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Response of postharvest treatments on shelf life, biochemical and microbial quality of banana variety Red Banana

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Abstract

The popular Red Banana variety faces transportation challenges and has a limited postharvest shelf life due to its ripe fruits being less resistant and being a climacteric fruit. This study aims to prolong the shelf life of Red Banana fruits through different postharvest treatments. Fruit bunches of Red Banana were harvested at the mature green stage, separated into hands, precooled, subjected to 12 treatments and stored in corrugated fibre board boxes till the end of shelf life under ambient conditions. Fruits coated with 10% bee wax + 0.5% clove oil (T_4), fruits subjected to coating with 10% bee wax and packaging with potassium permanganate (T_9) and fruits dipped in hot water at 50 °C for 10 min. and packaging with potassium permanganate (T_{11}) registered highest shelf life of 18.67 days. The highest TSS of 26.33°Brix was noticed in fruits stored with potassium permanganate (T_8) after 12.67 days of storage and lowest titratable acidity of 0.19% and the highest sugar-acid ratio of 79.76 was noticed in control (T_{12}) after 11.33 days of storage. Moreover, the highest vitamin C content (7.74 mg 100 g^{-1}), total sugar content (18.47%), reducing sugar content (15.49%), total carotenoid content (24.13 µg 100 g^{-1}) was noticed in treatment T_7 (hot water dipping at 50 °C for 10 min.) after 17.67 days, T_{10} (coating with 40% aloe vera extract and packaged with potassium permanganate) after 13.33 days, T_4 (coating with 10% bee wax + 0.5% clove oil) after 18.67 days and T_9 (coating with 10% bee wax + potassium permanganate) after 18.67 days of storage respectively. Furthermore, the lowest fungal and bacterial count was observed in treatments T_2 (dipping in 30ppm sodium hypochlorite solution), T_7 (hot water dipping at 50 °C for 10 min.), T_9 (coating with 10% bee wax + potassium permanganate) and T_{10} (coating with 40% aloe vera extract + potassium permanganate).

Key words: Bee wax, postharvest treatments, potassium permanganate, Red Banana, shelf life

Introduction

Bananas, belonging to the Musaceae family, stand out as one of the most crucial tropical fruits available globally. Loved by people of all ages for their delightful taste, bananas are enjoyed fresh or dried. They are not only affordable but also packed with nutrients and energy. Being climacteric fruits, they are typically harvested when still green, yet they continue to undergo metabolic processes even after picking, making them susceptible to rapid degradation. Storing bananas poses a significant challenge due to their quick ripening postharvest. Despite the development of various shelf life extension methods, postharvest losses remain a concern. According to Al-Dairi *et al.* (2023), these losses can range from 25% to 50%, attributed to physiological changes, flesh softening and vulnerability to microbial attacks.

Refrigeration in cold rooms (Lima *et al.*, 2014), chemical treatments (Aghofack and Yambou, 2005), controlled and modified atmospheres and the inclusion of antioxidants (Rodríguez *et al.*, 2010) are some of the existing conservation methods. These technologies have drawbacks such as the high expense of installing cold rooms, the sensitivity of fruits to lower temperatures, the negative influence of some chemicals on consumer health, or the altering of the organoleptic qualities of the fruit. Fruit preservation in a fresh state thus necessitates the utilization of natural mechanisms with no real change in storage temperatures.

Yumbya *et al.* (2019) reported a six-day enhanced shelf life in banana fruits (*Musa acuminata* var. Sweet Banana) over control upon treatment with 2% hexanal. Kazemi *et al.* (2013) reported a reduction in weight loss (29.74 per cent) for pomegranate fruits sanitized with 10 per cent sodium hypochlorite against fruits (35.80 per cent) washed with distilled water. According to Netravati *et al.* (2018), washing banana fruits with 30 ppm sodium hypochlorite solution reduced the physiological loss in weight during storage. Hot water treatment of banana fruits effectively suppressed the microbial growth on the fruit surface and extended shelf life (Dissanayake, 2019).

Edible coatings seem to be a suitable substitute for preserving fruits in their natural state. The presence of bioactive substances in plant extracts accounts for this preservation quality. *Aloe vera* extract, a secondary metabolite with antioxidant properties, is effective in slowing down the ripening process of fruits (Zhou *et al.*, 2008). Nidiry *et al.* (2011) reported the antifungal activity of aloe vera gel against *Colletotrichum* sp., which is the causative organism of anthracnose in banana. According to Jodhani and Nataraj (2019), clove oil was beneficially used to help reduce pathogen attacks, the primary cause of strawberry fruit deterioration. Kumah *et al.* (2020) identified beeswax as a suitable coating for maintaining the quality and prolonging the shelf life of banana var. Mysore for four days more than the control.

