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Review

Modified atmosphere packaging and active packaging of banana (*Musa* spp.): A review on control of ripening and extension of shelf life

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Banana is one of the most important fruit crops in the world and is considered by millions of people as their main energy source. Post harvest shelf life extension has been a problem for years due to its climacteric respiration pattern and sensitivity to low temperature. Extensive research has been done in this area for many decades. Among various existing technologies, Modified Atmosphere Packaging (MAP) which extends shelf life of fresh fruits and vegetables by reducing their respiration rate is gaining popularity. Active packaging is a kind of MAP where different scrubbing/releasing materials are used. This review summarises important aspects behind the ripening physiology of banana, controlling factors and recent advance technologies of MAP and active packaging.

Key words: Banana, ripening, biochemical changes, modified atmosphere packaging, active packaging.

INTRODUCTION

Banana

Banana is the fifth most important commodity in world trade after cereals, sugar, coffee and cocoa (Uma, 2008). Banana is popular because of its easy availability, low cost, various usage and high nutritive content. Total banana and plantain production all over the world is calculated as 95.8 million metric tons (FAOSTAT, 2009). India ranks first in banana production (26.4 million MT, 28% of total production) followed by Philippines, China, Ecuador and Brazil (FAOSTAT, 2009). Banana is monocotyledon and belongs to family Musaceae. Two basic types of genome groups are there, *Musa acuminata* (A genome, 2n = 22) and *Musa balbisiana* (B genome, 2n = 22). Polyploidy and hybridization of A and B genomes have given rise to diploid (AA, AB, BB), triploid (AAA, AAB, ABB, BBB), and tetraploid (AAAA, AAAB, ABBB, AABB) banana (Mahapatra et al., 2010). Various other varieties also exist naturally or developed by hybridization of these genomes which have different nomenclatures (Robinson, 1996). Three common species of Musa (*M. cavandishii*, *M. paradisiaca* and *M. sapientum*) are widely grown in the world. Commercially popular banana is usually triploids (2n = 33). Economically important sweet bananas which are eaten as a dessert fruit are from the AAA genome and the plantains which are usually cooked before consumption because of their higher starch percentage are from the AAB genome (Seymour, 1993). Banana is used as a treatment for gastric ulcer and diarrhoea in everyday life. It is also beneficial for preventing cancer and heart disease because of high vitamin A and B6 contents. High potassium content reduces cardiovascular disease and thus controls blood pressure.

Average nutritional composition of raw banana (AAA

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Abbreviations: **ACC,** 1-aminocyclopropane-1-carboxylic acid; CI, chilling injury; **MA,** modified atmosphere; **MAP,** modified atmosphere packaging; **PAL,** phenylalanine ammonia lyase; PPO, polyphenol oxidase; **SAM,** S-adenosyl methionine.

Table 1. Nutritional composition of raw banana.

Nutrient and unit	Value	Nutrient and unit	Value
Proximate (%)			
Water	74.91	Riboflavin (mg)	0.073
Energy (kcal)	89	Niacin (mg)	0.665
Protein (N x 6.25)	1.09	Pantothenic acid (mg)	0.334
Total lipid (fat)	0.33	Vitamin B-6 (mg)	0.367
Ash	0.82	Choline, total (mg)	9.8
Carbohydrate, by difference	22.84	Betaine (mg)	0.1
Fiber, total	2.6	Vitamin A, RAE (mcg_RAE)	3
Sugars, total	12.23	Phytosterols (mg)	16
Sucrose	2.39	Carotene, beta (mcg)	26
Glucose (dextrose)	4.98	Vitamin A, IU (IU)	64
Fructose	4.85	Vitamin E (alpha- tocopherol) (mg)	0.10
Starch	5.38		
		Lipid (%)	
Mineral (mg/100 g)		Fatty acids, total saturated	0.112
Calcium, Ca	5	Fatty acids, total monosaturated	0.032
Iron, Fe	0.26	Fatty acids, total polyunsaturated	0.073
Magnesium, Mg	27		
Phosphorus, P	22		
Potassium, K	358	**Amino acid (%)**	
Sodium, Na	1	Leucine	0.068
Zinc, Zn	0.15	Lysine	0.050
Copper, Cu	0.078	Phenylalanine	0.049
Manganese, Mn	0.270	Valine	0.047
		Arginine	0.049
		Histidine	0.077
Vitamin		Alanine	0.040
Vitamin C, total ascorbic acid (mg)	8.7	Aspertic acid	0.124
Thiamin (mg)	0.031	Glutamic acid	0.152

Source: USDA National Nutrition Database (2010).

genome) is given in Table 1. In spite of being such an important fruit in the world economy, due to its highly perishable nature, local consumption of banana is more popular than export market (Pillay and Tripathi, 2007).

