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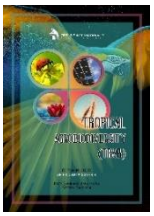

REVIEW ARTICLE

REVIEW ON: TECHNIQUES TO MAINTAIN QUALITY AND POST-HARVEST SHELF-LIFE OF BANANA FRUITS

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ABSTRACT

Banana is a climacteric fruit, which has a higher respiration rate and rapid ripening as well as senescence process. There is about 40% of fruit loss during post-harvest handling. Because of its tropical origin, more sensitive to chilling injury at sufficiently lower storage temperature (<13ºC). Banana fruits stored at the optimum temperature of 13-14ºC and higher relative humidity of 90-95% is suitable for better extension of the shelf-life of banana by 7 to 12 days. In addition to maintenance of post-harvest storage temperature and relative humidity, some techniques are intervened to slow down the respiration rate, ethylene evolving rate, delay ripening and postpone the senescence process. These techniques may be pre-harvest spray, post-harvest packaging, edible coating, post-harvest dipping treatments, hot water treatment, irradiation technique, controlled atmosphere storage, and use of ethylene absorbent and ethylene inhibitors treatments. Some practices impose more than one above mentioned techniques like modified atmosphere packaging (MAP) + green keeper treated banana fruits kept at 12 ± 1°C and 85–90% RH have long shelf-life i.e. 49 days. Some techniques like banana fruits treated with 0.5 µl/l 1-MCP and packed in sealed polyethylene bags could achieve successful lengthening of post-harvest shelf-life of banana for about 58 days at good marketable condition. Based on availability, profitability and our objective selection of appropriate combinations of these techniques can achieve a longer shelf-life of banana with better quality.

KEYWORDS

Atmosphere, Chilling, Edible, Humidity, Inhibitor

1. INTRODUCTION

Banana (*Musa paradisiaca*) is a large monocarpic perennial herb. Which is one of the most popular fresh fruits all over the world because of its higher nutritive value, good taste and chief price. Banana is a good source of carbohydrate, vitamin A, vitamin C, vitamin B-6, potassium, and fibre with low fat (Agriculture, 2015). In terms of export value; bananas are the most important fruit traded worldwide (Voora et al., 2020). In the year 2020, about 5.6 million ha of land was dedicated to banana fruit production from which around 114 million tonnes of banana was harvested (Statista, 2022).

Huge post-harvest losses estimated at 40 % are a major constraint facing small-holder fruit farmers in developing countries (Peninah et al., 2018). After harvest, when banana fruits start to ripen, the color, texture, aroma, and sweetness improve. Bananas ripen more quickly in the summer, but more slowly in the winter. The ripening process can be speed up or slowed down by adopting some interventions on factors affecting on ripening process. The banana is a perishable fruit that is linked with physiological changes such as weight loss due to transpiration and respiration, softening of the flesh, and lack of resistance to microbial attack (Kandel et al., 2018). Banana is highly climacteric in nature, respiration rate and ethylene evolving rate is very high, which leads a rapid senescence process.

Primarily rapid respiration rate and secondarily infection of pathogens are the major causes of short shelf-life of pathogen. In general there is visual appearance of change in peel colour from yellow to muddy brown colour at the termination of shelf-life of banana. Crown rot is the most important post-harvest disease of banana fruit throughout the world. Rot causes blackening and softening of tissues, which begins at or near the cut surface of the crescent shaped crown (Greene and Goos, 1963). Mechanical injuries, induced by shock, vibration, and compression during handling and distribution, are one of the most common causes of increasing respiration and avenue for pathogen entry results in huge losses during marketing.

Bruising and skin abrasion are the most common mechanical injuries that leads in poor fruits quality. In banana during the post-harvest period browning of both external skin and internal flesh occurs. Here, cell breakage causes increase in rate of respiration as well as phenolic substances to come in contact with enzymes like polyphenol oxidase (PPO), in presence of oxygen this enzyme results in formation of brown pigments (Leelaphiwat and Chonhenchob, 2020). Since this ripening and senescence process are highly dependent on storage temperature, relative humidity (RH), and gaseous composition of storage environment adjusting these factors to the optimum can achieve better shelf-life of banana fruits with optimum quality.

2. LITERATURE REVIEW

Temperature and respiration have direct relation, so each 10°C increase in temperature increase rate of respiration. Although rate of respiration is slowdown at lower temperature we cannot store banana at less than 13-14°C because of its higher sensitivity with chilling injury (Kader, 2012). Similarly RH of storage atmosphere have inverse relation with

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transpiration and relative weight loss of the commodity. Therefore maintaining RH at 90-95 % is optimum to slowdown transpiration rate and minimizes the weight loss, if > 95% there is again problem of pathogens (Kerbel, 2004). Along with temperature and RH there are some techniques intervened to enhance post-harvest shelf-life of banana were reviewed here in following topics.