Ethylene, a natural plant hormone, plays a central role in initiating ripening and accelerating fruit senescence. Its removal from the storage atmosphere is known to extend the shelf life of fruits.

Since potassium permanganate ($KMnO_4$) oxidizes ethylene to produce carbon dioxide (CO_2) and water, it is very effective at lowering ethylene levels (Elzubeir *et al.*, 2017; Sujayasree and Fasludeen, 2017).

Hence, the aim of this study was to establish standardized postharvest protocols aimed at slowing the ripening process and extending the shelf life of Red Bananas while minimizing any loss of nutritional value.

Materials and methods

The research was conducted in the Horticulture Labouratory at the School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, between 2022 and 2023. Red Banana bunches were procured from the Booluvampatti market, Coimbatore and selected based on their 80% maturity level, consistent size, shape and colour. After cleaning and precooling (hydrocooling) to reduce field heat, the bunches were divided into hands. Subsequently, various postharvest treatments were applied, and the fruits were packed in Corrugated Fibre Board (CFB) boxes. They were then stored at ambient temperatures until reaching the end of their shelf life, with evaluations conducted on shelf life duration, biochemical changes, and microbial parameters.

The treatment details of the study are: T_1: 2% hexanal (dipping), T_2: dipping in 30ppm sodium hypochlorite solution, T_3: coating with 10% bee wax, T_4: Coating with 10% bee wax + 0.5% clove oil, T_5: coating with 40% aloe vera extract, T_6: cling film wrapping, T_7: hot water dipping at 50 °C for 10 min., T_8: potassium permanganate, T_9: coating with 10% bee wax + potassium permanganate, T_{10}: coating with 40% aloe vera extract + potassium permanganate , T_{11}: Hot water dipping at 50 °C for 10 min. + potassium permanganate* and T_{12}: Control. *6 g $KMnO_4$ per seven fingers of banana fruits as sachets.

The study followed a Completely Randomized Block design (CRD). In a treatment, three boxes with three hands each were stored. Observations on the biochemical and microbial quality of the fruits were recorded at the beginning and at the end of shelf life.

Shelf life: The number of days required to ripe the fruits fully to retain optimum marketing and eating qualities were counted to calculate the shelf life of Red Banana influenced by different postharvest treatments.

Total soluble solids (° Brix): The total soluble solids (TSS) content of banana fruit pulp was estimated using digital refractometer (Model-MA 871) and expressed in degree brix (AOAC, 1980).

Titratable acidity (%): The titratable acidity was estimated by titrating with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed as per cent of malic acid (Ranganna, 1997).

Vitamin C: Ascorbic acid was estimated by using standard indicator dye 2,6- dichlorophenol indophenol and expressed as mg $100g^{-1}$ of fruit (Sadasivam and Manickam, 1996).

Total sugars (%): The total sugar content of banana pulp was determined calorimetrically by the anthrone method (Jayaraman, 1981) using anthrone reagent and expressed in percentage.

Reducing sugars (%): Reducing sugar content of banana pulp was determined by the dinitrosalicylic acid method (Miller, 1959).

Total carotenoids (μg 100 g^{-1}): The supernatant obtained by grinding fresh sample with 80% acetone and centrifuging at 3000 rpm for 10 min. were read at 480 nm in UV spectrophotometer (Jensen, 1978).

Sugar: acid ratio: The ratio between the total amount of sugars and the acidity content of the fruit was taken to find the sugar-acid ratio.

Bacterial and fungal population (cfu g^{-1}): The enumeration of microbial load in pre and post-treated sample was carried out by serial dilution technique. Nutrient agar was used for enumeration of bacteria and potato dextrose agar medium was used for the enumeration of fungal population of the fruit surfaces. The following formula calculated the number of microorganisms (bacteria and yeast) per cm^2 of pre and post-treated sample.

No. of colony forming units (cfu) / mL of the sample = (Total number of colonies formed x Dilution factor)/Aliquot plated

Statistical analysis: The data was analysed statistically by applying the variance analysis techniques (Panse and Sukhatme, 1985).