RIPENING PROCESS

Different biochemical and physiological changes take place within a short span of time during ripening, so it is necessary to understand the ripening process of banana in order to extend its shelf life.

Climacteric nature of respiration

Respiration is the oxidative breakdown of complex substrates like carbohydrates to simpler molecules like CO_2 and H_2O. The glycolytic pathway which occurs in the cytoplasm of the cell is the first step of respiration followed by tricarboxylic acid cycle, pentose phosphate pathway and electron transport system. Fruits can be classified into two broad categories - climacteric and non climacteric according to their respiration pattern (Figure 1). In climacteric fruit, respiration rate shows a decreasing trend to the lowest value termed as pre-climacteric minimum followed by a sharp rise in respiration rate to the climacteric peak. This sudden rise is called as respiratory climacteric followed by a decrease in respiration rate in the senescence period. Banana being a climacteric fruit shows a sudden increase of respiration rate and consequently a burst of ethylene production at the onset of climacteric peak. Enzymes play a key role in the climacteric rise in respiration rate during gycolytic pathway (Ball et al., 1991; Seymour, 1993). Role of various enzymes and possible biochemical changes during respiration and carbohydrate metabolism is given in Figure 2.

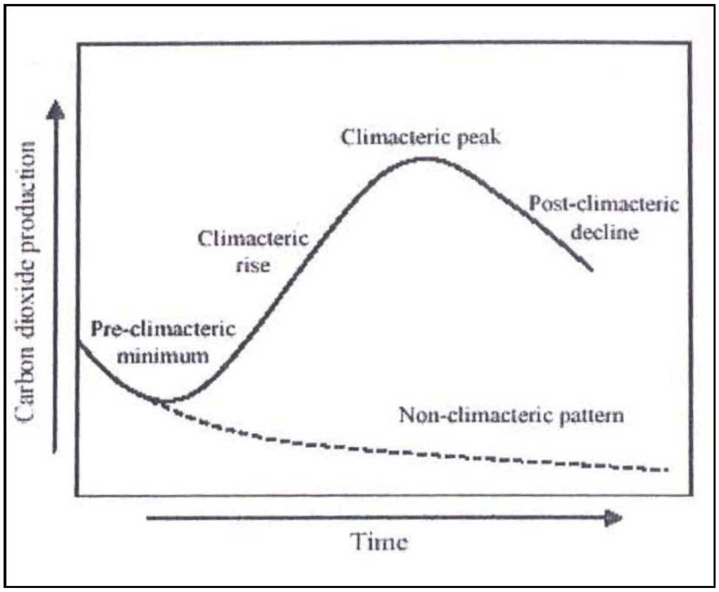

Figure 1. Climacteric and non climacteric ripening (Salveit, 2004).

