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Biochemical and Physiological Changes During Storage of Banana cv Nendran as Influenced by Postharvest Treatments

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ABSTRACT

Banana is an important tropical fruit crop of India which plays a vital role in socio-economic and nutritional security of the country. Nendran banana is a dual purpose plantain cultivar of commercial significance. As banana belongs to climacteric fruit category, the changes after the harvest occur at a faster rate leading to ripening and senescence with short shelf life. Delaying the ripening process in banana is of utmost importance for safe transportation and storage to enhance the shelf life of fruits without loss in quantity as well as quality. Postharvest treatments prior to storage can delay the ripening process in banana and fruits can be stored at room temperature for a longer duration. Hence the present study was conducted to evaluate the efficiency of postharvest treatments with Calcium chloride (4%), Gibberellic Acid (150 ppm), Oxalic Acid (20 mM) and Salicylic Acid (2 mM). The Nendran banana fruits harvested, at optimum uniform maturity, after sanitization were dipped in post-harvest treatment solution for 10 minutes and stored at room temperature were analyzed periodically for ripening associated changes. The postharvest treatments significantly influenced the biochemical and physiological changes during storage and ripening of Nendran banana and the Salicylic Acid 2mM was recorded as the most effective treatment in delaying the ripening process which was followed by the treatment with GA_3 150 ppm. The postharvest pre-treated fruits could be stored at room temperature for a longer time with minimum nutritional loss which will help in better market ability of fruits.

Keywords: Nendran banana, Calcium chloride, Salicylic Acid, Oxalic Acid, GA_3.

INTRODUCTION

Banana (*Musa* spp.) is an important tropical fruit of the world with commercial value. India is the second largest in global banana production and more than 50 different cultivars of banana are grown which plays a vital role in socio-economic and nutritional security of the country. Kerala has rich diversity in banana and Nendran banana (AAB genome), is an important plantain cultivar used for culinary, table purpose as well as for processed products. Banana being a climacteric fruit, ripening is associated with 'climacteric peak' leading to high respiration, ethylene biosynthesis and other metabolic activities making it highly perishable with short shelf life. In fruits, several factors account for postharvest losses of which rapid ripening is a major challenge hampering a postharvest loss of about 15% (Jogdand *et al.* 2017).

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Banana fruits are generally harvested at mature green stage and then transported to markets and later got ripened before reaching to the consumer. For export, long distant transport and domestic markets, green life of banana is a major factor determining the shelf life so that it can be stored for a longer time before it reaches to the consumer in ripened yellow stage. Delaying the ripening process in banana is of utmost importance for safe transportation and storage to enhance the shelf life of fruits without loss in quantity and quality. Research on appropriate methods to extend the shelf life of banana and to maintain fruit quality for long distance and domestic markets is vital (Kudachikar *et al.* 2011). Several research works are being conducted on different postharvest treatments in banana with a view to delay the process of ripening to increase the shelf life. Hence the present study was conducted to evaluate the efficiency of postharvest treatments on delaying biochemical and physiological changes during storage and ripening of Nendran banana for extending the shelf life.

MATERIALS AND METHODS

Nendran banana bunches (cv Kaliethan) of optimum uniform maturity, size, weight, shape, without damages were procured from the progressive farmers of Farmer Producer Organization, Thiruvananthapuram and brought to the research lab of Department of Postharvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University. The dehanded Nendran banana were washed and sanitized by ozonation (2 ppm) for 10 minutes. The sanitized Nendran banana hands were subjected to the postharvest treatments with 4% Calcium chloride (T_1), 150 ppm Gibberellic Acid (T_2), 20 mM Oxalic Acid (T_3) and 2 mM Salicylic Acid (T_4) by dipping for 10 minutes along with control as Nendran fruits without any postharvest treatments. After the postharvest treatments, the fruits were air dried and stored in Corrugated Fiber Board boxes under room temperature (30 ± 2ºC and 80–85% RH). The fruits were analyzed for biochemical and physiological changes at an interval of 3 days during storage till the end of shelf life.

