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ORIGINAL ARTICLE

Studies on optimization of ripening techniques for banana

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Abstract Fruits of banana (*Musa* spp) cultivar 'Grand Naine' were harvested at physiological green mature stage. The first lot of fruit was exposed to ethylene gas (100 ppm) for 24 h in ripening chamber. The second lot was treated with different concentrations of aqueous solution of ethephon (250, 500, 750, 1000 ppm) each for 5 min. The fruits were packed in plastic crates and stored in ripening chamber maintained at 16–18°C and 90–95% RH. Treatment with ethylene gas (100 ppm) or ethephon (500 ppm) resulted in adequate ripening of fruits after 4 days with uniform colour, pleasant flavour, desirable firmness and acceptable quality and better shelf-life. The untreated control fruits were hard textured and poor in colour and quality. The ripening with ethylene gas or ethephon treatment seems to hold promise in reducing postharvest losses and boosting the economy of banana growers and traders.

Keywords Banana · Ethylene gas · Ethephon · Ripening · Quality

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Introduction

Banana (*Musa* spp) is fourth most important commodity after rice, wheat and corn. It is produced in tropical and subtropical regions of developing economies. In India, it is grown in Andhra Pradesh, Assam, Bihar, Gujrat, Kerala, Maharashtra and Tamil Nadu states in an area of 565 thousand hectare with production of 19.19 million tonnes (Singh 2007). The cultivation of banana has become a success in Punjab State through tissue culture raised plants of cultivar 'Grand Naine'. In Punjab, the acreage under banana cultivation is increasing rapidly and presently it occupies 66 acres with average production of 990 MT (Chahil et al. 2007). However, to further boost the production of this crop, adequate ripening technology needs a great attention. Bananas are generally ripened in the markets by calcium carbide and use of this chemical is prohibited due to health reasons (PFA 2003). Therefore, alternative measures need to be investigated for improving the ripening of banana fruits, so that uniformly ripened and quality fruits are made available to consumers in domestic and distant markets. In this investigation, effort is made to study the effect of ethylene and ethephon on ripening of banana.

Materials and methods

The fruits of banana cv. 'Grand Naine' were harvested at green mature stage when the angularity on fruit surface disappeared. After harvesting the bunches were kept slanting towards the stalk end for delatexing in order to avoid blackening of fingers. The bruised and diseased fruits were sorted out and healthy, uniform sized banana hands were selected. The first lot (30 kg) of banana fruits was exposed to ethylene gas (100 ppm) using portable ethylene gas generator (9002, Ventech Agrionics, South Africa) inside the ripening chamber maintained at 18°C and 90–95% RH. The second lot of 30 kg each was dipped in aqueous solutions of ethephon (250, 500, 750 and 1000 ppm) each for 5 min.

Thereafter, fruits were air dried, packed in plastic crates and stored in ripening chamber maintained at 18°C and 90–95% RH. Simultaneously a control lot of banana fruits (30 kg) was also kept at the same temperature without ethylene gas and ethephon treatments. A 4-day ripening cycle was followed in which temperature was brought down from 18 to 16°C in 4 days (1st day=18°C, 2nd day= 18°C, 3rd day= 17°C and 4th day=16°C). There were 3 replications for each treatment and experiment was laid out in completely randomized design. The post-storage ripening behaviour of banana fruits was also studied at 16–18°C (supermarket conditions) as well as at 30–32°C (ordinary market conditions). The observations on various physico-chemical attributes were monitored daily till 4 days. The physiological loss in weight (PLW) of fruit during storage was calculated on initial weight basis and expressed in per cent. The fruit firmness was measured with the help of 'Texture anlyzer (Model TA-Hdi, Make Stable Microsystem, UK) using stainless steel probe of 2 mm diameter and results were expressed in g-force. The sensory quality of fruit was determined by a panel of 10 judges as per Hedonic scale (1–9 points) as described by Amerine et al. (1965). The total soluble solids (TSS) of the pulp were determined with the help of a Erma Hand Refractometer, and expressed in percent after making the temperature correction at 20°C. The titratable acidity was estimated as per AOAC (1990). The colour of the fruit was measured with colour difference meter (Mini Scan XE Plus, Hunter Lab, USA) and expressed as L, a, b values (Hunter 1975). The ripening percentage of the fruits was estimated by counting the total number of ripened fruits on the basis of their appearance and desirable colour.

