EFFECT OF STORAGE TEMPERATURE AND HANDLING OF SABA BANANA BUNCHES AND HANDS TO ITS POSTHARVEST QUALITY

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ABSTRACT

A study on effect of storage temperature and Saba banana bunches and hands handling to its postharvest quality was carried out at Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, which was to compare different storage temperature such as cold room temperature (10±2°C), room temperature (24±3°C) and outside temperature (28±5°C). Every storage temperature had three whole bunches, three half top bunches, three half bottom bunches and three hands of bananas to be tested. After 2 weeks, bananas were withdrawn and tested for data analysis. Completely randomized design with three replicates for analysis was used in this study. Among the physico-chemical parameters such as total weight loss, peel and pulp colour, firmness, pulp to peel ratio, total soluble solid concentration, pH value, titratable acidity were tested in this study. There was no significant interaction between samples handling and storage temperature observed in the study as well as no significant difference on sample handling towards the postharvest quality of Saba banana. Cold room temperature recorded minimum (9.04%) weight loss in this 2 weeks storage, whereas outside temperature exhibited maximum (21.07%) weight loss. The highest firmness (3.36kg/f) was recorded in cold room temperature, whereas outside temperature had lowest firmness (1.12kg/f). For the pulp to peel ratio and total soluble solid concentration, room temperature recorded maximum value (2.33 and 23.2% Brix) respectively. Outside temperature recorded lowest pulp to peel ratio (0.87) and cold room temperature exhibited minimum soluble solid concentration (5.90% Brix). Lowest titratable acidity was shown by cold room temperature (0.14%) and room temperature recorded maximum (0.34%) titratable acidity. The best temperature was cold room storage temperature which resulted in the optimum postharvest quality of banana.

KESAN SUHU SIMPANAN DAN PENGENDALIAN TANDAN DAN TANGAN TERHADAP KUALITI LEPAS TUAI PISANG SABA

ABSTRAK

Satu kajian berkenaan kesan suhu simpanan dan pengendalian tandan dan tangan pisang Saba terhadap kualiti lepas tuai telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah, untuk membandingkan suhu simpanan berlainan seperti dalam bilik sejuk (10±2°C), suhu bilik (24±3°C) dan suhu luar (28±5°C). Setiap suhu simpanan akan ada tiga tandan, tiga tandan atas, tiga tandan bawah dan tiga tangan pisang untuk dikaji. Selepas dua minggu, pisang dikeluarkan dan dikaji untuk mengumpulkan data. Rekabentuk Rawak Lengkap dengan tiga replikasi bagi agronomi analisis telah digunakan untuk kajian ini. Antara parameter fiziko-kimia seperti pengurangan berat, warna kulit dan daging, ketegangan, nisbah antara kulit dan daging, jumlah kepekatan pepejal larut, nilai pH, tertitrat keasidan telah diuji dalam kajian ini. Tidak ada interaksi antara sampel pengendalian dan suhu penyimpanan diperhatikan dalam kajian ini dan juga tiada perbezaan yang signifikan dalam pengendalian lepas tuai terhadap kualiti pisang Saba. Suhu bilik sejuk mencatatkan minimum (9.04%) pengurangan berat selama penyimpanan 2 minggu, manakala suhu luar dipamerkan maksimum (21.07%) pengurangan berat. Ketegangan tertinggi (3.36kg/f) dicatatkan pada suhu bilik sejuk, manakala suhu luar mempunyai ketegangan paling rendah (1.12kg/f). Untuk nisbah antara daging dan kulit, dan jumlah kepekatan pepejal larut, suhu bilik mencatatkan nilai maksimum (2.33 dan 23.2% Brix) masing-masing. Suhu luar merekodkan nisbah minimum (0.87) dan suhu bilik sejuk mempamerkan kepekatan pepejal larut minimum (5.90% Brix). Keasidan tertitrat terendah telah ditunjukkan oleh suhu bilik sejuk (0.14%) dan suhu bilik merekodkan maksimum (0.34%) keasidan. Suhu terbaik untuk lepai tuai pisang yang paling optimum adalah suhu sejuk simpanan.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
°C	degree Celsius
ANOVA	Analysis of Variance
CA	Controlled Atmosphere
cm	centimetre
CO_2	Carbon dioxide
g	gram
HCI	Hydrochloric acid
kgf	Kilogram Force
$KMNO_4$	Potassium permanganate
l	litre
M	molar
MA	Modified Atmosphere
min	minutes
ml	millilitre
mm	millimetre
NaOH	Sodium hydroxide
O_2	Oxygen
TA	Titratable Acidity
DOA	Department of Agriculture
FAO	Food and Agriculture Organisation
UNCTAD	United Nations Conference on Trade and Development