Biochemical parameters

Total Soluble Solids (TSS) of the fruits was assessed using digital refractometer (At ago- 0 to 53%) and expressed in degree brix (°Brix). Titrable acidity, starch content, reducing sugar and total sugar and ascorbic acid content of Nendran banana fruits were analyzed as per the procedure described by Ranganna (1986). Titrable acidity was expressed in terms of percent citric acid equivalent and starch, reducing sugar, total sugar were expressed as percentage. Ascorbic acid content was measured by DCPIP (2, 6 -dichlorophenol indophenol) dye method and expressed as mg $100g^{-1}$. The carotenoid content was analyzed using the method suggested by Saini *et al.* (2001) and expressed in mg $100g^{-1}$. DPPH radical scavenging assay was used to measure the antioxidant activity using 2, 2 – diphenyl -1- picryhydrazyl and the scavenging effect on free radical was estimated according to the procedure described by Sharma and Bhat (2009).

Physiological parameters

Physiological Loss in Weight (PLW) was determined by recording the initial fruit weight and fruit weight at intervals during the storage. The cumulative physiological loss in weight was calculated by subtracting the fruit weight on particular storage day from the initial fruit weight and expressed in percentage. Respiration rate of Nendran banana fruits was determined based on the CO_2 concentrations (Kader and Saltveit 2003) using Checkpoint Portable Gas Analyzer and was expressed in mL CO_2 $kg^{-1}h^{-1}$.

RESULTS AND DISCUSSION

Total Soluble Solids (TSS) content of Nendran fruits increased during storage and is considered as an index of fruit ripening (Table 1). An increase in TSS of fruits was observed during the process of ripening. It increased from 2.75 ºBrix to 23.84 ºBrix during 12 days of storage. Among the treatments, the highest value of 16.20 ºBrix was recorded for the fruits stored without any treatment (T_5- control) and the lowest TSS of 10.74 ºBrix was for the treatment T_4 (SA 2 mM) after 12 days of storage. The fruits without any postharvest treatments (control) were discarded due

Table 1. Effect of postharvest treatments on TSS (ºB) of banana cv Nendran during storage. *Banana fruits were discarded due to spoilage.

Post harvest treatments	Days after storage (D) 0	3	6	9	12	Treatment mean (T)	15
T_1 ($CaCl_2$ 4%)	2.73	6.65	9.72	20.24	23.59	12.59	25.57
T_2 (GA_3 150 ppm)	2.71	5.29	8.62	18.54	22.48	11.53	25.03
T_3 (OA 20 mM)	2.78	5.70	9.14	19.56	23.38	12.11	25.43
T_4 (SA 2mM)	2.75	4.47	7.69	16.57	22.20	10.74	24.60
T_5 (Control)	2.79	7.27	18.74	24.65	27.56*	16.20	-
Days (D) mean	2.75	5.88	10.78	19.91	23.84		
	SE ± (m)		CD (0.05)			SE ± (m)	0.145
						CD (0.05)	
Treatment (T)	0.067		0.192			0.453	
Days (D)	0.067		0.192				
Teatment (T) × Days (D)	0.154		0.43				

to spoilage after 12 days of storage. The postharvest treatment with Salicylic Acid 2mM recorded the lowest TSS of 22.20 and 24.60 56 ºBrix after 12 and 15 days of storage respectively. The increase in TSS during storage and ripening might be due to the conversion of starch and other form of polysaccharides into soluble sugar. The application of Salicylic Acid could decrease the rate of breakdown of starch to sugar in banana which lowered the accumulation of soluble sugar (Hu *et al.* 2009). The TSS of banana fruits treated with GA_3 also experienced a slower increase during the storage and recorded 25.03 ºBrix after 15 days of storage and similar result was also reported by Alali *et al.* (2018) in banana fruits cv Grand Naine.

Titratable acidity in banana showed a gradual increase during storage due to production of organic acids such malic acid and citric acid as during ripening (Yap *et al.* 2017). The titratable acidity of Nendran banana increased from 0.18 % at the time of storage to 0.46% after 12 days of storage (Table 2). The treatment T_4 (SA 2 mM) recorded the lowest titratable acidity of 0.28 % followed by T_2 (GA_3 150 ppm) with 0.30 % and T_5 (control) recorded the highest acidity of 0.39% after 12 days of storage. After 15 days of

Table 2. Effect of postharvest treatments on acidity (%) of banana cv Nendran during storage.

