in weight was worked out and expressed as percentage over the initial weight.

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

The organoleptic evaluation for assessing the flavour, taste, texture and overall acceptability of ripe banana fruits was carried out by the panel of five judges by using 9-point Hedonic scale (Amerine et al 1965).

The data were collected on changes in physico-chemical and physiological parameters of banana and were statistically analyzed by using completely randomized design technique as described by Panse and Sukhatme (1995).

RESULTS and DISCUSSION

The data on changes in physico-chemical and physiological parameters of banana as affected by different treatments are given in Table 1.

Fruit firmness: It is revealed that the firmness loss proceeded faster after fruits were exposed to both the sources of ethylene and there was 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 treatment T_3 ie 150 ppm ethylene gas recorded significant loss in fruit firmness and resulted in 3.50, 2.60, 1.90 and 1.20 kg/cm^2 fruit firmness on 2nd, 4th, 6th and 8th day of treatment respectively. The loss in fruit firmness was minimum in T_7 (Control) and the fruit firmness was 12.53, 10.70, 8.17 and 5.97 kg/cm^2 on 2nd, 4th, 6th and 8th days of treatment respectively. The results are in conformity with the findings of Kulkarni et al (2011), Mebratie et al (2015) and Patil and Shanmugasundaram (2015).

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. The loss of pectin substances in the middle lamella of the cell wall is perhaps the key step in the ripening process that leads to the loss of cell wall integrity thus causeing loss of firmness and softening. According to Patil and Shanmugasundaram (2015) degradation of nutrients and increase in moisture content of pulp may also contribute to the softening of fruits.

Peel colour: 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. 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.

In the present investigations 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 8.00 on 2nd, 4th, 6th and 8thday of the treatment respectively. 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 rapidly progressed losing their marketable quality showing thereby that fruits had saleable quality up to 4th day after treatment.

Colour development induced by applying ethylene gas and ethylene releasing compounds has been well documented in banana by Mahajan et al (2010), Tapre and Jain (2012) and Mebratie et al

Table 1. Effect of ethylene gas and ethephon on fruit firmness, peel colour, TSS, reducing sugar, total sugar, non-reducing sugar, acidity, total phosphorus, PLW and sensory quality during ripening of banana

Treatment	Effect after days															
	Fruit firmness (kg/cm^2)				Peel colour				TSS (°B)				Reducing sugar (%)			
	2nd	4th	6th	8th	2nd	4th	6th	8th	2nd	4th	6th	8th	2nd	4th	6th	8th
Ethylene (ppm)																
50	5.40	4.90	3.53	2.20	3.00	5.00	7.00	8.00	15.93	20.50	18.37	16.03	7.14	13.32	17.42	19.38
100	4.57	2.67	2.23	1.77	4.00	5.67	7.00	7.67	17.60	21.73	19.20	18.93	8.22	14.56	19.33	20.60
150	3.50	2.60	1.90	1.20	5.00	6.00	7.67	8.00	17.93	22.87	20.10	18.17	8.84	14.81	19.89	20.93
Ethephon (ppm)																
50	10.70	8.70	7.33	5.97	1.00	3.00	5.00	7.00	7.07	19.73	21.03	20.60	2.13	3.90	5.43	11.65
100	9.00	8.27	7.00	5.80	2.00	5.00	7.00	8.00	10.90	20.17	22.07	19.7	2.63	6.04	7.95	12.65
150	8.17	6.47	5.40	3.73	3.00	5.67	7.00	8.00	16.73	20.87	21.63	19.37	3.00	8.84	12.67	14.94
Control	12.53	10.70	8.17	5.93	1.00	2.00	3.00	4.00	4.07	4.53	16.10	16.53	1.07	1.22	4.36	6.36
$CD_{0.05}$	0.857	0665	0.501	0.574	0.661	0.661	0.661	0.338	0.502	0.477	0.275	0.416	0.308	0.486	0.245	0.445

(2015). The change in colour during ripening may be due to the synthesis of carotenoids accompanied by the simultaneous loss of chlorophyll (Reyes and Paull 1995).