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.0 Background

Banana (*Musa spp*) is the most important tropical fruit in worldwide. In Malaysia, it is ranked second in term of production with 530,000 metric tons of total production (FAO, 2003). Among all the variety of banana cultivars grown, Saba (Musa balbisiana) are gaining popularity in both domestic and international market. Saba is known as a cooking banana which is cooked before been eaten. There are more variety of cultivars under cooking banana such as Pisang Nangka, Pisang Raja and Pisang Relong. Saba banana is usually processed into everyone's favourite banana chips where 95% of the country's earning is derived from this product. (Molina and Roa, 2000).

Most of the part of saba banana can be used economically which is very cost efficient. The fruit itself can be eaten fresh when ripe but is usually eaten when cooked. Different kind of food products are derived from it such as chips, banana flour and flakes. Inflorescene of banana is consumed as vegetables. Wrapping materials used the leaves of banana to wrap the food products. Finely chopped pseudostem is cooked and used as feed for livestocks mainly hog, cattle and poultry.

Bananas and plantains will be harvested while still in mature green stage especially for a commercial purpose because they need to be ripened in controlled conditions when transported to destination markets. The ideal harvesting time for banana fruit is when the fruits still have sufficient green life to maximise the yield and sustain long enough for marketing purpose. Plantains however, have faster maturity time than bananas if harvested at the same time.

There are several criterions to be factored in harvesting banana fruit. One of them is the age of bunch after emergence from pseudostem. When bananas are growing rapidly during harvesting time, fruit size and finger richness are important measures of harvest maturity. Hands maturity index vary in a stem where hands at the proximal end of thr stem are more mature than those at the distal end.

Banana plant is known as a large perennial herb with around twelve leaves that are up to 9 feet long. The inflorescence (flower stalk) grows through pseudostem. After 60-90 days, the fruits reached their maturity when flowers first appear. The banana fruits are made up of bunch, hands and fingers where each bunch consists of few numbers of hands along and each hand consists of two rows of fruits which called as fingers.

1.1 Justification

Postharvest handling is a major problem in the fruit industry in Malaysia. Proper handling of banana at the post-harvest stage is not given proper attention. Rough handling often resulted in damage and losses to the fruits when the products reach the market. All these losses of fresh produce had become a major challenge in the postharvest sector (Atanda, 2011). Growers tend not to understand the effect of their harvesting and handling on the quality of produce when it reaches to the market. This would result in disagreement between farmers and traders where farmers have sent to market what they consider to be good quality products but traders see the produce had deteriorated badly by the time these arrive at the market (FAO, 2003).

Banana is a climacteric fruit with poor storage characteristics because it has high respiratory rate and ethylene production after harvest. This make the banana highly perishable and prone to postharvest losses (Turner, 2001). Most of the problems are mostly inclined towards harvesting immature fruits but there are also cases where bunches remained longer after maturity due to labour shortages. In both cases, postharvest losses will be inflicted to the farmer and also traders where banana suffer difficulties for even ripening (Adam, 2015).

Some factors lead to the loss of postharvest in Malaysia are inappropriate production practices where the farmers do not have sufficient knowledge. Poor agri-business management like improper practices from farm to market would affect the banana quality. To minimise these losses, there must be a proper guideline on the handling of banana during post-harvest stage (Hailu, 2013). A low quality produce from poor postharvest handling will result in reducing price and reputation of the production area. Improved harvesting and handling of produce will give better appearance and shelf life of the product.

1.2 Objective

The objective of this research is to study the effect of storage temperature and handling of Saba banana bunches and hands to its postharvest quality.