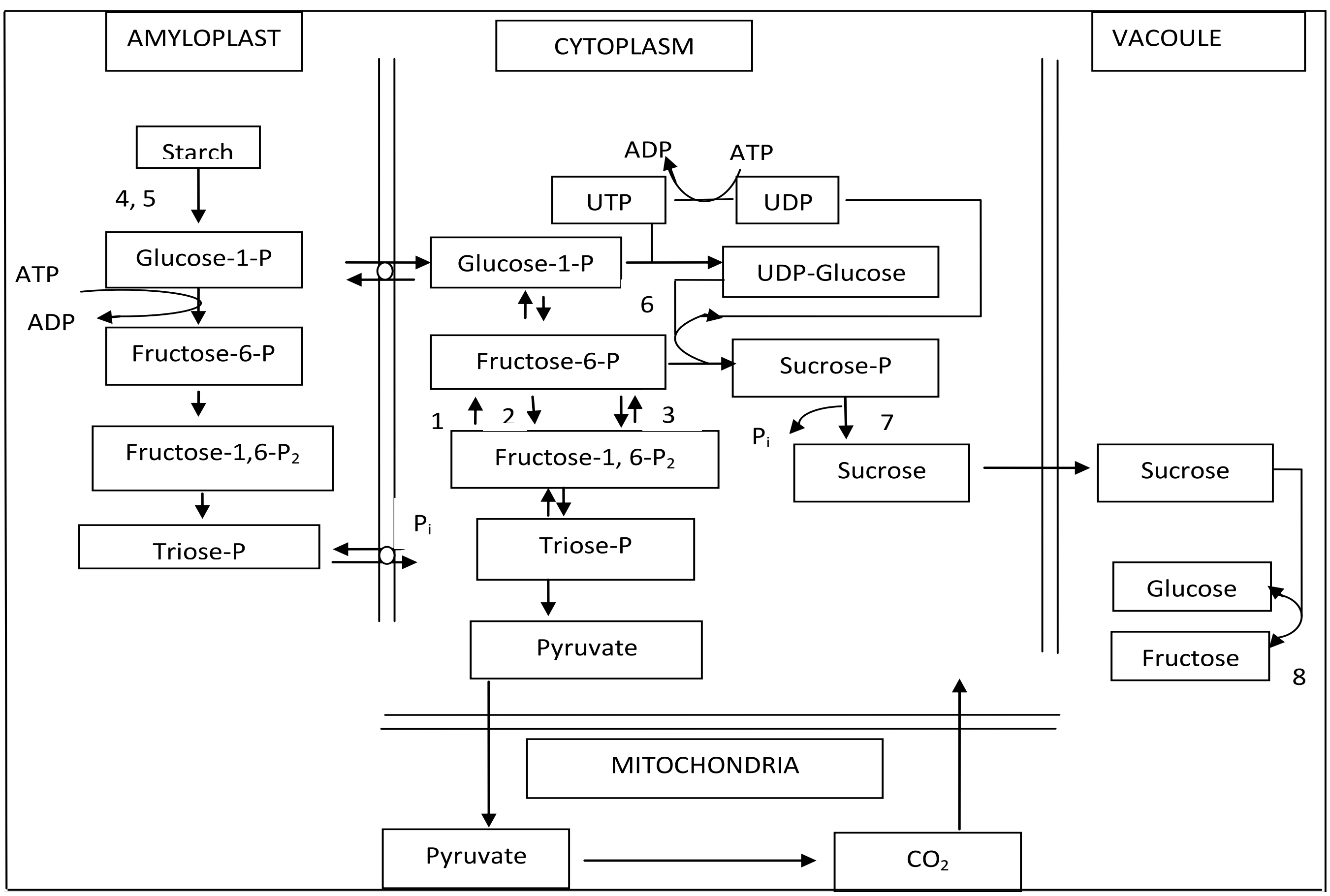

Figure 2. Outline of biochemical pathways and role of enzymes likely to be involved in respiration and carbohydrate metabolism in ripening bananas (Beaudry et al., 1987, 1989; Hubbard et al., 1990; Seymour, 1993). 1) Fructose 1, 6-bisphosphatase, 2) ATP phosphofructokinase, 3) Pyrophosphate-dependent phosphofructokinase, 4) Phosphorylase, 5) α – amylase, β – amylase, α 1,6 – glucosidase, 6) Sucrose phosphate synthase, 7) Sucrose phosphate phosphatise and 8) Invertase.

Table 2. Physical and chemical nature of ethylene.

Property		References
UV light absorbance	161, 166 and 175 nm	Yañez et al. (2004)
Molecular weight	28.05 g/mol	
Freezing point	-181°C	
Boiling point	-103.7°C	
Fusing point	-169°C	
Relative density in air	0.978	
Specific volume	861.5 ml/g at 21°C	Abeles et al. (1992)
Compounds formed after degradation	Acetylene, butane, ethane, hydrogen and methane	
Peak production of ethylene during climacteric phase	3 µl.kg^{-1}.h^{-1}	McMurchie et al. (1972)