2.1 Pre-harvest treatment

Pre-harvest application of GA_3, at 150 ppm after denaveling results in minimum physiological weight loss i.e. 7.25% at 12 days and which is 13.73% for control. Similarly post-harvest shelf-life of banana fruits can be extends by the application of GA_3 at 150 ppm, $CaCl_2$ 4% by 7 days and 5 days respectively over control (Bhusan et al., 2022). Post shooting spraying of 2% potassium dihydrogen phosphate + 0.5% calcium chloride + 2% boric acid on banana can kept for up to 10 days at optimum marketable condition with least physiological weight loss (Kumar and Bangarusamy, 2006).

2.2 Post-harvest packaging technique

Abrasion can cause skin to darken or blacken as a result of the friction. So, proper packing and cushioning can reduce skin abrasion by avoiding collision between fruits or against the interior surfaces of packaging containers. Similarly water loss can be reduced by storing the product at a high relative humidity (> 90% RH) (Leelaphiwat and Chonhenchob, 2020). Banana fruit packed in high-density polyethylene or low-density polyethylene bags have longer shelf-life for 36 days with less physiological weight loss i.e. 9.2%, which is 18 days and 20% in banana leaf and teff straw packing and only 15 days and 24% in control respectively (Hailu et al., 2014). In vaccum packing by using low density polyethylene (LDPE) banana fruits remains unripe and fresh up to 25 days, at the ripe stage, the incidence of crown rot was 2.8 % in the vacuum packaging which is 55.7 % in the control group (Esguerra et al., 2017). Modified atmosphere packaging + green keeper treated banana fruits have long shelf-life 7 weeks at 12 ± 1°C and 85–90% RH (Kudachikar et al., 2011).

2.3 Coating technique

Another new strategy is the use of chitosan biopolymer as an edible coating, which can increase the shelf life of fruit by avoiding moisture and aroma loss while also preventing oxygen penetration into the plant tissue. Banana fruits treated with 1.25% (w/v) chitosan, gives the better shelf-life of 11 days as compared to cold temperature storage (14 ± 1◦C) i.e. 9 days only (Parijadi et al., 2022). Banana fruits treated with 1% chitosan and stored at 15 ± 2°C and a relative humidity of 85–90% helps to maintain better fruits quality with longer shelf-life of 20 days (Hosseini et al., 2018). Paraffin wax and sesame oil coated banana fruits have prolonged shelf-life (10 days) as compared to control (8 days) (Aziz et al., 2020).

Banana fruits treated with 1.5 % carrageenan and stored at a cool temperature (20°C) result in a considerably longer shelf life (9 days) and retain fruit quality as compared to control (5 days) (Dwivany et al., 2020). The banana fruits coated with chitosan with incorporation of 0.5% ZnO nanoparticle having antibacterial properties maintain freshness for more than 17 days in comparison with less than 13 days for the control banana at 35°C temperature and 54 % RH (La et al., 2021).

2.4 Post-harvest dipping treatments

Generally, post-harvest dipping treatments are two types. They either slow down the metabolic process or protect against pathogens. Post-harvest treatment of banana fruits with GA_3 300ppm extends shelf-life up to 32.67 days. Similarly, 5 ppm Kinetin extends up to 28 days and it was only 18.33 days for control (Ghimire et al., 2021). Combined application of 10 mgL^{-1} CPPU and 50 mgL^{-1} GA_3 to postharvest banana fruit had the most beneficial effect on quality maintenance and shelf life extension (Huang et al., 2013). Salicylic acid in combination with wax-treated fruits resulted in minimum physiological weight loss (4.42%) and fruit decay (5.56%) at 8 days after storage, with significant ascorbic acid retention (11.65 mg/100 g fruit weight) and five days increased in shelf life over control (8.75 days) (Mandal et al., 2022). Shrink-wrapped banana hands treated with 50% stay fresh delayed banana ripening in all storage settings. However, banana hands kept in a cold room (12ºC) took 20 days to ripen, compared to 13 and 10 days in an evaporative cool (21.83-24.66ºC) storage structure and in ambient (26.33-30.34ºC) conditions, respectively, under the same conditions. Banana fruits obtained at the ripeness stage 2 (75% green fruits) dipping in the solution of 500 ppm Lysophosphatidylethanol- amine (LPE) for the 30 minutes extends the shelf-life by 1-2 days (Ahmed and Palta, 2015).

Cinnamon and clove essential oils have been proposed as possible postharvest treatments for banana anthracnose disease caused by *C. musae, L. theobromae, and F. proliferatum* due to their fungi static and fungicidal properties against these pathogens within a range of 0.03 to 0.11 % (v/v) (Ranasinghe et al., 2002). Banana fruits treated with cinnamon 5 gL^{-1} and stored at 13°C for 7 weeks have the least disease development (25%) as compared to those fruits treated with 0.75% carbendazim under the same storage condition (Win, Jitareerat, Kanlayanarat, & Sangchote, 2007). Banana fruit cv. Grand Nine harvested at green stage-1 treated with 1% alum and 1% benomyl then vacuum packaged in low-density polyethylene bags and stored in a cool room of 13°C temperature with 95 % relative humidity extends the shelf-life of banana for 25-30 days, and post storage life was found to be 4-6 days (Jadhav et al., 2018).