1.3 Hypotheses

H_{O1}: There is no significant difference of the effect of storage temperatures on the postharvest quality of Saba banana

H_{A1}: There is significant difference of the effect of storage temperature on the postharvest quality of Saba banana

H_{O2}: There is no significant difference of the effect of handling of Saba banana bunches and hands to its postharvest quality

H_{A2}: There is significant difference of the effect of handling of Saba banana bunches and hands to its postharvest quality

H_{O3}: There is no significant interaction between storage temperatures and handling of Saba banana bunches and hands to its postharvest quality

H_{A3}: There is significant interaction between storage temperature and handling of Saba banana bunches and hands to its postharvest quality

CHAPTER 2

LITERATURE REVIEW

2.1 Musa

The classification of banana is consisted of Musaceae family, genus Musa and species or hybrids in this genus. The name Musa is derived from Sanskrit. There are two type of bananas that are native from Southeast Asia. They are identified as Musa acuminate and Musa balbisiana (Robinson, 1996; Stover & Simmonds, 1987). Among the species, hybrids of diploid, triploid and tetraploid are found in Musa acuminata and between Musa acuminata and Musa balbisiana (Zhang *et al.*, 2005). For example, Musa cavendish is pure triploid acuminate (AAA group) and is a type of dessert banana but both Musa paradisiaca and Musa sapientum belong to AAB group (Stover & Simmonds, 1987b) and are characterized by higher starch concentration.

Banana is one of the most widely cultivated fruit in Malaysia. The whole banana plantation covered about 26,000 hectares with a total production of 530,000 metric tonnes (Chai *et al.,* 2014). About 50% of the bananas growing land is cultivated with Berangan banana and the popular cultivation of Cavendish types like Lady Finger banana, Silk banana, Raja banana, Awak banana and Saba banana. There is an excess of production and large quantities of fruits are lost during commerce, as a consequence of deficient postharvest handling. (Ovando-Martinez *et al.*, 2009). New economic strategies are considered for banana as a food ingredient (Maribel *et al.*, 2009).

Bananas are energy-rich in the form of starch and sugar (Molina *et al.*, 2002) and also contain high amounts of essential minerals, such as potassium, and various vitamins such as A, B, C, B1 and B2 (Noor Aziah and Choo, 2010). Banana are famous for its aroma and easy to peel and eat, besides rich in calcium as well as low in sodium content (Wall, 2006). A report by Sharrock and Lustry (2000) indicated that digestion time of banana is less than apple, which is 105 min and 210min, respectively. These characteristics of banana allow it to be used in special diets where low fat, minerals, ease of digestion and vitamins content are required (Nakasone and Paul, 1998, Aurore *et al.*, 2009).

2.2 Botanical description of banana

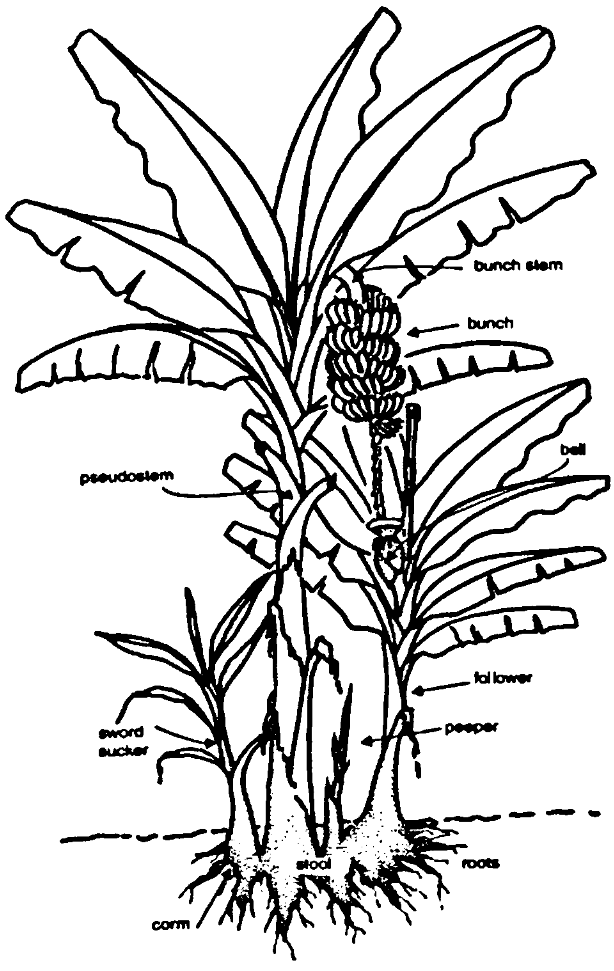

Figure 2.1 Banana stools- Reproduction Stage
Source: (Agrilink, 1998)

