Madras Agric. J., **2018**, *105 (7-9)(2)*: 420-425; doi: 10.29321/MAJ.2018.000175

Differential Responses of Storage Temperature and Ethylene Inhibitors on Postharvest Life of Rasthali Banana

P. Jeyakumar[1*], V. Rajeswari[1], M.K. Kalarani[2], K.S. Subramanian[3] and M. Kavino[4]
[1]Department of Crop Physiology, TNAU, Coimbatore.
[2]Tapioca and Castor Research Station,Yethapur.
[3]Department of Nano Science and Technology, TNAU, Coimbatore.
[4]Department of Fruit Crops, HC&RI, TNAU, Coimbatore.

Temperature is a key tool improving the postharvest life and for preventing the development of postharvest diseases. In this study rasthali banana fruits treated with different ethylene inhibitors (α- Amino isobutyric acid (AIB) and 1-MCP) and chemicals (Hexanal and $CaCl_2$) were stored under ambient and cold storage (CS) (17°C) condition and morphological characters were recorded. The physiological loss in weight were minimum under CS condition in that AIB treated banana fruits recorded 39.54 per cent on the 11th day of storage (DOS) compared to AS control fruits compared to other treatments. Rigid nature of the fruit was maintained high in $CaCl_2$ treated fruits under both CS and AS conditions compared to other treatments. Likewise $CaCl_2$ treated fruits under CS recorded 1.40 mm peel thickness on the 11th DOS were under AS it is very much reduced in control on 7thDOS itself. Fruits stored under low temperature also showed delayed ripening by measuring low chrome b value. In that the fruits treated with 1-MCP recorded minimum chrome value of 48.73 and 51.18 in CS and AS respectively. Percent Disease Index (PDI) on the 7thDOS were recorded which is found to be low in cold storage condition and ethylene inhibitor AIB recorded minimum disease incidence symptoms of anthracnose, collar rot and crown rot followed by 1-MCP. Postharvest life of banana was found to be high in the CS fruits treated with ethylene inhibitors (AIB and 1-MCP) with the extent of 15 days compared to AS (8 days). Hence the fruits treated with ethylene inhibitors and stored under low temperature will prolong the storage life of the banana fruit.

Key words:AIB, 1-MCP, Hexanal, $CaCl_2$, Postharvest, Shelf life, CS, AS

Banana is a major food crop grown globally and is the fourth most important food crop after rice, wheat and maize. Banana is a non-seasonal climacteric fruit with high potassium content, low fatand a good source of vitamins and fiber(ProMusa, 2013). *Musa sp. cv. Rasthali* is a medium tall variety with (AAB genome) also called as Martaman in West Bengal, Mutheli in Maharashtra and Amruthnapanl in Andhra Pradesh, has a good potential of being exported to overseas markets because of its unique fruit quality and has table preference (Hassan, 2002). Though the banana gains importance of being nutritive it possesvery short postharvest shelf life because of its climacteric nature and high ethylene and respiratory outbreak which makes the fruit highly perishable. Hence an attempt was made with different ethylene inhibitors and chemicals under two different storage conditions to know the differential response of the treatments under storage temperature.

α-amino isobutyric acid (AIB) inhibits ethylene production by acting as a biosynthesis inhibitor of conversion of ACC to ethylene by suppressing the activity of ACC oxidase. With this effect of ethylene inhibition the AIB treatment on harvested cut longan fruit showed reduced fruit decay, respiration rate, membrane permeability, PPO and POD activities and total phenolic contents in fruit pericarp(Wang *et al.,* 2015). Likewise the Exogenous application of AIB and β- aminoisobutyric acid (BAIB) treatments maintained higher proportion of edible fruit by inhibiting the deterioration percentage. AIB has the direct role in inhibiting the ethylene forming enzyme activity coupled with the action of hindering the ethylene production through auxin(Satoh and Esashi, 1983) and also used for extending the shelf life with quality maintenance in litchi, longan, kiwi, papaya and mango (Hongxia, 2013).

1-Methylcyclopropene (1-MCP) now a day's gains agricultural importance as it has role in improving the shelf life and retains the quality of the fruits by inhibiting the ethylene action by competing the receptor sites with ethylene.Therefore, no signal can be sent for a chemical reaction, which delays the further ripening by decreasing the ethylene concentration (Sisler and Blankenship, 1996 and Mattheis *et al*., 2005).1-MCP has the potential to inhibit ripening and senescence in harvested fruits and vegetables like tomato, banana and plum fruit, avocado, orange, custard, apricots, pine apple, litchi, pear, apple, durian and jujube (Golding *et al*., 1998). Sisler *et al.*(2009) found that the application of

*Corresponding author's email: jeyakumar@tnau.ac.in

5 µL L^{-1} for 24 h could delay the banana ripening for 12 days at 23°C.