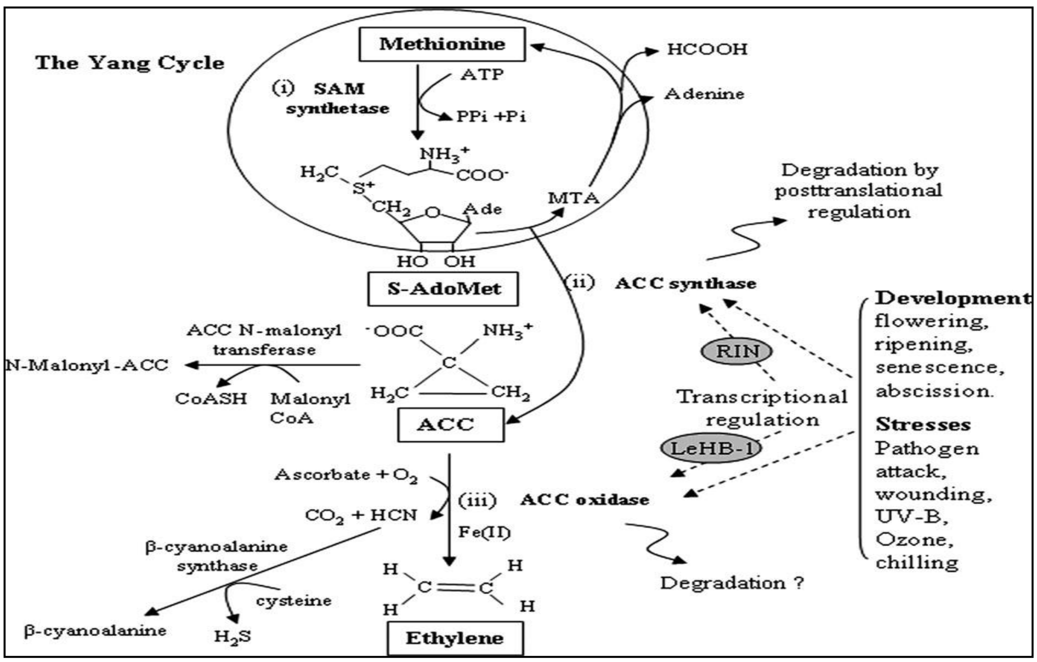

Figure 3. Ethylene biosynthesis pathway (Lin et al., 2009).

The average respiration rates of banana before, during and after climacteric peak are reported as 20 to 70, 120 to 125 and 100 to 125 ml CO_2 kg^{-1} h^{-1} respectively (Palmer, 1971; Yañez et al., 2004).

Effect of ethylene

Climacteric fruits ripen in the presence of ethylene which is a colourless, odourless, tasteless gas that has many effects in plant physiology and is active in such a small amount (part per million)that it is considered as a plant hormone (Theologis, 1993; Brandenburg and Zagory, 2009). Ethylene is transported by diffusion from its production site to active site. Ethylene diffusion gradients are determined by the surface to volume ratio, diffusion resistance and ethylene production rates (Abeles et al., 1992). Physical and chemical nature of ethylene are summarised in Table 2. The pathway of ethylene biosynthesis involves the steps linking S-adenosyl methionine (SAM), its conversion to 1-aminocyclopropane-1-carboxylic acid (ACC) and the subsequent production of ethylene from ACC (Seymour, 1993). Two most important enzymes which are responsible for ethylene production are ACC synthase (EC 4.4.1.14) which converts SAM to ACC and ACC oxidase (EC 1.4.3) which is known as Ethylene Forming Enzyme (EFE), it converts ACC to ethylene (Figure 3).

A thorough understanding of the biochemical basis of ripening is essential to ensure predictable ripening and good quality ripe fruit. Different biochemical changes that take place during ripening are described in Table 3.

MODIFIED ATMOSPHERE PACKAGING (MAP)

Immediately after harvest, the sensorial, nutritional and organoleptic quality of fresh produce start to decline as a result of altered plant metabolism. This quality deterioration is the result of produce transpiration, senescence, ripening-associated processes and the development of postharvest disorders (Gorris and Peppelenbos, 2007). Low temperature and proper hygienic handling of the material are the prime factors that can control these processes. MAP is a preservation technique that further minimizes the physiological and microbial decay of perishable produce. Modified atmosphere (MA) refers to any atmosphere different from the normal air (20 to 21% O_2, about 0.03% CO_2, about 78 to 79% Nitrogen and trace quantities of other gases) (Yahia, 2009). The modification of the internal package atmosphere may take place at the level of total pressure and/or partial pressures of gas components. MA can be created either by direct gas flushing (active MAP) or by respiration of the enclosed product (passive MAP). In both cases, the permeability of the packaging material is important to maintain atmospheres within desired limits. For respiring products, continuous depletion of O_2 and/or increase of CO_2 and water vapour create MA within the package that is known as passive MAP (Yahia, 2009). In active MAP, gas mixture of desired composition is introduced within the package either after evacuation or by a continuous flow of gas mixture to replace the air (Lee et al., 2010).