Results and discussion

Shelf life of Red Banana fruits: The study shows a significant difference between the postharvest treatments on the shelf life of Red Banana fruits stored in CFB boxes under ambient conditions (Table 1). Highest shelf life of 18.67 days was reported in treatments T_4 (coating with 10% bee wax + 0.5% clove oil), T_9 (coating with 10% bee wax + potassium permanganate) and T_{11} (hot water dipping at 50 °c for 10 min. + potassium permanganate). It was found to be on par with treatments T_5 (coating with 40% aloe vera extract) and T_7 (hot water dipping at 50 °C for 10 min.) with a shelf life of 18.33 days and 17.67 days respectively. The lowest shelf life of 11.33 days was registered in control (T_{12}), which was found to be on par with Red Banana fruits subjected to storage with potassium permanganate (T_8) (12.67 days). A similar finding of delayed fruit ripening and enhanced shelf life upon waxing and packaging with potassium permanganate was also reported by Elzubeir *et al.* (2017) in mango. This increased shelf life of fruits might be due to the modified atmosphere (lower O_2 and higher CO_2 concentration) generated within the CFB box due to waxing, in combination with the use of potassium permanganate which decreased the respiration rate and delayed the onset of the climacteric peak in banana (Abu-Goukh, 1986). The findings of Giri *et al.* (2016) in banana was also found in accordance with the study. They stated that the shelf life of banana fruits increased on heat treatment which can be due to slowing down of enzyme activity and elimination of the disease incidence. de Figueiredo Sousa *et al.* (2019) documented clove essential oil as a suitable film material for coating banana fruits, which provides excellent antifungal activity against *Colletotrichum gloeosporioides* and enhances storage life.

Total soluble solids (TSS) **of Red Banana fruits:** The present study found that the TSS of Red Banana fruits increased during storage in all the treatments (Table 1). Initially the TSS of fruits were 18.60°Brix and at the end of storage life, TSS were found to be significantly different between treatments. The highest TSS of 26.33°Brix was observed in treatment T_8 (storage with potassium

Table 1. Effect of postharvest treatments on shelf life and biochemical parameters and microbial load of Red Banana fruits

Treatments	Shelf life (days)	TSS (°Brix)	Titratable acidity (%)	Vitamin C (mg $100g^{-1}$)	Total sugars (%)	Reducing sugars (%)	Total carotenoids (µg $100g^{-1}$)	Sugar: acid ratio	Fungal count ($\times10^4$ cfu g^{-1})	Bacterial count ($\times10^6$ cfu g^{-1})
Initial value		18.60	0.37	4.23	9.56	4.52	12.80	4.52	60.00	TNTC
T_1	13.33	22.73	0.25	7.30	16.64	13.73	19.77	66.14	13.33	TNTC
T_2	14.00	23.20	0.28	7.72	17.60	14.71	20.97	64.21	0.00	26.66
T_3	13.67	21.57	0.30	7.59	17.34	14.34	21.27	57.26	16.67	TNTC
T_4	18.67	23.23	0.28	7.64	18.24	15.49	22.20	66.58	10.00	TNTC
T_5	18.33	23.57	0.32	7.45	17.31	14.50	22.27	55.19	0.00	TNTC
T_6	13.33	24.93	0.26	7.33	17.02	13.47	22.43	65.66	26.67	TNTC
T_7	17.67	23.23	0.32	7.74	17.01	13.74	22.63	54.20	0.00	20.00
T_8	12.67	26.33	0.27	7.03	17.58	13.57	20.90	66.36	13.33	TNTC
T_9	18.67	24.23	0.32	7.02	18.41	14.28	24.13	58.35	0.00	13.33
T_{10}	13.33	21.77	0.30	7.31	18.47	13.63	21.00	61.13	0.00	13.33
T_{11}	18.67	21.80	0.34	7.33	17.37	14.05	21.33	51.20	0.00	TNTC
T_{12}	11.33	25.03	0.19	7.59	15.04	12.64	18.17	79.76	66.67	TNTC
SE (±m)	0.58	0.50	0.00	0.47	0.38	0.47	0.55	0.75	0.58	
CD (5%)	1.69	1.46	0.02	NS	1.10	1.38	1.62	2.18	1.67	

*TNTC- Too numerous To count

permanganate) after 12.67 days of storage. It was found to be on par with T_{12} (control) with a TSS of 25.03 °Brix after 11.33 days of storage. The lowest TSS (21.57°Brix) was noticed in fruits subjected to coating with 10% bee wax (T_3) after 13.67 days of storage life, which was found to be on par with T_{10} (coating with 40% aloe vera extract + potassium permanganate) (21.77°Brix) after 13.33 days of storage.

The hydrolysis of starch into sugar likely caused an increase in the TSS concentration up to a certain point during storage. Akter *et al.* (2013) also reported similar findings of enhanced shelf life in banana fruits subjected to modified atmosphere packaging with $KMnO_4$. The degree to which TSS values increased for various postharvest treatments may be linked to the physiological characteristics and altered interior environment of banana fruits, as well as to suppressed respiration and metabolic processes, all of which contribute to TSS accumulation to varying degrees.