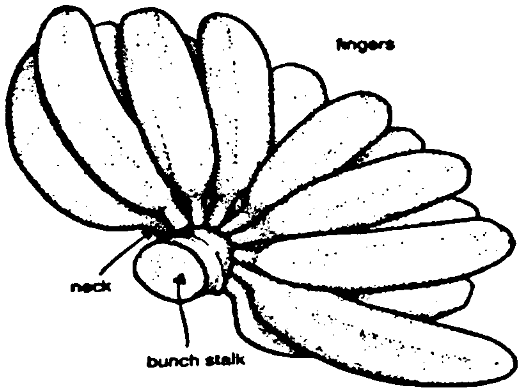

Figure 2.2 Hand of Bananas
Source: (Agrilink, 1998)

The banana plant is believed can last up to 50 years due to its characteristics which are monocotyledonous, herbaceous and evergreen. Rhizome of the plant is responsible for bearing developing suckers and inflorescence that bear flowers which eventually bear the fruit. The plant itself also has an adventitious root system. According to figure 2.1, the banana flowers can be found on nodal structures which are arranged accordingly by a stout peduncle. At the nodal structures, each node comprised of two rows of flowers. Female flowers are on the basal node that develop into fruit and sometimes will grow in numbers between 5 to 16 nodes per stalk. In comparison, the male flowers can be found on the distal part. The flowers remain tightly closed on the node and these form the bell. Banana fruits will be developed from hermaphrodite flowers which formed by several nodes between the male and female nodes.

In order to increase the fruit size, the bell is cut when the distance between the last hand and the top bell is about 15 cm. This is to prevent the growth of meristem and direct the plant photosynthetic energy. (National Agriculture Research Institute Guyana, 2003). After harvesting the fruits, the aerial parts of the plant die and usually chopped down or naturally fallen down to the ground. New suckers will grow up from the base of the mother plant to replace the aerial parts that have died. The suckers eventually grow into a mature plant with a height of 3 metres or more depending on variety and conditions (Karamura *et al*, 1995).

Water is the most abundant element in the banana fruit especially within the pulp and peel of banana. A plantain fruit has lower water content compared to the pulp of a dessert banana. A fully ripe banana has 75% water of its pulp mass while the plantain has 66% of its pulp water mass (Robinson *et al*, 1984). The water content increases at ripening but started to decrease from the peel externally due to transpiration. Degradation of the peel from continuous ripening process further reduces the water loss. The two main components for yield of bananas are fruit mass and cycle time. Fruit mass included hands per bunch (Figure 2.2), fingers per bunch, finger length and caliper. Cycle time refer to the interval between harvest time. Improving yield, therefore involves either an increase in fruit mass or a reduction in cycle time. These two components, as well as fruit quality are affected by the environment, cultural practises, biological and post-harvest factor

2.3 Different stages of maturation

Chlorophyll is produced within the peel of banana when banana starts to develop as a result of direct sunlight that required to grow the fruit. The green peel as the interior fruit absorb all the sunlight and begins to undergo a chemical change that helps in reaching the maturity of the fruit. During the process, the sweetness of the fruit is enhanced with the release of nutrients of the interior of the peel. After achieving maturity, the peel begins to lose chlorophyll content and changes from green to yellow. The peel will continue to deteriorate, leaving only a thin covering that can be peeled away manually from fruit with ease during this transformation. Since banana is a climacteric fruit and ripen quickly, it does not take a long time to go from a bitter green banana to a sweet yellow banana. According to the desired use, banana and plantain are consumed or locally processed at various stages of maturation which have been classified from stage 1, green skin, to stage 7, yellow skin with black spots (Emaga *et al.*, 2010).