Several researchers recommended optimal MA conditions for fresh banana as 13 to 15°C, 90 to 95% relative humidity with 2 to 5% CO_2 and O_2 concentration (Ahmad et al., 2001; Yahia and Singh, 2009; Lee et al., 2010).

Respiration rate modelling in MAP

In MAP, the O_2 partial pressure is typically reduced while that of CO_2 is often increased. The purpose of this is to lower the respiration rate and slow down the metabolic pathways that negatively affect the quality of the stored product. The respiration rate is a good indicator of the physiological stage of the fruit and its storage potential, so, many efforts have been put to model respiration or gas exchange of fruit and vegetables (Nicolaï et al., 2009). Temperature is generally recognized as the most important external factor influencing respiration. Biological reactions generally increase two - or threefold for every 10°C rise in temperature. The respiration rate is usually maximal at moderate temperatures between 20 and 30°C, but decreases considerably to almost zero around 0°C, depending on the genus, species and even cultivar. At high temperatures over 30°C, enzymatic denaturation may occur resulting in reduced respiration rates. The respiration rate is affected by the development stage and the respiration pattern (climacteric/non climacteric) of the fruit as well (Nicolaï et al., 2009). The more recent approach for modelling respiration rate by employing Michaelis–Menten type equation is based on enzyme kinetics (Lee et al., 1991). McLaughlin and O'Beirne (1999) described the respiration rate in three ways as no inhibition, competitive inhibition and uncompetitive inhibition.

Heydari et al. (2010) developed a Microsoft Visual Basic computer package (MM-Calculator) using object linking and embedding (OLE) technique to fit the respiration rate of banana. This is reported to be a comprehensive and graphic program which computes parameters of three types of Michaelis-Menten equation of respiration rate. The related mathematical equations are presented in Equations 1, 2 and 3 respectively:

$$RO_2 = \frac{(VmO_2.[O_2])}{(KmO_2+[O_2])} \quad (1)$$

$$RO_2 = \frac{(VmO_2.[O_2])}{KmO_2.(1+[CO_2]/KmCCO_2)+O_2)} \quad (2)$$

$$RO_2 = \frac{(VmO_2.[O_2])}{KmO_2+[O_2].(1+[CO_2]/KmuCO_2)} \quad (3)$$

Where RO_2 is respiration rate [ml (O_2) $kg^{-1}h^{-1}$], (O_2) and (CO_2) are O_2 and CO_2 concentrations (%), Vm_{O2} is the maximum O_2 consumption rate, Km_{O2} the Michaelis constant for O_2 consumption (%), Kmc_{CO2} the Michaelis constant for the competitive inhibition of O_2 consumption by CO_2 (%) and Kmu_{CO2} the Michaelis constant for the uncompetitive inhibition of O_2 consumption by CO_2 (%).
Among the three types of enzymatic kinetics, banana respiration supports the uncompetitive model of inhibition (Bhande et al., 2008; Heydari et al., 2010). However, sufficient experimental verification in this area is scanty.

ACTIVE PACKAGING

MAP is one of the most accepted methods for extending the shelf-life of perishable and semi-perishable food products by altering the relative proportions of atmospheric gases that surround the produce. However, high capital cost of gas packaging machinery has limited the use of this technology. This gives rise to the concept of active packaging. Besides being independent of

Table 3. Compositional changes during ripening.