Results and discussion

PLW: The PLW of fruits increased during ripening process (Table 1). The highest PLW was observed with ethephon

Table 1 Effect of ethylene gas and ethephon treatments on PLW, firmness, TSS, acidity and sensory quality during ripening of banana

Ripening period, days	Ethylene, 100 ppm	Ethephon				Control	CD, 0.05
		250	500	750	1000		
PLW, % (n = 3)							
1	1.1	1.0	1.3	1.8	2.1	0.50	T = 0.3
2	1.8	2.1	2.4	2.9	3.8	1.15	S = 0.2
3	2.6	2.9	3.1	4.0	5.2	2.00	T × S = 0.6
4	3.2	3.5	3.7	5.8	7.0	2.8	
Firmness, g-force (n = 3)							
1	530	580	550	510	510	660	T = 3.2
2	370	420	320	310	305	520	S = 4.0
3	120	170	105	95	80	345	T × S = 5.3
4	67	93	65	48	45	256	
TSS, % (n = 3)							
1	9.6	9.2	9.4	9.4	9.6	9.2	T = 0.4
2	11.0	11.8	11.0	12.8	12.6	10.0	S = 0.2
3	14.6	13.0	15.6	15.2	15.8	11.2	T × S = 0.9
4	17.0	15.2	18.0	18.4	19.0	13.0	
Acidity, % (n = 3)							
1	0.36	0.33	0.32	0.30	0.30	0.32	T = NS
2	0.40	0.36	0.38	0.34	0.32	0.35	S = 0.2
3	0.44	0.36	0.40	0.40	0.38	0.40	T × S = NS
4	0.50	0.40	0.44	0.37	0.36	0.38	
Sensory quality (n = 10 panelists)							
1	4.5	4.5	4.5	4.5	4.5	4.0	T = 0.2
2	5.0	5.0	5.0	5.0	5.0	4.0	S = 0.1
3	6.5	6.0	6.5	7.3	7.5	4.0	T × S = 0.3
4	7.8	6.0	7.5	7.0	7.0	4.0	

PLW= Physiological loss in weight, TSS= Total soluble solids Initial value at harvest: Firmness= 685 g, sensory score= 4, TSS= 9%, Acidity=0.30%

1000 ppm (7%) during ripening period of 4 days, which was followed by ethephon 750 ppm (5.8%) and these treatments resulted in shriveling, softening and over-ripening of fruits and found unsuiatable. Ethylene gas (100 ppm) and ethephon (500 ppm) recorded 3.2% and 3.7% weight loss, respectively during ripening period of 4 days leading to adequate ripening and softening of fruits. Lowest PLW (2.8%) was recorded in control fruits and these fruits were green and hard in texture. The increase in weight loss during ripening of banana fruits by ethephon or ethylene application may be due to upsurge in respiration rate of the fruit. Mahajan et al. (2008) reported an increased weight loss in guava fruits during ripening process caused by ethylene application.

Firmness: The firmness of fruits declined during ripening period in all treatments (Table 1). Untreated control fruits were hard (256 g-force) and remained unripened, while ethephon (1000 ppm) treated fruits were least firm (45 g force). The fruits treated with ethylene gas (100 ppm) and ethephon (500 ppm) registered adequate firmness of 67 and 65 g force, respectively during ripening period of 4 day (Table 1). Firmness is one of the most crucial factors in determining the post-harvest quality of fruits (Shear 1975). 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 (Brinston et al. 1988). The hard or semi hard banana fruits are not liked by most of the consumers. Therefore, to develop desirable quality, the banana fruits need to be ripened artificially for enhancing consumer acceptability.

Sensory quality: Fruits treated with ethylene gas (100 ppm) recorded 7.8 score on 4th day and were rated as very much desirable and this treatment was very closely followed by ethephon 500 ppm (Table 1). The untreated control fruits were rated poor (4) in taste on 4th day. The improvement in sensory quality with ethylene gas or ethephon treatments may be due to the role of ethylene / ethephon in promoting changes which are important to flavour quality and formation of aroma volatile in climacteric fruit (Pratt and Goeschl 1969, Medlicott et al. 1987, Kulkarni et al. 2004)

TSS: The TSS content of fruits increased during ripening irrespective of treatments (Table 1). The TSS content of banana were maximum (19%) with ethephon 1000 ppm and lowest (13%) in control fruits. The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss (Ryall and Pentzer 1982). The increase may also be possible due to numerous anabolic and catabolic processes taking place

Table 2 Effect of ethylene gas and ethephon treatments on development of colour and ripening of banana fruits

Ripening period, days	Colour value	Ethylene 100, ppm	Ethepone, ppm				Control
			250	500	750	1000	
			Hunter values				
1							
	L	50.2	47.8	58.4	59.6	60.2	46.7
	a	–7.2	–8.6	–6.8	–5.4	–5.2	–9.6
	b	18.0	17.2	20.2	20.0	22.4	17.2
2							
	L	56.4	49.4	66.7	67.8	69.2	46.9
	a	–5.0	–5.6	–4.2	–4.0	–3.6	–9.2
	b	20.6	19.8	22.4	23.6	23.0	18.0
3							
	L	63.8	51.6	70.3	69.5	70.8	47.0
	a	1.30	–4.2	1.5	2.3	2.0	–8.7
	b	25.2	21.5	28.6	29.2	29.8	18.7
4							
	L	74.0	53.3	76.0	71.5	72.0	47.6
	a	2.27	–3.8	1.7	5.3	5.4	–8.8
	b	29.7	24.5	30.2	31.8	32.1	20.8
			Ripening				
1		0	0	0	0	0	0
2		0	0	0	0	0	0
3		78	30	75	83	88	0
4		100	55	100	100	100	30

Initial value of colour at harvest L =45.5, a=–9.9, b =16.7 (n=3)

in the fruit preparing it for senescence (Smith et al. 1979). Kulkarni et al. (2004) reported an increase in TSS and sugars in mango fruits treated with ethrel.