Titratable acidity (%) of Red Banana fruits: The titratable acidity of Red Banana fruits was found to decrease during storage irrespective of the treatments (Table 1). The value was 0.37% at the beginning of storage and later decreased and differed significantly among treatments. The lowest titratable acidity (0.19%) was noticed in T_{12} (control) after 11.33 days of storage, whereas T_{11} (hot water dipping at 50 °c for 10 min. + potassium permanganate) registered the highest titratable acidity of 0.34% after 18.67 days of storage.

The decrease in acidity during storage is linked to the use of acids in the respiration process and conversion to sugars, indicating fruit ripening. The result indicates that fruits subjected to different postharvest treatments delayed the ripening in banana whereas in fruits with no postharvest treatments (control) ripening was hastened. Slow ripening of banana fruits in all treatments except that of control resulted in the delayed breakdown of organic acid and higher titratable acidity. Similar findings of higher titratable acidity in hot water-treated Basari fruits of banana after 15 days of storage were reported by Kaka *et al.* (2019) compared to fruits subjected to control.

Vitamin C content (mg $100g^{-1}$) of Red Banana fruits: The vitamin C content of banana fruits at the beginning of storage was 4.23 mg $100g^{-1}$ and it was found to increase during storage irrespective of treatment given (Table 1). However, there was no significant difference between treatments on vitamin C content at the end of storage. The highest vitamin C content of 7.74 mg $100g^{-1}$ was noticed in treatment T_7 (hot water dipping at 50 °C for 10 min.) after 17.67 days and the lowest value of 7.02 mg $100g^{-1}$ was observed in T_9 (coating with 10% bee wax + potassium permanganate) after 18.67 days. The rise in ascorbic acid level during storage could be related to an increase in lipid peroxidation, which occurs concurrently with ripening.

Total sugars (%) of Red Banana fruits: The initial total sugar content of mature Red Banana fruits was 9.56%. As indicated in Table 1, total sugar levels increased over time during storage. Among the treatments, Red Banana fruits coated with 40% aloe vera extract and packaged with potassium permanganate (T_{10}) exhibited the highest total sugar content of 18.47% after 13.33 days. This was comparable to treatments T_9 (coating with 10% bee wax + potassium permanganate), T_4 (coating with 10% bee wax + 0.5% clove oil), T_2 (dipping in 30 ppm sodium hypochlorite solution), and T8 (storage with potassium permanganate), which showed total sugar contents of 18.41% after 18.67 days, 18.24% after 18.67 days, 17.60% after 14 days, and 17.58% after 12.67 days, respectively. Conversely, the control treatment (T12) had the lowest total sugar content of 15.04% after 11.33 days.

Banana fruits undergo physiological changes during ripening and the most notable chemical changes that occur during the postharvest ripening of banana fruits are starch hydrolysis and sugar buildup (Al Muzahid *et al.*, 2021) which might be the reason for the increase in total sugar content in all the treatments. According to Wills and Rigney (1980), the slow rate of increase in sugar in the wax-treated fruits compared to the control could be attributed to the usage of waxes that alter the activity of mitochondria and certain enzymes, especially sucrose synthase and pectinase. Sucrose synthase responsible for starch accumulation if affected will affect the starch-to-sugar conversion (Shahid and Abbasi, 2011).

Reducing sugars (%) of Red Banana fruits: An upward trend was noticed in reducing sugar content of Red Banana fruits irrespective of treatments during storage and a significant difference was observed between the values at the end of storage (Table 1). Reducing sugar was found to be 4.52% at the beginning of storage and the highest value (15.49%) was noticed in treatment T_4 (coating with 10% bee wax + 0.5% clove oil) at the end of storage (18.67 days). It was found to be on par with T_2 (dipping in 30ppm sodium hypochlorite solution), T_5 (coating with 40% aloe vera extract), T_3 (coating with 10% bee wax) and T_9 (coating with 10% bee wax + potassium permanganate) with a reducing sugar content of 14.71% after 14 days, 14.50% 18.33 days, 14.34% after 13.67 days and 14.28% 18.67 days respectively. The lowest percentage of reducing sugar (12.64) was noticed in T_{12} (control) after 11.33 days.

The findings of the present study align with those of Salunkhe and Desai (1984), who observed an increase in reducing sugar content as fruit ripens. Similarly, Ahmad et al. (1986) reported that wax-treated fruits showed a slower increase in reducing sugars compared to the control group.