Composition	Summary of biochemical changes during ripening	References
Moisture	Moisture content in pulp increases because of respiratory breakdown of starch to sugar and migration of water from peel to pulp.	Mariott et al. (1981); Mahapatra et al. (2010).
Carbohydrate	Starch decreases (20-30 to 1- 2%) Sugar increases (1-2 to 15-20%). The main starch degrading enzymes are phosphorylases (EC 2.4.1.20), α-amylase (EC 3.2.1.1), β-amylase (EC 3.2.1.2) and α-1, 6-glucosidase (EC 3.2.1.11) (Figure 3).	Seymour et al. (1993); Mahapatra et al. (2010).
Organic acids	Organic acid content increases. Oxalic acid which is responsible for the astringent taste of unripe banana, undergoes significant decarboxylation by the action of oxalate oxidase. During the climacteric, malic acid becomes the major acid (65% of total acidity). pH decreases from 5.4 ±0.4 to 4.3±0.3.	Seymour et al. (1993); Yanez et al. (2004).
Proteins	Increases from 1-2.5% to 3.8-4. 2%. Glutamate oxaloacetate transaminase (EC 2.6.1.1) and glutamate pyruvate decarboxylase (EC 2.6.1.2), involved in aspartate and alanine synthesis respectively are found to be maximum at the initiation of climacteric.	Seymour et al. (1993); Mahapatra et al. (2010).
Lipids	No substantial changes. In the phospholipid fraction, the proportion of linolenic acid increases and proportion of linoleic acid decreases. Increases in the unsaturation of the phospholipid fraction results in increased fluidity in cellular membranes during ripening.	Colinas (1992); Yanez et al. (2004).
Pectins	Insoluble protopectin is converted into soluble pectin. Main pectin degrading enzymes are: pectin methyl esterase (EC 3.1.1.11) poly galacturonase (EC 3.2.1.15), cellulase (EC 3.2.1.4) and hemicellulase.	Abdullah and Pantastico (1990); Kotecha and Desai (1995); Yanez et al. (2004).
Phenolic compounds	Main phenolics compounds are: 3, 4-di hydroxyphenylethyla- mine and 3, 4-dihydroxyphenylalanine. Main browning causing enzymes are polyphenol oxidase (EC 1.10.3.1), and phenyl alanine ammonialyase. Tannins of banana peel cause astringent fruit taste which gradually disappears due to tannin depolymerisation as fruit ripens.	Seymour et al. (1993); Nguyen et al. (2003).
Pigments	Chlorophyll decreases due to increased activity of chlorophyllase (EC 3.1.1.14) at the onset of the climacteric peak. The principal agents responsible for this degradation are pH changes and oxidative systems. After chlorophyll degradation, carotenoid pigments (mainly Xanthophylls and carotene) become visible.	Yanez et al. (2004); Mahapatra et al. (2010).
Volatiles	Volatile production increases until the onset of peel browning. Among almost 200 volatile components in ripe banana, Acetates and butyrates are predominating. ‘Banana like’ flavour is due to the presence of amyl esters, and distinctive ‘fruity’ like flavour is due to butyl esters.	Seymour et al. (1993); Yanez et al. (2004).

package permeability and gas packaging equipment, this packaging system is more rapid and accurate than traditional MAP. The concept of active packaging is one of the emerging technologies in food packaging. It has been defined as a system in which the product, the package and the environment interact in a positive way to extend shelf life or to achieve some characteristics that cannot be obtained otherwise (Miltz et al., 1995). The active system can be an integral part of the package or be a separate component placed inside the package (Yahia, 2009). Different substances that can either absorb or release a specific gas, control the internal atmosphere within the package. Active packaging components can work as either absorbing or releasing system.

For banana, or any fresh fruits, absorbents are generally used as active packaging components to remove undesired gases and substances (O_2, CO_2, moisture, ethylene and taints) in order to extend the shelf life. Commonly used active packaging systems for fresh fruits/vegetables are described in Table 4.

EFFECTS OF MAP AND ACTIVE PACKAGING ON QUALITY OF BANANA

It is highly challenging to keep banana in good and fresh condition for long duration. Over the years, several researchers have worked on this problem and both MAP and active packaging have been proved to be beneficial.

Effect on chilling injury (CI)

Storage of mature green 'Cavendish' bananas in low-density polyethylene (0.05 mm thickness) bags for up to 30 days at 8, 11, and 14°C developed an in-package atmosphere of 3 to 11 kPa O_2 and 3 to 5 kPa CO_2 (Hewage et al., 1995). However, these authors reported that these storage conditions did not affect ripening and sensory quality, nor did they alleviate CI symptoms developed at 8 and 11°C. In contradiction to their result, Nguyen et al. (2004) reported that MAP (about 12 kPa O_2 and 4 kPa CO_2) resulted in less visible CI in 'Kluai Khai' bananas at 10°C. Total free phenolics in the peel of MAP bananas decreased slowly and the fruits had low phenylalanine ammonia lyase (PAL) and polyphenol oxidase (PPO) activities. Pulp softness, sweetness and flavour of MAP fruit were good.