Hexanal, a naturally occurring volatile C_6 aldehyde compound, a strong inhibitor of phospholipase D (PLD) action, has been successfully applied for the pre and postharvest treatment of fruits, vegetables and flowers.Phospholipase D (PLD), a phospholipid-degrading enzyme, catalyzes hydrolysis of membrane phospholipids by initiating a lipolytic cascade of catabolic reactions leading to membrane deterioration during senescence and stress (Paliyath *et al.,* 2012). Hexanal treatmentshowed promising results in enhancing shelf life of several fruits,such as apple, banana, cherry, peach, strawberry, vegetables such asbroccoli, tomato, and several fresh-cut vegetables and flowers suchas carnation and rose by decreasing he enzyme activities (Paliyath and Subramanian, 2008; Thavong *et al*., 2010).The preharvest application of a hexanal formulation (Enhanced Freshness Formulation, EFF) showed better color, brightness, firmness, soluble salts and higher antioxidant enzyme activity and also reduces the diseases incidence (Sharma *et al.,* 2010).

Calcium an important micronutrient which has its presence as backbone in the membrane rigidity also has direct role in improving the postharvest shelf life, decreased ripening and quality maintenanceof the fruit by acting as a firming agents in whole and fresh cut fruits (Wilnwright and Burbage, 1989). Postharvest treatments of fruits with low concentrations of calcium salts found to reduce physiological disorders and delay senescence (Conway, 1982). Postharvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus extending storage life of fresh fruits (Picchion*et al.,* 1998). Calcium binds to the cell wall and polygalacturonic acid residues of the middle lamella and thus improving structural integrity (Van-Buren, 1979). Thus with this background, a study was conducted to know the ethylene inhibitors and chemicals for the postharvest shelf life of the fruits under storage temperature.

Material and Methods

The *Rasthali*banana fruit at 75 per cent ripening stage were de-handed from the bunch and the hands to be taken for experiment were graded for uniformity. After de-handing, fruit were cleaned under running tap water and then treated with 100 ppm sodium hypochlorite for 2 minutes and left to dry and arranged in crates. Then the fruit were treated with 100 ppm ethylene for 12 hours and the fruits were taken for treatments. After the ethylene treatments the fruits were dipped with AIB @ 150 ppm (T_2), EFF (0.2 % hexanal) @ 2%(T_4), $CaCl_2$ @ 0.5%(T_5) solutions and control fruits with normal water (T_1) for five minutes. For 1-MCP application by vaporization, were fruits are loaded into the treatment containers (150 L capacity). After loading the fruit, 1-MCP generator attached with the release vial was placed inside the container. 18± 5 mL of the activator solution was added the release vial. Then the appropriate concentration tablets +1 activator tablet was added to the vial for the release of 1-MCP gas. The treatment container was tightly sealed within 30 seconds. 1-MCP was thus applied to banana fruit for duration of 16 hours @ 17°C, RH 90-95 per cent.

External firmness

Fruit Hardness Tester (LT Lutron, FR-5120, Taiwan) was used to evaluate the firmness of the bananas. The test was performed on whole bananas at two points; three fingers of banana per replicates were used to perform the firmness test. The maximum force generated was used as a measure of firmness. Firmness was expressed in Newton (N).

Peel thickness

The peel thickness was measured using a digital vernier caliper and expressed in millimeters (mm)

Physiological loss in weight

Physiological loss in weight was expressed in percentage (%) in comparison with the initial weight.

$$PLW\ (\%) = \frac{\text{Weight of the fruit at first interval} - \text{Wt. of the fruit at second interval}}{\text{Weight of the fruit at first interval}} \times 100$$

Chromacity

Three fingers per replicates were used to evaluate the peel colour. The change in peel colour was measured in the L*a*b* color mode using a chromameter (CR-400, Konica Minolta). The chromacity ‘b’ values indicate the yellowness of the fruits i.e. higher the ‘’b’ value faster is the color change.

Shelf life

Shelf life of the fruit were taken based on the keeping quality and expressed in days.

