BANANA POST HARVEST PRACTICES: CURRENT STATUS AND FUTURE PROSPECTS- A REVIEW

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ABSTRACT

Banana is one of the most appreciated fruit all over the world because of its multipurpose use as food. Lack of suitable post harvest management practices may lead to a huge economic loss for the banana producing regions. Different postharvest management practices are in use to enhance its shelf life by delaying the ripening, reducing respiration rate, and controlling the disease causing organisms, during transport and storage. An integrated approach can ensure product safety and quality that reaches the consumer, residing far away from the production area. In this article different pre-storage treatments viz. pre-cooling, chemical and biological treatment for disinfection, modified atmospheric packaging, chemical treatment, irradiation, and coating for enhancement of shelf life is discussed in brief.

Key words: Banana, Shelf life, Disinfestations, Ripening, Respiration, Packaging

Banana is one of the widely grown and consumed fruits due to their distinct aroma and taste, in all parts of the world. It is the staple food and economic life line for many countries. It is cheap source of carbohydrate and rich source of potassium, calcium, antioxidants and other micronutrients. The sugar rich and low-fat bananas have varied uses as infant food, functional food, dessert, carbohydrate based staple food and many more diversified food/feed uses (Agunbiade et al., 2006; Aparicio-Saguilán et al., 2007; Aurore et al., 2009; Mohapatra et al., 2009). But this fruit is highly perishable owing to its high water content and is susceptible to many diseases, especially fungal infection. Being a climacteric fruit, it produces enough ethylene bringing about rapid changes in physico-chemical properties, such as colour, texture, aroma, chemical composition, respiration rate and senescence. The climacteric phase is characterised by enhanced ethylene production, higher oxygen consumption, starch to sugar conversion, chlorophyll degradation and relocation of the micro and macro nutrients between the pulp and other plant parts (Marriott et al., 1981).

Though India is one of the major producers of bananas with a production over 21766400 MT worth $310193000, as reported for the year 2007; the export figure is much lower than that of the other banana producing countries (FAO, 2009). The major banana producing states of India are Tamil Nadu, Maharashtra and Gujarat. Bulk of the production caters mostly to the domestic need, with an estimated domestic consumption of 13445130 MT (FAO, 2009). In many places, there is significant loss of the food value of banana due to improper post harvest management practices that causes huge economic loss. Post production losses of banana can be reduced by adopting various post-harvest management practices that are currently in practice all over the world to prolong its shelf life. Post harvest management practices such as cleaning, sorting, and pre-storage treatments, viz. pre-cooling, chemical treatment for disinfection, modified atmospheric packaging, for banana are discussed in brief, in the following sections.

Harvesting

The harvesting standard varies from place to place, season, transport distance and the end use of the fruit. For local use, the fruits may be harvested

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at fully matured stage; for short distance transport, the fruits may be harvested at 90% maturity level and for long distance transport, the fruits may even be harvested at a maturity level of 75%. Again, the fruits are used for table purpose or processed for value addition. For processing, fully matured and yellow banana is preferred. In the later case, usually, green banana is used which has yet to reach the climacteric stage. In the cooler season, the fruits may be harvested after 105 days of flowering, but during hot season, the fruits can be harvested between 98 to 115 days (Robinson, 1996). After harvest, bunches are properly cushioned and transported to the warehouse. Mechanical damage to bananas during transport results in crown browning caused by enzymatic oxidative degradation of phenolic compounds by polyphenol oxidase. This can be avoided by dehanding the fruits under water, applying vacuum, waxing and application of antioxidants like thiourea and potassium aluminium sulphate (Ismail et al., 2004).

Precooling

Field heat generated due to the harvest stress can cause overheating of the fruits. This may result in damage of the plant tissues and acceleration of the biochemical activities, causing spoilage. Several methods like hydro cooling, air-blast cooling, vacuum cooling and liquid carbon dioxide gas cooling have been in use, separately or in combination, to take care of this heat load from horticultural crops (Smith, 1963; Robinson, 1996; Bagnato et al., 2003). Hydro cooling is achieved by dipping/ drenching, rinsing/ immersing or spraying cold water over the bananas bunches for effective field heat removal. In air blast cooling method, banana bunches are subjected to a jet of cooled air for removal of field heat whereas in vacuum cooling the fruits are treated under vacuum for few minutes (Brosnan and Sun, 2001). The bananas are cleaned and disinfected properly before packaging to maintain quality during distribution.