Post harvest treatments	Days after storage (D) 0	3	6	9	12	Treatment mean (T)	15
T_1 ($CaCl_2$ 4%)	0.18	0.25	0.35	0.42	0.49	0.34	0.51
T_2 (GA_3 150 ppm)	0.17	0.24	0.30	0.37	0.43	0.30	0.45
T_3 (OA 20 mM)	0.17	0.23	0.32	0.35	0.44	0.30	0.46
T_4 (SA 2 mM)	0.18	0.23	0.25	0.33	0.42	0.28	0.45
T_5 (Control)	0.18	0.34	0.42	0.49	0.51*	0.39	–
Days (D) mean	0.18	0.26	0.33	0.39	0.46		
	SE ± (m)		CD (0.05)			SE ± (m)	0.003
						CD (0.05)	0.011
Treatment (T)	0.002		0.006				
Days (D)	0.002		0.006				
Treatment (T) × Days (D)	0.005		0.013				

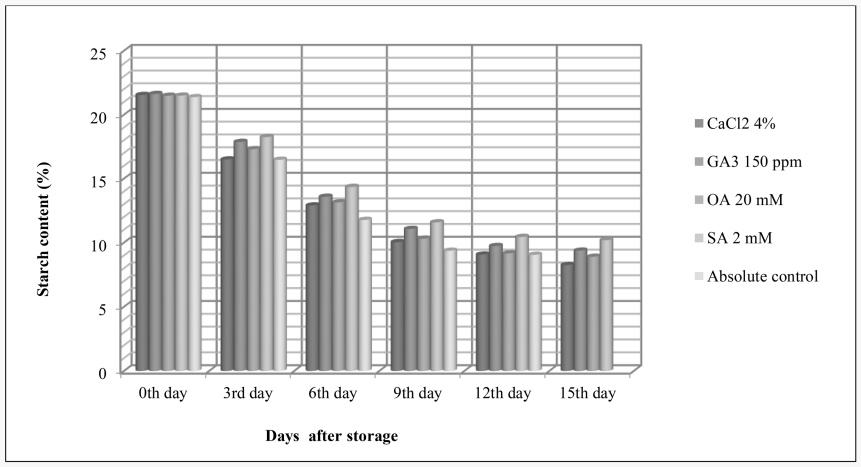

Fig. 1. Effect of postharvest treatments on starch content (%) of banana cv Nendran during storage.

storage T_4 (SA 2 mM) recorded the lowest titratable acidity of 0.45 %, which is statistically at par with T_2 (GA_3 150 ppm) and the highest titratable acidity of 0.51% was recorded for 4% $CaCl_2$ treated fruits (T_1). This could be because salicylic acid has an antagonistic effect on the activity of malic synthase that corresponds to decarboxylation of malic acid in banana (Mandal *et al.* 2016). Gibberellic Acid (GA_3 150 ppm) was also found to delay the acid development during ripening of banana and is supported by earlier workers.

During ripening, Nendran banana fruits experienced a decrease in starch content irrespective of the postharvest treatments but the rate of decrease in starch content was lower in the treated fruits as compared to untreated fruits. Banana fruits treated with SA 2 mM recorded the highest starch content (10.44 %) followed by the fruits treated with GA_3 150 ppm (9.74 %) and the lowest starch content (9.05 %) was recorded by untreated fruits at the end of 12 days of storage (Fig. 1). The highest retention of starch content (10.19 %) was recorded in fruits treated with SA 2 mM followed by GA_3 150 ppm (9.38 %) at the end of 15 days of storage. This indicates the delay in ripening, as Salicylic Acid reduced the break- down

Table 3. Effect of postharvest treatments on total sugar (%) of banana cv Nendran during storage.