Total soluble solids (TSS): All treatments with ethylene gas and ethephon exhibited increase in the TSS. TSS increased with the increase in the concentration of ethylene gas and ethephon. Further as the ripening progressed, there was increase in the TSS up to 4th day of ripening and then it declined on 6th and 8th day of treatment. The treatment T_3 ie banana treated with 150 ppm ethylene recorded highest TSS of 17.93 and 22.87°B on 2nd and 4th day of treatment followed by T_2 ie banana fruit treated with 100 ppm ethylene gas which was 17.60 and 21.73°B 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 day of treatment was observed in T_4 (ethephon 50 ppm) followed by the T_5 (ethephon 100 ppm) fruits had no marketable quality. Increase in TSS with increase in ripening in banana has been reported by Kulkarni et al (2011). The increase in TSS may be attributed to the beakdown of starch into simple sugars during ripening process and also to an increase in concentration of organic solutes as a consequence of water loss. The decrease in TSS in later stage ie 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 sugar: All treatments with ethylene gas and ethephon showed increase in the reducing sugars. Reducing sugars increased with the increase in the concentration of ethylene gas and ethephon. Further with the progress of ripening there was increase in reducing sugars. The treatment T_3 (150 ppm ethylene gas) recorded maximum reducing sugars (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 in recording reducing sugar ie 14.56 and 20.60 per cent on 4th and 8th day of treatment 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 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).

Table 1. Contd…..

Treatment	Effect after days											
	Total sugar (%)				Non-reducing sugar (%)				Titratable acidity (%)			
	2nd	4th	6th	8th	2nd	4th	6th	8th	2nd	4th	6th	8th
Ethylene (ppm)												
50	9.24	15.27	19.43	21.13	1.99	1.85	1.91	1.66	0.52	0.38	0.33	0.30
100	10.19	16.41	21.13	22.05	1.87	1.80	1.69	1.50	0.48	0.37	0.31	0.27
150	10.84	16.93	21.49	22.21	1.77	1.57	1.51	1.30	0.46	0.33	0.26	0.21
Ethephon (ppm)												
50	2.62	3.37	7.47	13.50	0.47	0.50	1.93	1.76	0.52	0.46	0.39	0.32
100	3.11	8.34	9.95	14.51	0.46	1.18	1.90	1.77	0.50	0.43	0.34	0.31
150	5.40	10.52	14.51	16.74	2.27	1.93	1.75	1.71	0.48	0.39	0.33	0.30
Control	2.63	3.13	6.44	8.22	1.49	1.82	1.98	1.77	0.54	0.51	0.40	0.33
$CD_{0.05}$	0.173	0.314	0.195	0.436	0.075	0.184	0.141	0.153	0.048	0.044	0.024	0.29

Table 1. Contd…..

Treatment	Effect after days											
	Total phosphorus (mg/100 g)				PLW (%)				Sensory quality (score)			
	2nd	4th	6th	8th	2nd	4th	6th	8th	2nd	4th	6th	8th
Ethylene (ppm)												
50	45.00	46.00	46.00	48.00	5.85	9.81	14.71	19.42	5.00	6.00	7.00	3.25
100	46.67	47.00	48.00	48.33	6.22	14.05	20.90	28.22	6.00	7.75	7.25	2.00
150	46.00	46.33	47.00	47.33	7.67	14.65	22.08	31.05	6.00	8.00	7.00	2.00
Ethephon (ppm)												
50	44.67	45.00	46.67	47.00	2.84	6.41	10.13	14.35	5.00	5.33	6.25	4.00
100	45.00	46.00	46.00	47.67	2.75	6.44	10.62	14.79	5.00	5.38	6.88	4.00
150	45.00	45.67	46.33	47.33	3.93	8.38	13.13	18.54	5.88	6.38	6.88	3.00
Control	43.67	45.00	45.00	46.00	2.43	5.22	9.10	13.25	5.00	5.00	5.00	6.00
$CD_{0.05}$	0.672	0.593	0.525	1.027	1.564	3.123	4.035	6.123	-	-	-	-