Cleaning and disease control

The banana hands, cut out from the bunch, are washed in clean and flowing water, to remove the accumulated dirt and dust, as well as the latex that exudes from the cut surface of crown. Cleaning, delatexing and fungal control can also be done using hot water, which is quite effective in controlling the crown rot disease. The hot water temperature above 50ºC causes severe scalding and hence it is recommended that the bananas should be treated at 50ºC for 20 minutes for effective control of crown rot disease (Reyes et al., 1998). Hot water treatment not only cleanses and disinfects but also prevents peel blackening of the bananas going for successive cold storage (Promyou et al., 2008).

Chemical treatment

The fruit is susceptible to crown rot diseases caused by a fungus Fusarium aff. Sacchari. The crown rot disease can be effectively controlled by using chemicals extracted from citrus seed, in combination with the wax-based adjuvant and fungicides like thiabendazol, imazalil, ammonium sulphate, potassium sorbate, sodium benzoate, oxalic and maleic acids, cinnamon extract, piper extract, garlic extract, chlorine water and chitosan solution along with or without hot water treatment (Al Zaemey et al., 1993; Win et al., 2007)

Fungicidal coating

Banana preservation has two phases i.e. an initial preservation period between harvesting and initiation of the ripening process and a second preservation period between initiation of the ripening process and the time of consumption. Some of the coating processes may be employed to banana for preservation in either or both of these periods. Polyvinylidene chloride copolymer along with surfactant and optional ingredients i.e. antimicrobials, plasticizers and antifoaming agents, can be effectively used as pre-ripening and post ripening coating (Petcavich, 2007; Davie et al., 2007). The anthracnose infection can be inhibited by coating the bananas with organic acids like oleic, palmitic, lauric, malic, citric, oxalic, and maleic acids, incorporated in coating materials like chitosan, carboxymethyl cellulose and carboxymethyl chitosan (Al Zaemey et al., 1993). The coating creates partial anaerobic conditions, favouring greater production of metabolites like acetaldehyde and ethanol. This helps in quality improvement in coated bananas through astringency removal. Application of acetaldehyde, a natural aroma component, with ethanol or alone, results in removing astringency in banana (Pesis, 2005). The ethanol vapour impregnation under vacuum is unsuitable for banana as it causes brown spot development in the peel (Bagnato et al., 2003).
Biological control

Recent years have seen developments in research pertaining to the control of diseases by using biological agents that compete with other parasites for food. Many of them produce useful enzymes. *Pichia anomala* Kurtzman (strain K), *Candida oleophila* Montrocher (strain O) and *Pseudomonas syringae* (strain ESC-11) with or without any other fungicides act antagonistically for controlling the crown rot and anthracnose disease of banana (Lassoisa et al., 2008; Williamson et al., 2008).

Ripening and storage

Banana fruits continue to grow while attached to the parent plant and accumulate starch in the pulp. When maturation begins after 80-90 days of flowering, the fingers stop elongating and the fruit starts getting rounded, bloated up width wise. Unless the fruits are harvested when they are ¾th quarters round, the fruits split while still green. The harvested banana passes through three physiological stages of growth i.e. pre-climacteric or ‘green stage’, climacteric or ‘ripening stage’ and finally senescence stage (Robinson, 1996). Unripe banana shows a low level of ethylene, a natural plant hormone that regulates every facet of plant growth. During ripening stage, higher ethylene production induces higher metabolic rates of starch to sugar conversion; chlorophyll degradation and unmasking of carotenoids, thus the green banana turns progressively yellow and dark coloured. This also brings about decrease in astringency, decrease in polyphenol content, increase in polyphenol oxidase activity, attributing to browning of peels, increased respiration rate, loss in firmness and increase in moisture content in the pulp (Kiyoshi and Wahachiro, 2003; Siriboon and Banlusilp, 2004; Adeyemi and Oladiji, 2009). Artificial ethylene, application can also enhance the polyphenol oxidase activity and respiration rate (Shuji et al., 2001). For local consumption, the fruits can be treated with ethylene or ethephon (Vendrell, 1985; Domínguez and Vendrell, 1994), but for long distance transport it is desirable to have longer green period or pre climacteric phase. The ripening phase thus can be delayed by controlling storage environmental conditions and using different methodologies as discussed in the following sections.