Effect on peel and senescent spotting

Banana fruit (Sucrier) packed in polyvinyl chloride film and held at 29 to 30°C prevented the early senescent peel spotting, typical for this cultivar (Choehom et al., 2004). CO_2 and ethylene concentrations within the packages increased, but the addition of CO_2 scrubbers or ethylene absorbents had no effect on spotting. Experiments with continuous low O_2 concentrations confirmed that the effect of the package was mainly due to low O_2. The positive effect of MAP on peel spotting was accompanied by reducing PAL and increased PPO activity in the peel. Therefore, senescent spotting of banana peel seems to require rather high O_2 levels. Maneenuam et al. (2007) confirmed that high O_2 (90 ± 2 kPa) is associated with the enhanced peel spotting in banana. The *in vitro* activities of both PAL and PPO measured both in the whole peel and peel spots were lower in high O_2 levels. It has been concluded that peel spotting was not correlated with *in vitro* PAL and PPO activities, but decrease in the dopamine levels correlated with peel spotting, indicating that it might be used as a substrate for the browning reaction.

Effect of silicone membrane, diffusion channel and N_2O treatments

Stewart et al. (2005) reported that silicone membrane system offers an inexpensive and easy to use alternative to the traditional MAP of bananas. 'Cavendish' bananas were stored for 42 days at 15°C under MA conditions using silicone membrane and diffusion channel systems. Fruit in these atmospheres had fresh appearance, good colour, minimum mould and excellent marketability. According to Poubol and Izumi (2005), N_2O treatments extended the storage life of banana fruit without causing adverse effects on physicochemical quality. The capability of N_2O to slow down fruit ripening is thought to be due to its anti-ethylene activity as suggested by the delay in the climacteric associated rise in ACC oxidase activity.

Effect of ethylene scrubber

Ripening in bananas can be delayed by using an ethylene scrubber. There are several compounds that can be used as inhibitors of ethylene, for example aminoethoxyvinylglycine (AVG), an inhibitor of ethylene synthesis; 1- Methylcyclopropene (1-MCP), an inhibitor of ethylene action and potassium permanganate ($KMnO_4$), an oxidising agent. For banana, 1-MCP and $KMnO_4$ are the most commonly used ethylene scrubbers.

1-Methylcyclopropene (1-MCP)

The application of the anti-ethylene compound 1-MCP in combination with the use of polyethylene bags was reported to extend the postharvest life of banana fruit (Yueming et al., 1999). 1-MCP treatment delayed peel colour change and fruit softening, and extended shelf life

Table 4. Active packaging system for fresh fruits and vegetables.

Active packaging components	Scavengers/absorbers	Working principle	Purpose	References
O_2 absorbers (sachet, labels, films, corks)	Ferro-compound (iron powders), ascorbic acid, metal salt, glucose oxidase, alcohol oxidase.	The most successful oxygen scavengers of sachet form on commercial scale are based on iron. Powdered iron is contained alone or with other catalysts in oxygen permeable film pouch. The basic oxidation reaction for absorbing oxygen is: $4\ Fe + 3O_2 + 6\ H_2O \rightarrow 4\ Fe\ (OH)_3$ Rough estimation of iron's capacity to absorb oxygen is around 300 ml O_2 per gram of iron.	Reducing respiration rate, mould, yeast and aerobic bacteria growth, prevention oxidation of fats, oil, vitamins, and colours. Prevention damage by worms, insects and insect eggs.	(Mangaraj and Goswami, 2009; Lee et al., 2010).
CO_2 absorbers (sachets)	Calcium hydroxide, Sodium hydroxide, Potassium hydroxide, Calcium oxide and Magnesium oxide, activated charcoal and silica gel	The most versatile commercial CO_2 absorber is Calcium hydroxide, which reacts with carbon dioxide to produce calcium carbonate: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$ Sodium carbonate can also absorb CO_2 under high humidity condition: $Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$ Active charcoal and zeolite acts as Physical adsorbents of carbon dioxide.	Removing excess CO_2 formed during storage to prevent fruit damage and bursting of package.	(Lee et al., 2001; Shin et al., 2002; Mangaraj and Goswami, 2009).
Ethylene absorbers (sachets/ films)	Aluminum oxide and potassium permanganate (sachets), activated hydrocarbon (squalane, apiezon) + metal catalyst (sachets), Builder- clay powders (films), zeolite films, japanese oya stone (films) and other compound like silicones (phenyl- methyl silicone)	The most popular method is oxidation of ethylene by potassium permanganate ($KMnO_4$) adsorbed on an inert carrier with large surface area such as silica gel, alumina, and activated carbon. $3\ C_2H_4 + 12\ KMnO_4 \rightarrow 12\ MnO_2 + 12\ KOH + 6CO_2$	Prevention fast ripening and softening.	(Vermeiren et al., 2003; Zagory, 1995; Lee et al., 2010; Mangaraj and Goswami, 2009)