Total sugars: All treatments with ethylene gas and ethephon exhibited increase in total sugars and the increase was in linear fashion. It was also witnessed that total sugars increased with the increase in the concentration of ethylene gas and ethephon. Further there was linear increase in total sugars with the progress of ripening. Maximum total sugars of 10.84, 16.93 and 21.99 per cent at 2nd, 4th and 6th day of treatment respectively was registered in the treatment T_3 (150 ppm ethylene gas) which was significantly highest than rest of the treatments. However the treatment T_2 ie 100 ppm ethylene gas was at par with T_3 on 8th day of treatment which recorded 22.05 per cent total sugars. 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 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 (Venkata Subbaiah et al 2013).

Non-reducing sugar: In general there was increasing trend in the 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 decline on 8th day of the treatment. It was further observed that significantly highest non-reducing sugar was recorded in the treatment T_6 ie banana fruits treated with 150 ppm ethephon and it was 2.27 per cent on

2nd day of treatment. However the content was higher in the treatment T_7 (Control) on 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 to use of non-reducing sugar for triggered respiration because of accelerated ripening due ethylene gas and ethephon. Similar findings were reported Nair and Singh (2003).

Titratable acidity: Gradual decrease in titratable acidity was noted with the progress of ripening process. Even the acidity decreased with the increase in the concentration of ethylene gas and ethephon. Lower acidity was observed in the fruits treated with ethylene gas. The titratable 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 respectively 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. Present findings are in confirmation with those of Mebratie et al (2015).

Dhillon and Mahajan (2011) while studying ethylene and ethephon induced fruit ripening in pear observed decrease in acidity and they ascribed this to 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.

Total phosphorus: The total phosphorus content increased with increase in days after treatment. Maximum phosphorus (48.33 mg/100 g edible portion) was observed in the treatment T_2 (100 ppm ethylene gas) and it was at par with the treatment T_1 (50 ppm ethylene gas) which recorded 48.00 mg/100 g edible portion on 8th day of treatment. There is no information regarding changes in phosphorus content that occur during ripening of banana. However phosphorus is an essential mineral primarily used for growth and repair of body cells and tissues (Narayana 2015).

Physiological loss in weight (PLW): PLW is a 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 in ripening of fruit. It is 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. The physiological loss in weight was highest in the treatment T_3 (150 ppm ethylene gas) and it was 7.67, 14.65, 22.08 and 31.05 per cent on 2nd, 4th, 6th and 8th day of treatment respectively. The treatments T_3 and T_2 were on par with each other. The minimum physiological loss in weight of 2.43, 5.22, 9.10 and 13.25 per cent on 2nd, 4th, 6th and 8th day respectively was observed in treatment T_7 (Control) ie untreated fruits. 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 might have increased the loss of moisture of the fruits resulting into loss of weight as compared to control. The significant increase in the physiological loss in weight may be due to the continuous processes of respiration and transpiration during ripening. The results are in accordance with those of Mahajan et al (2010) and Mebratie et al (2015).

Organoleptic evaluation: In general the organoleptic rating increased up to 6th day after treatment and thereafter the rating declined. This means that fruits had acceptability up to 4th day of the treatment and then there was decrease. 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 were reported by Kulkarni et al (2004) in mango cv Kesar and Mahajan et al (2010).

CONCLUSION

The treatment T_3 ie treating banana fruits with 150 ppm ethylene gas recorded its superiority for most of the characters studied. Besides this treatment showed the uniform yellow colour and highest edible

quality on 4th day of ripening. Furthermore use of ethylene for artificial ripening of fruits is also permitted. Therefore it can be concluded that ripening banana with 150 ppm ethylene gas in low cost ripening chamber at 20°C temperature and 85-90 per cent relative humidity for 36 hours is the safe way.

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