2.5 Post-harvest hot water treatment

Post-harvest disease severity in banana was greatly reduced by hot water treatment (50 ± 2°C for 5 min) and fungicide application (prochloraz 250 ppm). Untreated fruits under ambient temperature have the highest disease severity (61.8%), which is very low i.e. (< 3.4%) in hot water and fungicide treated and cold stored banana fruits (Hassan et al., 2004). Banana fruit of cv. Gros Michel treated with hot water (42°C for 15 minutes) then stored at 14°C delayed peel blackening by cold storage by 4 days as compared to untreated fruits. Hot water treatment lowers catechol oxidase activity and also increases the abundance of a Hsp70 transcript and delayed the peel blackening process during low temperature storage (Promyou et al., 2008).

2.6 Controlling storage environment

Since the rate of respiration is directly influenced by temperature, relative humidity, and oxygen availability, adjustment of our storage environment to the optimum temperature, RH and CO_2 and O_2 concentration in the atmosphere slow down the respiration rate and could achieve maximum shelf-life. Banana fruits stored in the chamber having 4-6% O_2 with 4-6% of CO2 had a storage life of 12-16 days longer than the control, with good eating quality (Ahmad et al., 2001). Banana fruits stored at modified atmosphere conditions in MA chamber, it can be stored for three time longer period of time (nine days) at ambient temperature without much loss of quality as compared to control (Madan et al., 2014).

Banana fruits stored at cold room storage condition with any of the packaging materials i.e. polyethylene plastic cling wrap and whole banana leaf produced the best results, with no significant differences in pulp hardness, total soluble solids value, and total titratable solids value up to 10 days of storage as compared to those value at the day of harvesting (Sagran, 2015). Fruits harvested at 75 % maturity and held at 12°C had the best green life and overall shelf-life, whereas fruits harvested at 75 % maturity and stored at 14°C had the best yellow life and overall shelf-life. Fruits collected when fully matured and stored at 16°C had the best color and texture (Gonge et al., 2013).

2.7 Irradiation technique

Recently harvested banana fruits treated with optimum dose (0.15-0.3 kGy) of gamma irradiation in air at 25°C at a dose rate of 1.98 kGy h^{-1} delayed ripening for 10–12 days at the storage condition of 25±2°C and 68–75% relative humidity (Aina et al., 1999).

2.8 Ethylene absorbents and inhibitors

The use of 1% $KMnO_4$ as an ethylene absorber dramatically reduced banana yellowing, preserved flavour lasting up to 15 days at room temperature (28°C) and extended the fruit's shelf life up to 45 days at 13°C (Tan, 2009). Banana fruits treated with 1% KMnO4 and stored at low temperature (7°C ± 2°C) improve most of the postharvest quality parameters along with increasing shelf-life (19.51 days) (Ahmed et al., 2021). The application of KMnO4-zeolite (10 g per sachet) inhibits ripening and maintains the quality of banana fruits and also increases marketability for 15 days (Yin et al., 2020).

Banana Fruits treated with 0.5µl/l 1-MCP and packed in sealed polyethylene bags had the longest shelf life of about 58 days. C_2H_4 and CO_2 concentrations in polyethylene bags were measured to confirm that 1-MCP inhibited both C_2H_4 evolution and respiration (Jiyang et al., 1999). Banana fruits exposed to 1 mM H_2S storage at 25 °C and 75–80% RH extend postharvest life of banana through down-regulation of oxidative metabolism (Siddiqui et al., 2021).

3. Conclusion

Post-harvest loss is the serious problem in banana, because of its rapid rate of respiration and ripening process. There is another problem of higher sensitivity to chilling injury for sufficient lowering of storage temperature. However, maintaining storage temperature at its optimum of 13-14 °C along with higher RH (90-95%) gives better shelf-life of banana with better quality. Besides this temperature and RH, there are some interventions which delay in ripening process and extend shelf-life of banana. Pre-harvest, post-shooting spray of GA_3 or other nutrients containing Ca, K, Zn and B have better results in extending post-harvest shelf-life, and keep optimum quality too. In similar way post-harvest treatments like LDPE packing, vacuum packing, MAP is also a healthy way of extending shelf-life. Edible coating by using Chitosan, sesame oil, paraffin wax, carrageenan, ZnO nanoparticles added chitosan are also beneficial for better shelf-life and marketability of fruits.

Post-harvest dipping treatments of hormones like GA_3, kinetin, CPPU, salicylic acid, stay fresh; LPE etc delay ageing process of cells and postpone senescence of fruits. Similarly, treatment of fruits with solutions having antimicrobial or fungicidal properties like clove oils, cinnamon, binomyl and carbendazim also helpful in prolong shelf-life. Hot water treatment of fruits at (50 ± 2°C for 5 min) and fungicide or irradiation with gamma radiation also can enhance shelf-life. Banana fruits treated with ethylene absorbent like $KMnO_4$, $KMnO_4$-Zeolite or ethylene inhibitors like 1-MCP, H_2S delayed ripening process and increase shelf-life. In this way we can delay the ripening and senescence process in banana which have direct role in increasing marketability and economic returns.

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