Table 1. Cont'd

Humidity absorbers (drip absorbent sheets, films, sachets)	Silica gel (sachets), clays (sachets), sucrose, xylitol, sorbitol, potassium chloride, calcium chloride and sodium chloride.	Desiccants of silica gel, calcium chloride, and calcium oxide are most widely used sachet sealed with the moisture permeable spun bonded plastic film. Silica gel removes moisture by physical adsorption mechanism which can be reversible by temperature change. Calcium oxide reacts to remove water irreversibly as: $CaO + H_2O \rightarrow Ca(OH)_2$ Sachets of hygroscopic sugar and in organic salt works by buffering water activity inside the fresh produce package.	Excess moisture control in packed produce. Water activity reduction on food surface to check moulds, yeast and spoilage bacteria	(Shirazi et al., 1992; Lee et al., 2010; Mangaraj and Goswami, 2009)

in association with suppression of respiration and ethylene evolution. Banana fruit ripening was delayed when exposed to 0.01 to 1.0 µL 1-MCP/L for 24 h. Increasing concentrations of 1-MCP were generally more effective for longer periods of time. The greatest longevity of about 58 days was obtained by packing the fruit in sealed polyethylene bags with 1-MCP. Pelayo et al. (2003) conducted detail experiments with 1-MCP on bananas at intermediate stages of ripeness after 36 to 48 h which has been commercially treated with ethylene. Several conditions for the application of 1-MCP including concentrations (100, 300 and 1000 nl/L); temperatures (14 and 20°C) and durations of exposure (6, 12 and 24 h) were studied and the authors concluded that, under the conditions tested in this study, the efficacy of 1-MCP in delaying ripening of partially ripened bananas was too inconsistent for commercial application.

Potassium permanganate ($KMnO_4$)

A MAP system to extend the shelf life of 'Kolikuttu' bananas at room temperature (approximately 25°C and 85% relative humidity) was developed by Chamara et al. (2000). The effect of various MAP conditions on sensory properties of fruit was evaluated and efficacy of $KMnO_4$ as an ethylene absorber was also examined. MAP systems were created using low density polyethylene bags with no ethylene absorber or with wrapped or unwrapped bricks impregnated with permanganate. In-package O_2 and CO_2 levels were determined on 10, 14, 17, and 20 days; physicochemical properties and colour of fruits were monitored. MAP with wrapped ethylene absorber produced the optimal results with minimal changes in firmness, total soluble solids, weight, titratable acidity and pH. Chauhan et al. (2006) studied the effects of active packaging using $KMnO_4$ as ethylene scrubber and reported that this method could extend the shelf life of banana to 36 days at 13 ± 1°C. The researchers used impregnated $KMnO_4$ in an inert matrix consisting of white cement and lime stone powder packed in sachet form using high density polyethylene woven fabric.

The study also showed that the synergistic effects of the developed ethylene and CO_2 scrubber could restrict the accumulation of excessive CO_2 within pouches lowering the cytotoxicity and symptoms of anaerobiosis in the ripened banana.

Conclusions

Low temperature storage of banana brings undesirable changes to the fruit physiology. MAP lowers, but could not remove the chances of physiological disorders, so it is necessary to find out the process by which banana could be stored at ambient temperatures. Active packaging is a simple and cost effective alternative to traditional MAP. In some countries like USA, Japan and Australia, the active packaging concepts are successfully being applied. In other parts, active packaging could not be popular because of the lack of legislations and fear of consumer restrictions. More research work is needed about the dosage, health hazards and environmental impact of the components used. Further advancements are also needed to enlighten the synergistic effects of MAP and active packaging to delay the ripening and to maintain good quality.

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