Titratable acidity: The acidity values were in the narrow range of 0.3–0.5% in all the treatments (Table 1) and differences were not statistically significant.

Fruit colour: The fruits treated with ethylene gas or ethephon solution recorded significant improvement in yellow colour of the peel as indicated by increase in 'b' value, compared to untreated control, which remained greenish soft with dull appearance (Table 2). The fruits treated with ethylene (100 ppm) and ethephon (500 ppm) developed uniform yellow colour, whereas ethephon (750 and 1000 ppm) resulted in deep yellow colour with black spots on fruit surface leading to over-softening of fruits. Ethylene gas and ethephon are treatment are known to accelerate the chlorophyll degradation and induce yellowness in green tissues of many fruits (Reyes and Paull 1995, Mahajan et al. 2008).

Ripening: For initial 2 days the fruits remained hard and green in all the treatments as judged by their visual appearance (Table 2). However, on third day there was dramatic increase in ripening of fruits and highest ripening percentage (100%) of banana fruit was observed after 4 days with ethylene gas (100 ppm) and ethephon (500 ppm) as well as its higher doses while lowest was in control fruits (30%). The role of ethylene in hastening ripening of fruit is evident because it binds to receptor forming an activated complex which leads to a wide variety of physiological responses including ripening (Yang 1980). The improvement in ripening of banana fruits is due to multifunctional nature of ethylene, which triggers a dramatic change during ripening process and ensures faster and uniform ripening in many fruits (Abeles 1973, Kadar et al. 1994, Kadar and Mitcham 1994).

Shelf-life studies: The shelf-life studies of banana fruit was carried out to study the post-ripening behaviour of fruit

Table 3 Effect of ethylene gas and ethephon treatments on shelf life of banana fruits under supermarket (16–18°C) and ordinary market (30–32°C) conditions

Ripening period, days	Shelf life at 16–18°C					Control
	Ethylene					
	100	250	500	750	1000	
	PLW, %					
1	3.5 (5.3)	3.7 (4.9)	3.9 (5.5)	5.9 (6.4)	7.3 (7.8)	3.0 (3.4)
2	3.9 (7.0)	4.0 (6.4)	4.2 (6.7)	6.3 (8.6)	8.0 (10.3)	3.3 (5.7)
3	4.2	4.2	4.6	6.5	8.4	3.7
4	4.7	4.5	4.8	6.7	9.0	4.0
	Firmness, g force					
1	62 (58)	90 (84)	62 (58)	45 (43)	41 (40)	210 (140)
2	57 (46)	83 (72)	55 (40)	40 (30)	37 (30)	150 (80)
3	53	80	51	36	35	110
4	50	78	47	32	30	83
	TSS,%					
1	17.4 (17.6)	15.2 (15.4)	18.4 (18.0)	18.4 (18.0)	18.6 (18.0)	13.4 (13.6)
2	18.0 (17.0)	15.6 (15.0)	18.4 (17.0)	18.0 (16.0)	18.0 (16.0)	13.8 (13.0)
3	18.2	16.0	18.6	17.6	18.0	14.0
4	18.6	15.4	19.0	17.2	17.6	14.0
	Acidity,%					
1	0.46 (0.32)	0.35 (0.30)	0.40 (0.33)	0.35 (0.30)	0.30 (0.28)	0.35 (0.32)
2	0.40 (0.25)	0.31 (0.20)	0.34 (0.22)	0.31 (0.25)	0.27 (0.21)	0.30 (0.24)
3	0.33	0.28	0.30	0.30	0.22	0.30
4	0.28	0.25	0.26	0.28	0.20	0.28
	Sensory quality (n=10 panelists)					
1	7.5 (7.2)	6.5 (7.0)	7.5 (7.2)	6.8 (6.5)	6.8 (6.5)	4.5 (5.0)
2	7.8 (7.0)	7.0 (6.5)	7.5 (6.8)	6.5 (6.0)	6.5 (6.0)	5.0 (5.5)
3	7.5	6.2	7.8	6.5	6.5	5.5
4	7.0	6.0	7.2	6.0	6.0	6.0

(n = 3) Figures is parenthesis indicate shelf-life values at 30–32°C

during retail marketing at 16–18°C (super market condition) and 30–32°C (ordinary market condition). The data on different attributes revealed that banana fruit treated with ethylene gas (100 ppm) or ethephon (500 ppm) can be kept for 4 days at 16–18°C and 2 days at 30–32°C with optimum weight loss, desirable firmness and highly acceptable colour and organoleptic quality (Table 3).The higher doses of ethephon (750 and 1000 ppm) resulted in shattering of fingers from bunch, over-softening and shriveling of fruits.

Conclusion

Exposure of green mature banana fruits to ethylene gas (100 ppm) for 24 h or dipping in ethephon solution (500 ppm) for 5 min followed by storage at 16–18°C and 90–95% RH, ensures faster and uniform ripening in 4 days with development of pleasant colour and consumer acceptability.

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