Storage temperature

Temperature is the single most important parameter controlling respiration rate. For every 5-10°C rise in temperature, the respiration rate doubles or triples thereby shortening the shelf life (Bhande et al., 2008). Maintaining optimum temperature is of utmost importance for the shelf life extension of food materials have been adopted since centuries. The metabolic processes like ripening, respiration and microbial growth require optimum temperature to be maintained. Ripening in bananas can be delayed through refrigeration, but these fruits are very sensitive to temperature abuse. Therefore proper temperature regime should be followed during transportation and storage of the bananas, depending on the duration of storage, by using brine solution, refrigerant or liquid carbon dioxide (Smith, 1963). Storing under 10°C causes chilling injury in the bananas, resulting in development of brown spots on the peel (Broughton and Wu, 1979). This could be attributed to the oxidation of dopamine (El-Wahaba and Nawwara, 1977). Furthermore, bananas do not fully degreen when stored at tropical temperatures i.e. about 30°C, due to ethylene production inhibition above the storage temperature of 25°C and the reduction of Mg-dechelatase activity, which in turn represses chlorophyll degradation, leading to uneven degreening (Yang et al., 2009). The ideal temperature of storage is about 13-14°C (Robinson, 1996,). Acceptability of bananas ripened at 20°C, under ethylene treatment, is higher due to the better flavour, lesser astringency and sweetness (Ahmad et al., 2001). Therefore, it is recommended that the bananas for transport should be stored at about 13-14°C, for delaying the ripening process but should be treated with ethylene to bring about better quality characteristics in the stored bananas.

Relative humidity

High humidity (95%) favours ripening process by preventing browning spot on the peels but it causes the dropping off of the fingers, due to rupture of peel at the pedicel. Pectin degradation at high RH is the cause of rupture of peel. If the fruits are stored under water stress conditions, at lower humidity, that would affect the shelf life of the product through enhanced ethylene production and respiration in the pre-climacteric stage (Finger et al.,...
The ideal relative humidity is about 80% at a storage temperature of 20°C (Broughton and Wu, 1979).

**Chemical treatment**

The bananas can be chemically treated for delaying the ripening process and associated physico-chemical changes. Nitrous oxide alone or in combination with reduced oxygen levels can work synergistically to delay the ripening process without any adverse effect on physicochemical qualities. Nitrous oxide inhibits the activities of ACC oxidase which in turn retards the ethylene biosynthesis. Application of nitrous oxide however, is time and dose dependant, which works at the concentration level of 40-80%. Therefore, it has the potential to control postharvest ripening of banana during handling, transportation and storage (Palomer et al., 2005). Nitric oxide, a free radical, when applied in the oxygen sans environment can help in decreasing respiration rate and delaying senescence (Leshem et al., 1998). Chemicals like salicylic acid and 1-methylecyclopropane decreases the activities of enzymes like ACC synthase, cellulase, polygalacturonase and xylanase that regulates the ripening process (Srivastava and Dwivedi, 2000; Blankenship and Dole, 2003; Pelayo et al., 2003; Watkins, 2006). These chemicals have been approved by FDA.

**Coating**

Various type coatings have been in and the market is flooded with such packaged food materials. Some of the packaging materials are biodegradable, and some of them are composites. Some of the biodegradable as well as composite packaging materials are edible. For fresh whole banana fruits, edible coating will not be a suitable option as the banana is usually consumed after being peeled. In such cases both biodegradable and non biodegradable or composite films with distinct potential to delay the ripening and reduce the respiration rate as well as microflora population, will be of utmost importance. Coating the fruit prior to ripening initiation delays the rapid ethylene production, thus delaying the ripening process and the chlorophyll loss which normally accompanies ripening (Banks, 1985).