Post harvest treatments	Days after storage (D) 0	3	6	9	12	Treatment mean (T)	15
T_1 ($CaCl_2$ 4%)	10.35	12.72	17.41	18.34	21.66	16.10	22.04
T_2 (GA_3 150 ppm)	10.47	11.64	15.72	17.43	20.95	15.24	21.05
T_3 (OA 20 mM)	10.25	12.07	16.18	17.94	21.27	15.54	21.61
T_4 (SA 2 mM)	10.29	11.00	14.60	15.62	19.81	14.26	20.21
T_5 (Control)	10.48	13.61	17.61	19.47	22.66*	16.77	–
Days (D) mean	10.37	12.20	16.30	17.76	21.27		
	SE ± (m)		CD (0.05)			SE ± (m)	0.188
						CD (0.05)	0.586
Treatment (T)	0.068		0.194				
Days (D)	0.068		0.194				
Treatment (T) × Days (D)	0.152		0.44				

Table 4. Effect of postharvest treatments on reducing sugar (%) of banana cv Nendran during storage.

Postharvest treatments	Days after storage (D) 0	3	6	9	12	Treatment mean (T)	15
T_1 ($CaCl_2$ 4%)	9.23	11.73	15.51	16.57	18.61	14.33	19.50
T_2 (GA_3 150 ppm)	9.21	10.52	12.20	14.90	17.11	12.78	17.80
T_3 (OA 20 mM)	9.15	10.84	12.57	15.84	17.56	13.24	17.92
T_4 (SA 2 mM)	9.24	10.27	11.53	14.58	16.72	12.47	17.34
T_5 (Control)	9.18	13.39	16.40	18.81	20.37*	15.63	–
Days (D) mean	9.20	11.35	13.69	16.14	18.07	–	
	SE ± (m)		CD (0.05)			SE ± (m)	0.205
						CD (0.05)	0.64
Treatment (T)	0.058		0.165				
Days (D)	0.058		0.165				
Treatment (T) × Days (D)	0.129		0.368				

of starch into sugar by hindering the activity of amylase enzyme (Hu *et al.* 2009). Degradation of starch during ripening also provides flavor forming volatile compounds and carbon for the synthesis of sucrose (Saraiva *et al.* 2013).

During the process of ripening, accumulation of sugar is one of the main changes occurring in fruit composition (Li *et al.* 2011). The total sugar content of Nendran banana fruits exhibited an increment irrespective of the postharvest treatments (Table 3). However, the rate of change varied among the treatments. The total sugar content increased from 10.37 % at the time of storage to 21.27% during the process of Nendran ripening at the end of 12 days of storage. After 15th day of storage, the minimum total sugar content of 20.21% was recorded by T_4 (SA 2 mM) followed by T_2 (GA_3 150 ppm) (21.05 %) and the maximum total sugar content of 22.04 % was observed for T_1 ($CaCl_2$ 4%) which showed no significant difference with T_2 (OA 20 mM). The increase in total sugar content could be due to the hydrolysis of starch into sugar during ripening and also the increased activity of enzymes related to the process of ripening like starch phosphorylase, α-

Table 5. Effect of postharvest treatments on carotenoid content (mg 100 g^{-1}) of banana cv Nendran during storage.

Postharvest treatments	Days after storage (D) 0	3	6	9	12	Treatment mean (T)	15
T_1 ($CaCl_2$ 4%)	0.13	0.18	0.21	0.27	0.32	0.22	0.33
T_2 (GA_3 150 ppm)	0.13	0.16	0.19	0.26	0.30	0.21	0.32
T_3 (OA 20 mM)	0.14	0.17	0.20	0.26	0.31	0.22	0.32
T_4 (SA 2 mM)	0.13	0.15	0.17	0.23	0.25	0.19	0.29
T_5 (Control)	0.14	0.19	0.26	0.31	0.35*	0.25	
Days (D) mean	0.13	0.17	0.21	0.27	0.31		
	SE ± (m)		CD (0.05)			SE ± (m)	0.005
						CD (0.05)	0.014
Treatment (T)	0.02		0.006				
Days (D)	0.02		0.006				
Treatment (T) × Days (D)	0.005		0.014				