Green banana is rich in starch and greater part of the starch found is the resistant starch type 2 (Faisant *et al.*, 1995). Around 70g/100g of starch (dry basis) is contained in its flour and around 12g/100 (dry basis) of fibre content in it. (Juarez-Garcia *et al.*, 2006). At different maturity stages, banana fruit exhibits significant difference ($p < 0.01$) on physio-chemical characteristics and fruit firmness. The soluble solids concentration increase from early stages until the end of maturity, while fruit firmness become softer during ripening, due to the action of enzymes involved in pectin degradation in the cell wall and middle lamella

Banana especially plantain is very abundant in starch content and becoming a primary replacement for the starch industry. (Chong and Noor Aziah, 2009). Ethylene acted as a catalyst for climacteric change and ripening process for consumption. The quality and appearance of banana are determined when consumed fresh with yellow-coloured peel, flavors, consistency of pulp and starch-sugar transition. The classification of ripening defined by various stages of colour index where stages 1 to 3 are not ideally to be consumed because the fruit is still green, hard and rich in starch. At stage 7 however, banana is overripe and muddy. (Aurore *et al.*, 2009).

2.4 Post-harvest Physiology

2.4.1 Pigments

Visual maturity index often look for colour changes in fruits during ripening process. The colour is usually determined by various pigments present in the peel and flesh (Rood, 1957). When fruits start to reach maturity, the fruit colour changed from green to yellow, red or other colours due to the presence of accessory pigments. (Romani and Jennings, 1971). Colour changes are either dependent or independent of ethylene action based on the types of pigments involved and the species of fruit. (Lelievre *et al.*, 1997). Chlorophyll 'a' and 'b' are the most dominate pigments in fruits and vegetables where these pigments can be found in all photosynthetic and storage tissues.

Chlorophyll degradation is mainly responsible for the colour change in fruits from green to yellow, which later exposed the presence of yellow carotenoids pigments. (Seymour *et al.,* 1993). Carotenoids are C_{40} iso-propanoid compounds that contribute in various physiological processes in plants and other organisms (Fraser *et al.*, 2004). These carotenoids compounds are important in photosynthesis where they act as energy carriers and photo-oxidation protectors (Van Berg *et al.*, 2000). Some other functions of these compounds are as pollinator which mediated by insects in flowers and serve as indicators of maturity in fruits that make fruits attractive for human consumption (Arias *et al.*, 2000).

Carotenoids are free radical scavengers and act as a natural antioxidant. One of the most significant values of carotenoids is its essential role in human nutrition and prevention of diseases (Ye *et al.*, 2000). Since we cannot synthesize carotenoids, thus we only consume fruits and vegetables to meet our nutritional requirements. The most studied carotenoids are β-carotene and lycopene. There are also some other carotenoids which received considerable attention like lutein and zeaxanthin due to their antioxidant properties (Volker *et al.*, 2002).

2.4.2 Ethylene Production and Respiration

The most important biological process is respiration accompanied by the release of ethylene in climacteric fruit like banana. As a growth regulating hormone, ethylene plays a significant role in the shelf life of banana by affecting the ripening rate (Pech *et al.*, 2008). This result into flesh softening, the development of colour and production of aroma compounds that attributed to the evolution of ethylene. Ethylene biosynthesis takes place through enzyme mediated metabolic pathway by using sulfur containing amino acid methionine as the biological precursor (Argueso *et al.*, 2007).

Excessive softening and firmness loss is correlated to ethylene emission in banana (Botondi *et al.*, 2003). The mechanism behind the ethylene emission is the conversion of structural carbohydrates into simple sugars. This conversion usually functions as an energy source for continued respiration. Respiration and evolution of ethylene speed up the ripening process, leading to accelerated membrane deterioration, nutrient depletion and excessive water losses. During ripening, respiration considerably increases over a short period (Eskin, 1991). If the storage atmosphere is not properly managed, rapid ripening leads to internal tissue breakdown with the production of volatile characteristics of over ripe fruit (Mathooko, 1995).

The respiration process involves oxygen and carbohydrates to make intermediate products and eventually carbon dioxide and water. This mechanism accompanied by enzymatic activities cause excessive textural softening leading to adverse effects on the nutritional and sensory quality of produce (Prasanna *et al.*, 2007). Certain enzymes like catalase and superoxide dismutase play a protective role against the destructive mechanism evolved during ripening which scavenging free radicals harmful to the tissues. Reactive oxygen species were involved in senescence and aging of fresh commodities (Yang and Ying, 2008). These enzymes avert the harmful effect of active oxygen species and hydroxyl groups by converting them into the water. The pace of action of different enzymes vary with the species and variety of fruits (Vicente, 2007).