Total carotenoid (µg 100g^{-1}) of Red Banana fruits: The total carotenoid content of Red Banana fruits increased during storage and differed significantly at the end of storage (Table 1). 12.80 µg 100g^{-1} was the carotenoid content in Red Banana fruits at the beginning of storage and treatment T_9 (coating with 10% bee wax + potassium permanganate) registered a higher total carotenoid content of 24.13 µg 100g^{-1} after 18.67 days of storage. It was found to be on par with fruits dipped in hot water at 50 °C for 10 min. (T_7) with a carotenoid content of 22.63 µg 100g^{-1} after 17.67 days of storage. However, T_{12} (control) registered the lowest value for total carotenoid (18.17 µg 100g^{-1}) after 11.33 days.

Maina *et al.* (2019) reported a delayed development of carotenoid content in waxed fruits of mango as a result of low O_2 and high CO_2, which hampered the enzymes involved in the synthesis or unmasking of preexisting colour pigments.

Sugar-acid ratio of Red Banana fruits: The sugar-acid ratio of Red Banana fruits calculated at the end of storage revealed a significant difference between treatments (Table 1). The highest sugar-acid ratio of 79.76 was observed in T_{12} (control) after 11.33 days, followed by T_4 (coating with 10% bee wax + 0.5% clove oil) with a sugar-acid ratio of 66.58 after 18.67 days. However, the lowest sugar acid ratio (51.20) was noticed in T_{11} (Hot water dipping at 50 °C for 10 min. + potassium permanganate) after 18.67 days.

As the fruit ripens, the sugar content increases, the fruit acids decrease, and the sugar-acid ratio increases in value. The primary cause of the rise in the sugar-acid ratio level could be ripening, caused by the breakdown of starch into water, soluble sugars, sucrose, and glucose.

Microbial load of Red Banana fruits: The microbial load of Red Banana fruits under different treatments, observed as fungal and bacterial counts, showed significant differences at the end of storage (Table 1).

The fungal count at the beginning of storage was found to be 60.00 ×10^4 cfu g^{-1} in Red Banana fruits and it decreased in all the treatments except control at the end of shelf life. The lowest fungal count of 0.00 ×10^4 cfu g^{-1} was observed in treatments T_2 (dipping in 30ppm sodium hypochlorite solution), T_5 (coating with 40% aloe vera extract), T_7 (hot water dipping at 50 °C for 10 min.), T_9 (coating with 10% bee wax + potassium permanganate), T_{10} (coating with 40% aloe vera extract + potassium permanganate) and T_{11} (hot water dipping at 50 °C for 10 min. + potassium permanganate) at the end of storage, whereas, highest fungal count of 66.67 ×10^4 cfu g^{-1} was noticed in control.

The bacterial load was Too Numerous to Count (TNTC) at the beginning of storage in all the treatments and it continued to be the same in a few treatments including the control at the end of storage except in T_2 (dipping in 30ppm sodium hypochlorite solution), T_7 (hot water dipping at 50 °C for 10 min.), T_9 (coating with 10% bee wax + potassium permanganate) and T_{10} (coating with 40% aloe vera extract + potassium permanganate).

Implementing various postharvest techniques likely led to decreased fungal counts across all treatments except the control group. Bhowmik and Pan (1992) also reported a significant reduction in the microbiological count of tomato fruits when sterilized with sodium hypochlorite prior to packaging. Similarly, Jayasheela (2014) found that papaya fruits sanitized through a hot water treatment at 50°C for 20 min., coupled with waxing and ethylene absorbent, exhibited the lowest levels of bacterial and fungal populations. Kester and Fennema (1986) also noted that edible films and coatings act as barriers against microbial invasion. Issar et al. (2010) suggested that the reduced spoilage in wax-coated fruits was likely due to the wax sealing bruised areas, thereby limiting microbial entry. This may have contributed to the lower fungal and bacterial counts observed in Red Banana fruits coated with aloe vera and bee wax. Furthermore, Martínez-Romero *et al.* (2006) described the antimicrobial properties of aloe vera gel extract against various types of yeast, old, and bacterial growth, which aligns with the findings of this study.

The study revealed that Red Banana fruits harvested at the mature green stage, precooled, and coated with 10% bee wax, then packaged with potassium permanganate and stored under ambient conditions showed the longest shelf life of 18.67 days. Additionally, they exhibited the highest total carotenoid content and lowest fungal and bacterial counts. Therefore, coating the fruits with 10% bee wax and packaging them with potassium permanganate is recommended to significantly reduce decay and maintain quality, thus enhancing the shelf life of Red Banana fruits.

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