Percent disease index

Percent disease index showing the exact status of the disease combining both incidence and severity was calculated by using the following formula (Wheeder, 1969) and expressed in percentage.

$$PDI = \frac{\text{Sum of individual ratings}}{\text{Total no. of fruits}} \times \frac{100}{\text{Maximum score}}$$

On the resultant 0 to 100 scale, 0 = disease free or no apparent symptom, 25 = market acceptable fruit, having only slight evidence of symptom, 50 = fruit with apparent symptom, barely acceptable by consumer, and 75 to 100 = fruit with large lesion, not marketable to totally unacceptable.

Results and Discussion

Firmness directly dictates the shelf life of fruits which measures the softness of the fruits during the period of ripening. In the present study, firmness of treated and control fruits of banana decreased gradually irrespective of both the storage conditions. Among the treatment with ethylene inhibitors and

chemicals, the highest firmness was recorded in treatment with 0.5% $CaCl_2$ while the lowest was recorded in untreated control fruits in both cold storage(CS) and ambient storage(AS) conditions (Table 1).The fruit stored under ambient condition, showed a faster rate of fruit softening than the cold storage fruit. These results are also in accordance with those reported by Shuiliang*et al*.(2002) that postharvest dips with $CaCl_2$ maintained firmness and eating quality of loquat. It is also involved in reducing the rate of senescence and fruit ripening (Ferguson, 1984).The retention of firmness in calcium treated fruits might be due its accumulation in the cell walls leading to facilitation in the cross linking of the pectic polymers which increases wall strength and cell cohesion (White and Broadly, 2003).

Table 1. Effect of ethylene inhibitors and chemicals on firmness in *Rasthali* banana

Treatments	Cold storage (17°C)							Ambient storage (27±2°C)				
	1st day	3rd day	5th day	7th day	9th day	11th day	Mean	1st day	3rd day	5th day	7th day	Mean
T_1	17.95	13.16	9.34	6.12	4.19	2.16	8.82	16.51	7.25	4.75	2.09	7.65
T_2	17.05	14.02	11.47	9.86	7.51	4.05	10.66	17.82	9.21	5.75	3.12	8.98
T_3	17.44	14.16	11.02	8.81	5.12	3.2	9.96	16.32	9.56	4.25	3.32	8.36
T_4	17.65	14.36	11.49	9.24	7.98	3.98	10.78	17.84	10.17	5.01	3.67	9.17
T_5	17.95	14.59	12.12	10.81	7.91	4.25	11.27	17.88	10.82	5.87	3.99	9.64
Mean	17.61	14.06	11.09	8.97	6.54	3.53		17.27	9.40	5.13	3.24	
SEd	0.15	0.12	0.10	0.08	0.05	0.03		0.15	0.08	0.04	0.03	
CD (P=0.05)	0.32	0.26	0.21	0.17	0.12	0.06		0.32	0.18	0.09	0.06	

Table 2. Effect of ethylene inhibitors and chemicals on chromacityin *Rasthali* banana

Treatments	Cold storage (17°C)							Ambient storage (27±2°C)				
	1st day	3rd day	5th day	7th day	9th day	11th day	Mean	1st day	3rd day	5th day	7th day	Mean
T_1	45.8	50.5	52.9	54.6	56.9	57.9	53.30	48.6	51.2	57.4	58.4	54.50
T_2	43.5	46.2	48.7	52.1	52.3	53.3	49.67	44.9	49.6	54.9	55.9	51.75
T_3	42.6	46.5	48	50.1	52.5	52.7	48.73	45.3	49.9	53.1	54.1	51.18
T_4	43.9	47.9	48.9	50.4	53.8	54.8	50.18	43.5	50.9	57.8	58.8	52.78
T_5	43.6	45.8	49.7	51.2	54.3	55.3	50.28	46.8	50.8	56.3	57.3	53.33
Mean	43.88	47.38	49.64	51.68	55.34	54.80		45.82	50.48	57.62	56.90	
SEd	0.38	0.42	0.44	0.45	0.49	0.48		0.41	0.45	0.51	0.50	
CD (P=0.05)	0.83	0.89	0.93	0.98	1.04	1.03		0.87	0.96	1.08	1.07	