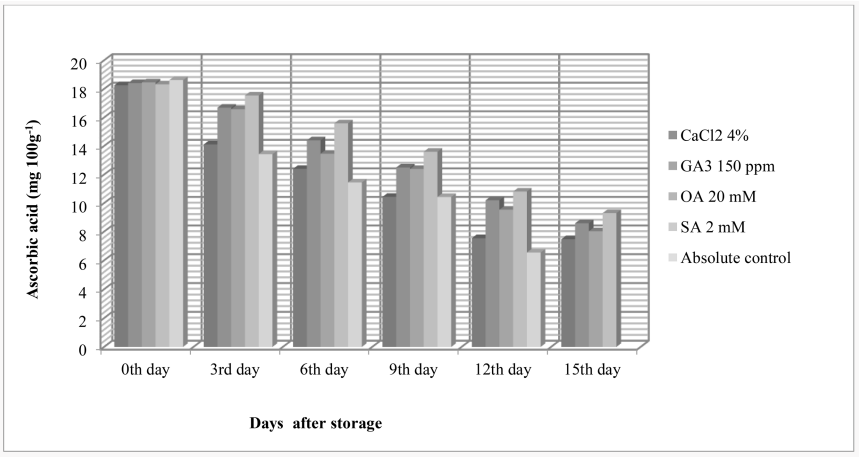

Fig. 2. Effect of postharvest treatments on ascorbic acid (mg $100g^{-1}$) of banana cv Nendran during storage.

amylase and β-amylase resulting in enhanced TSS and sugars (Mulagund *et al.* 2015).

Each postharvest treatment had a different effect on the reducing sugar content of Nendran banana fruits (Table 4). The fruits without any post-harvest treatment T_5 (control) recorded the highest reducing sugar content of 20.37 % followed by T_1 ($CaCl_2$ 4%) and the lowest reducing sugar content (16.72 %) was observed in SA 2 mM (T_4) followed by T_2 (GA_3 150 ppm) with 17.11 % after 12 days of storage (Table 4). The fruits treated with Salicylic Acid 2 mM recorded the lowest sugar content (17.34 %) followed by GA_3 150 ppm with 17.80% after 15 days of storage. This clearly shows that postharvest treatments have a significant role in reducing the rate of biochemical changes related to starch sugar conversion during ripening. Salicylic Acid inhibited the rise in reducing sugar content in fruits and is supported by Khademi and Ershadi (2013) reported that Salicylic Acid reduces ethylene production in fruits which may result in lowered enzyme activity, leading to a decrease in the formation of sucrose synthesis.

During ripening, the carotenoid content gradually increased in all the treatments but the rate of change was decreased by the postharvest treatments (Table 5). The highest carotenoids content (0.35 mg 100 g^{-1}) was observed in Nendran banana fruits kept without postharvest treatment while carotenoids content was the lowest (0.25 mg 100 g^{-1}) in fruits treated with SA 2 mM followed by fruits treated with GA_3 150 ppm (0.30 mg $100g^{-1}$) at the end of 12 days of storage. This clearly shows that the postharvest treatments with SA and GA_3 were efficient enough to delay ripening so that biochemical changes associated with carotenoid development is also influenced as reported by Supapvanich and Promyou (2017) in papaya during ripening.

The ascorbic acid content of Nendran banana fruits subjected to postharvest treatments decreased with ripening. However, the postharvest treatments had an upper hand in the retention of ascorbic acid content. At the end of 12 days of storage, banana fruits treated with Salicylic Acid 2 mM recorded the highest retention of ascorbic acid content (10.81 mg 100 g^{-1}) followed by GA_3 150 ppm (10.20 mg 100 g^{-1}) whereas the untreated fruits recorded the least retention of ascorbic acid (6.55 mg 100 g^{-1}) (Fig. 2). The fruits treated with SA 2 mM recorded the highest ascorbic acid content (9.30 mg 100 g^{-1}) followed by GA_3 150 ppm (8.59 mg 100 g^{-1}) after 15 days of storage also. The higher retention of ascorbic acid by Salicylic could be attributed to the activation of ascorbate peroxidase by Salicylic Acid, which in turn increased the antioxidant ability and ascorbic acid content in fruits (Wang *et al.* 2006).