**Modified atmospheric storage/controlled atmospheric storage/active packaging** Storage techniques like controlled atmospheric storage and modified atmospheric packaging involves manipulation of respiration rate of the stored produce, by altering the CO$_2$:O$_2$ in the packaging system. For fruits and vegetables, a modified atmospheric packaging environment with 3-8% CO$_2$, 2-5% O$_2$ and 87-95% N$_2$ has been found suitable (Phillips, 1996). Respiration rate is governed by storage temperature and composition of storage atmosphere. Post-climacteric nitrogen storage is not a suitable method for increasing shelf life, as it causes skin browning and decomposes the banana aroma ethyl acetate to 3-methylbutyl ester and 1-butanol that renders overripe aroma in the banana (Klieber et al., 2002). Banana stored under modified atmospheric package at lower temperature, with silicon membrane can reduce the respiration rate to a significantly lower level, impairing minimum damage to the product quality in terms of harvest-fresh appearance, colour, texture, in addition to improvement in the shelf-life (Stewart et al., 2005). Senescent spotting of banana peel can also be inhibited by modified atmospheric packaging through maintenance of low oxygen level in the packaging system. This reduces the phenylalanine ammonia lyase activity in the peel and increases polyphenol oxidase that might have attributed to the increase in potentially active protein, thus limiting the senescent spotting. At the same time higher oxygen level promotes spotting in banana peel (Maneenuam et al., 2007). The negative impact of higher concentration of carbon dioxide in the packaging system can be evaded by the inclusion of suitable oxygen scavenger, carbon dioxide scrubber and ethylene absorbents, which do not have any effect on spotting (Choehom et al., 2004). Chitosan based coating and some polymers like vinyl chloride with antioxidants, essential oils through either direct or indirect contact, have the capability of removing off odour, ethylene absorption and oxygen scavenging properties (Phillips, 1996).

These days, hurdle technology is gaining wider acceptance, which creates hurdles for microbial or biochemical reactions by the application of several less intense treatments. Extension of shelf life of banana has also been reported by application of 1-MCP and storing on polythene bags (Jiang et al., 1999). Similar mild treatments has been employed with fresh cut bananas.
for shelf life enhancement by the combined action of chemical dip with 1% (w/v) calcium chloride, 0.75% (w/v) ascorbic acid and 0.75% (w/v) cysteine and/or combined with a carrageenan coating and/or combined with controlled atmosphere (3% O₂ + 10% CO₂) (Bico et al., 2009).

Irradiation

The ripening process in bananas can be effectively delayed by irradiation at lower dose (0.2 kGy with a dose rate of 7.35 kGy h⁻¹) through retardation of softening and colour change. Irradiation decreases sensitivity of the banana to its own endogenous ethylene without causing any phytotoxicity. At the same time, it does not affect ripening using high concentrations of exogenous ethylene. However, a higher dose (0.4 -1.0 kGy) may cause discolouration, extensive tissue damage and change in respiration rate and reduced sensitivity to exogenous ethylene exposure (Strydom and Whitehead, 1990; Strydom et al., 1991). Though irradiation has been used for delaying the ripening process, its application in disinfection of banana can be explored, as it has already been proven worth for other fruits (Aziz and Moussa, 2002; Egea et al., 2003). UV-radiation can cause increase level of antioxidant activities of fresh cur bananas thus can help in reducing the microbial load, ensuring enhanced shelf-life (Alothman et al., 2009).

Apart from all these treatments to be maintained during post harvest handling, a cool infrastructure temperature is needed for safe-guarding the quality of banana (Brecht et al., 2003).

Future scope of Research

Post harvest heat treatment (Lurie, 1998), ozonization (Aguayo et al., 2006), radio frequency / Microwave, pulse light, heating, use of different immersion solutions (Ihl et al., 2003; Choi et al., 2009), calcium lactate, green-tea extract, whey permeate (Martín-Diana et al., 2005, 2006, 2008), neutral electrolyzed water (Rico et al., 2008), steam jet (Martín-Diana et al., 2007) have been used as sanitization practices of many horticultural produce preservation. Application of these techniques to prolong shelf life and quality control of fresh whole banana is yet to be explored. Further research in this area is required.

CONCLUSION

The extent of post harvest losses of fresh fruits attributed to mishandling, improper storage practices and lack of modern transport facilities. This invariably leads to qualitative and quantitative losses. Minimization of these losses can safeguard the export potential and will aid to the revenue generation. With post harvest technological evolution and new practices replacing the older ones, it seems that the treatments for the extension of shelf life through microbial decontamination, insect disinfections, and metabolic activity inhibiting methods can be applied alone or in coherent with each other to have synergistic effect on the spoilage caused in banana. Several niche technologies have been tried and tested successfully with other fruits and vegetables and are yet to be tried on banana for standardisation. This would immensely help the small as well as the large scale fresh banana retailers and related food processing industries, for further processing applications.

REFERENCES