During ripening process, the change in skin color from green to yellow, can be interpreted as the change in chrome 'b' value. Table 2 indicates increases in chrome value during the ripening process and shown a significant difference among the treatments under both CS and AS conditions. The fruits treated with 1- MCP showed the lowest chrome value of 48.73 and 51.18 under CS and AS respectively, which indicates the slow process of ripening (i.e. yellowing) than other treatments (Table 2).The fastest peel color change was observed in the fruits kept under ambient condition, where the fruits reached full yellow color on the 5th day of storage and the 'b' value was found to decrease at day 7 due to the development of brown spots. Chlorophyll degradation contributes to the change in banana fruitscolour during the maturation progress (Ding *et al.,* 2007), which is an important change because it allows other pigments, such as carotenoids, to provide an attractive fruit colour during ripening. These results were in agreement with those reported by Ashariya and Paull, (2007) found that application of 1-MCP delayed colour change in papaya fruit.

Peel thickness exhibited a declining trend over the period of storage regardless of the storage conditions and treatments (Fig.1). The fruits kept under CS were found to have comparatively higher peel thickness values than the AS fruits. Among the treatments $CaCl_2$ had exhibited the maximum mean thickness under both storage conditions.Reduction in peel thickness could be explained by modifications occurring in the cell wall and middle lamella during ripening leads to changes occurring in cell wall structure and loss of cell wall integrity (Subagio and Morita, 1997). This was added by findings from Glenn *et al.* (1988) that Ca^{2+} is effective in maintaining the cell wall structure, particularly the middle lamella hence calcium increases the thickness of the peel by binding the pectic substances together.

The *Rasthali* banana was predominantly infected by anthracnose, collar rot, crown rot disease as characterized by the formation of black spots on the fruit surface. The Percent Disease Index of anthracnose, crown rot, collar rot was significantly reduced under CS condition than ASon the 7th day of storage (Fig. 2). The

results showed that the fruits placed at cold conditions showed a lower per cent of disease incidence than that of AS fruits. Fruits treated with AIB exhibited significantly lesser disease index followed by 1-MCP than other treatments and has the market acceptability (<25% of PDI) till 7 days under CS.Studies have shown that aminobutyric acidand its derivatives were effective in inducing resistanceagainst pathogens in many fruits (Cohen, (2002). β-Aminobutyricacid was also effective in inducing resistance againstoomycete pathogens, bacteria, fungi and virus (Slaughter *et al.,* 2008). Furthermore, application of their derivativeγ-aminobutyric acid (GABA) reduced chilling injury andactivated the defense response of peach fruit (Yang *et al.,* 2011).

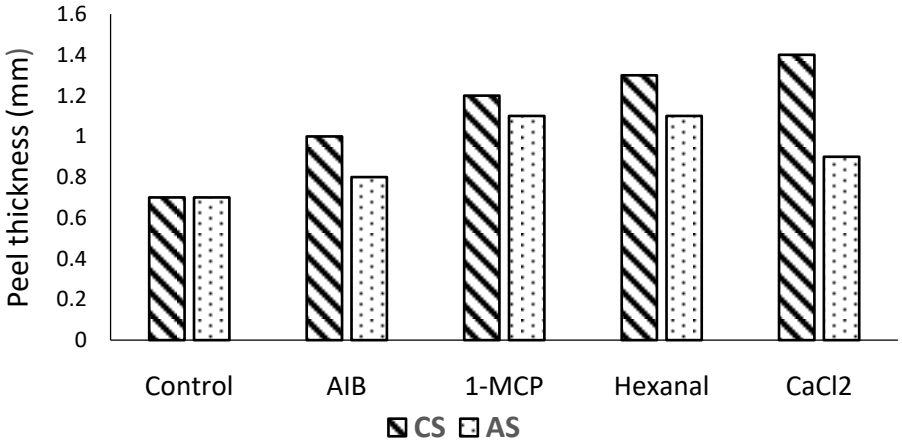

Fig.1.Effect of ethylene inhibitors and chemicals on peel thickness of *Rasthali*banana fruit under cold and ambient storage on the 7th day of storage

The ethylene inhibitors and chemicals treatment could significantly prolong the shelf life of the banana fruit by delaying the process of ripening. Fruit placed at cold storage had displayed an extended shelf life than the fruits under ambient conditions (Fig. 3). Under both the storage conditions, the treatment