Antioxidant activity of Nendran banana fruits decreased significantly with storage irrespective

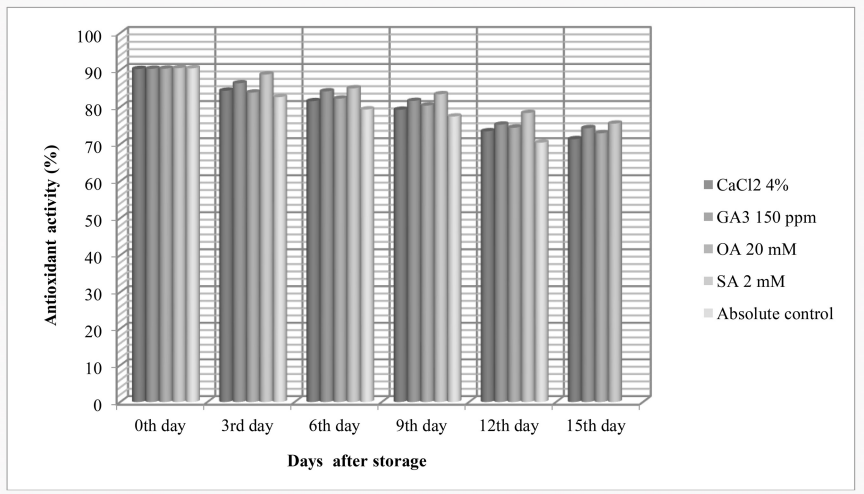

Fig. 3. Effect of postharvest treatments on antioxidant activity (%) of banana cv Nendran during storage.

of treatments. However, a reduced rate of loss was observed in fruits stored after postharvest treatments. Nendran banana fruits treated with Salicylic Acid 2 mM recorded better retention of antioxidant activity (78.39 %) followed by GA_3 150 ppm (75.23%) while the lowest (70.41 %) was recorded for untreated fruits at the end of 12 days of storage (Fig. 3). The reduction in antioxidant activity may be due to the degradation of phenol and ascorbic acid during ripening process. Postharvest application of SA significantly helped in retention of antioxidant activity which may be attributed to the increase in total phenolics and DPPH radical scavenging activity and total phenolics are positively correlated with the antioxidant activity (Khademi and Ershadi 2013).

Physiological loss in weight (PLW) plays an important role in postharvest life of fruits which

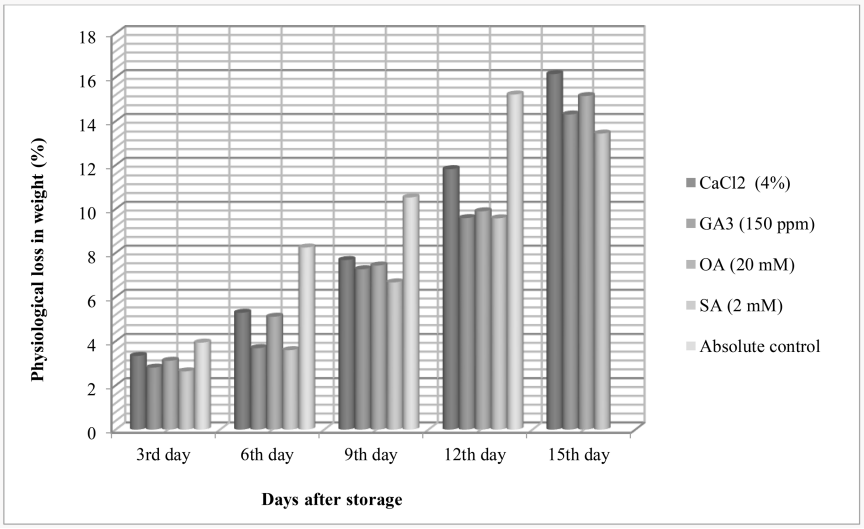

Fig. 4. Effect of postharvest treatments on physiological loss in weight (%) of banana cv Nendran during storage.