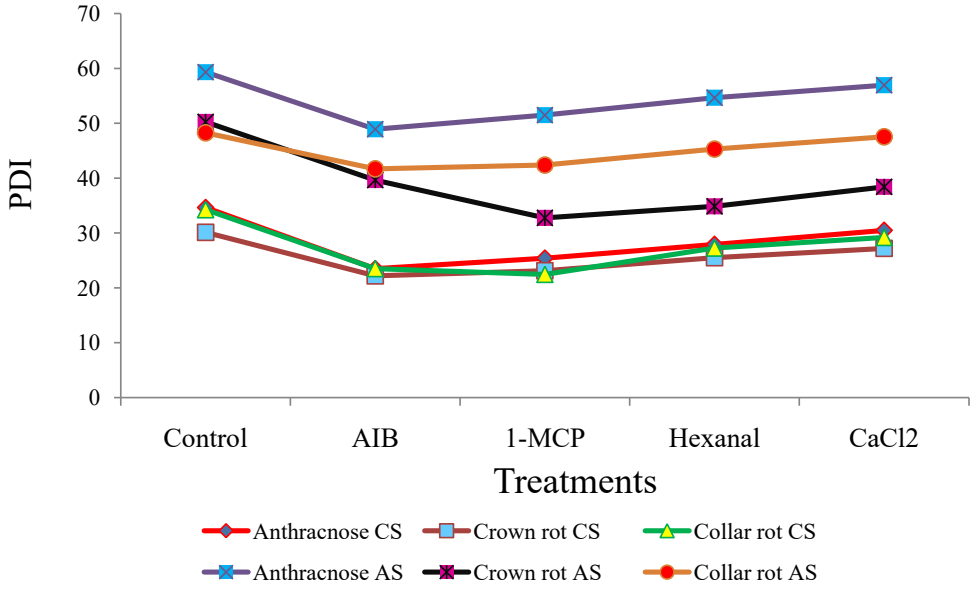

Fig.2. Effect of ethylene inhibitors and chemicals on Percent Disease Index (PDI) in Rasthali banana fruit under cold and ambient storage

with ethylene inhibitors AIB and 1-MCP had exhibited the longest days of shelf life (15 and 8) and showed effective in extending the shelf life of *Rasthali* fruits than the chemicals (EFF and $CaCl_2$). The above result were supported with the findings that AIB increases the shelf life by inhibiting the ethylene production by acting as competitive inhibitor of conversion of ACC to ethylene in cut flowers (Serrano *et al.,* 1990). α or β-AIB treated fruits can effectively reduce the rate of fruit rot, maintains fruit quality and extend the shelf life period. Reports also shown that 1-MCP application delay the process of ripening and extend the shelf life period of mango (Jiang and Joyce, 2000), plum (Manganaris*et al*., 2008), guava (Bassetto*et al*., 2005) and apples (Fan *et al*., 2000). Shi *et al*. (2014) reported that the combination of 1-MCP and low temperature could maintain the fruit quality and extend the shelf life of netted melons.

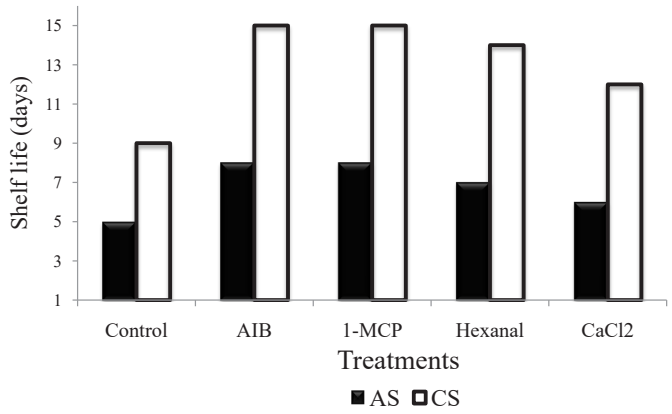

Fig.3.Effect of ethylene inhibitors and chemicals on shelf life of Rasthali banana fruit under cold and ambient storage

Rasthali banana fruits at 75 per cent ripening stage treated with AIB @ 150 ppm (5 min dipping) and 1-MCP @ 600 ppb (vapourizationfor 16 hours under cold storage) are found to have promising effect on ripening behaviour, postharvest quality and shelf life. Ethylene inhibitors and chemicals performed their own specific roles in delaying ripening and improvement of postharvest life. From the study it showed that, for minimizing the postharvest losses and to improve the quality of the fruit, the ethylene inhibitors and chemicals can be employed separately or in combinations for better improvement of postharvest life of banana fruits.

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