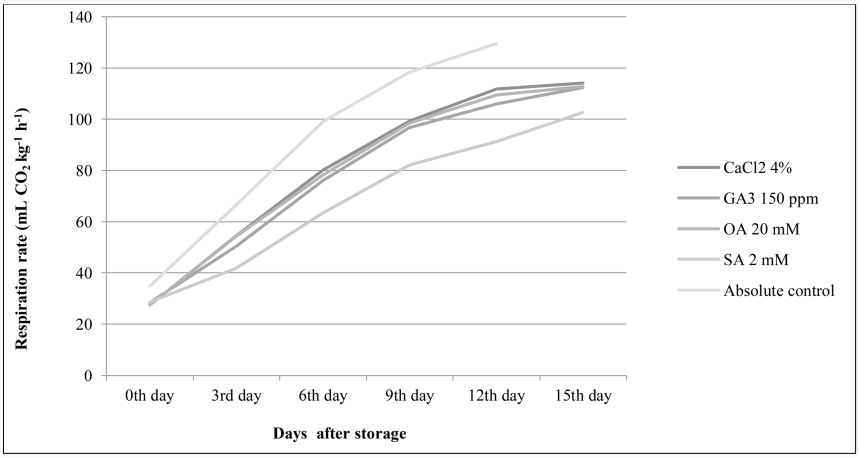

Fig. 5. Effect of postharvest treatments on respiration rate (mL CO_2 kg^{-1} h^{-1}).

affects sensory quality and marketability. The PLW of Nendran banana fruits increased during storage for both treated and untreated fruits but the postharvest treatments helped in reducing the loss in weight considerably. Among the different postharvest treatments, Salicylic Acid (2 mM) treatment recorded the lowest weight loss (13.43%) during the entire storage period of 15 days (Fig. 4). The postharvest treatment with SA 2 mM recorded the lowest PLW of 9.57% which showed no significant difference to GA_3 150 ppm with 9.58% as against the highest PLW (15.21%) for fruits without any postharvest treatment at the end of 12 days of storage. The PLW of fruits during storage is the result of loss of moisture through evapo-transpiration and use of reserve food materials by respiration process and the postharvest treatments helped to slow down these processes. Mandal *et al.* (2016) in banana cv Grand Naine treated with SA (2 mM) recorded a reduced weight loss (12.25%) as compared to the untreated fruits. Similar results were also observed by Alali *et al.* (2018) banana cv Grand Naine and Nair (2018) in Nendran banana.

As banana is a climacteric fruit, the respiration rate has been found to increase with the process of ripening and the rate of respiration is proportional to deterioration and shorter shelf life (Gonge *et al.* 2013). Respiration is a catabolic process in which organic materials like proteins, fats and carbohydrates are broken down into simple products with a release of energy (Hailu *et al.* 2013). The respiration rate of Nendran banana fruits increased in storage irrespective of the treatments (Fig. 5). However, application of postharvest treatments resulted in reducing the respiration rate. Salicylic Acid (2 mM) was found as the most effective treatment in reducing the respiration rate. The lowest respiration rate (91.27 mL CO_2 kg^{-1} h^{-1}) was observed in fruits treated with SA 2 mM, followed by GA_3 150 ppm (105.95 mL CO_2 kg^{-1} h^{-1}) and the highest respiration rate (129.58 mL CO_2 kg^{-1} h^{-1}) was observed in untreated fruits after 12 days of storage (Fig. 5). After 15 days of storage, SA 2 mM recorded the lowest respiration rate (102.70 mL CO_2 kg^{-1} h^{-1}) followed by GA_3 150 ppm with a respiration rate of 112.38 mL CO_2 kg^{-1} h^{-1}. This could be due to the effect of salicylic acid in reducing the respiration rate by inhibiting the ethylene biosynthesis or ethylene action as reported in several research works.

CONCLUSION

Postharvest treatments of Nendran banana harvested at optimum uniform maturity after sanitization with ozonation 2 ppm were found effective in delaying the ripening associated changes when stored at room temperature. The biochemical parameters viz., Total Soluble Solids, acidity, starch, total sugar, reducing sugar, carotenoids, ascorbic acid content and antiox-

idant activity undergo rapid changes during storage in untreated fruits. The physiological parameters ; respiration rate and physiological loss in weight of fruits which is an indication of respiration and evapotranspiration also exhibited a higher rate of increase in stored Nendran banana fruits without any treatment. The postharvest treatment of Nendran banana with 2mM Salicylic Acid slowed down the biochemical and physiological changes associated with ripening and thus delayed the ripening process. The treatment with 150 ppm GA_3 was also found effective in reducing the rate of changes and thus extending the period of ripening as compared to fruits without any postharvest treatment.

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