2.4.3 Phenolic

Polyphenol content is highest during fruit growth and under normal ripening condition. The content started to decrease with the fruit ripening process. (Lakshminarayana *et al.*, 1970). These observations indicate a correlation between fruit ripening and loss of secondary metabolic substrates. Polyphenolic compounds in fruit and fruit products were linked to prevention of degenerative diseases due to their antioxidant activity. Fruit phenolic phytochemicals have the potential to inhibit oxidative damage to cellular DNA by their antioxidant activities, thus preventing mutagenesis and tumorigenesis (Kelly *et al.*, 2001). Epidemiological studies have shown that the chemicals also have the capability to reduce the risk of cardiovascular disease and stroke through inhibition of cellular oxidative damage.

The maturity of fruit and processing techniques applied prior to consumption affected the chemical composition of fruit. This also directly related to the health of consumers who consume the fruits. When the fruit ripen, all sugars, ascorbic acid, soluble solids and pectin will reach their highest levels. Acidity and phenolic acids will show the lowest levels (Bulk *et al.*, 1997). Recently, awareness about the role of antioxidants become higher in the promotion of health due to their function as chemo-protective agents. (Teissedre and Waterhouse, 2000). This awareness has contributed to the rise in consumer demand for fresh fruits. There were enough evidence to show between in vivo and in vitro studies to support the role of antioxidant polyphenolic compounds in the prevention of disease and thus promotion of health.

2.4.4 Sweetness and starch content

Another characteristic of banana ripening is an increase of sugar content (Blankenship *et al.*, 1993). Unripe banana tastes starchy and less sweet since most of the carbohydrate is present in the form of starch, which is a long chain of covalently bonded glucose molecules (Zhang *et al.*, 2005). The starch is converted to soluble solids as the banana fruit starts to ripen. When the banana is fully ripe, the starch content drops from 25% to less than 1% while soluble solids content increase significantly (Cordenunsi and Franco, 1995). The types of sugar present include glucose, fructose, and sucrose, among which more than 70% of the total sugar is sucrose (Marriott *et al.*, 1981). Thus, the banana tastes sweet when ripe. Besides, the sugar content is considered a feasible parameter for evaluation of fruit ripening since it gains good correlation with optical properties and physical properties during ripening (Kader, 1999; Liew and Lau, 2012).

2.5 Factors affecting Postharvest Loss of Banana

2.5.1 Pre-harvest factors

Quality assessed after harvest is largely due to the result of conditions and treatments of fruit experience during growth and development and at harvest (Munasque *et al.*, 1990). Pre-harvest factors affecting the postharvest quality of banana, include harvest maturity, type of cultivar, climate, quality of soil, type of chemicals applied, and water status (Thompson 2003). Knowles *et al.* (2001) indicated that the soil type and its fertility affect the chemical composition of banana. Rabus and Streif (2000) also explained that the mineral content of banana, such as phosphorus, calcium and potassium can be used to test their postharvest quality. Water and nutrient uptake abilities are varied for rootstocks used in banana production and in resistance to pests and diseases, and thus have a profound effect on the postharvest life of the produce (Tomala *et al.*, 1999). Ferguson et al. (1999) also cited climate factors have a strong effect on the nutritional quality of fruits. Both light intensity and temperature are crucial factors in the postharvest quality of fruits. Trees that are constantly exposed to sunlight may have a different result in term of quality and postharvest characteristics from those growing on the shady side.

2.5.2 General postharvest factors

Before fruits are consumed, processed or cooked, they remained as living tissues. Therefore, by extending the shelf life of these living produce with controlling respiration technique will improve storability of the fresh produce (Daniel, 2007). Wounded tissues can be formed from minimally processed fruits which lead to browning discolouration and tissue softening. The intensity of the wound response is influenced by a few numbers of factors which included different species and variety, water vapour pressure, O2 and CO2 concentrations, and the presence of inhibitors (Brecht *et al.*,2004). During postharvest handlings like storage and packaging, banana undergo physiological changes such as degradation of chlorophyll, tissue softening, decrease in phenolic acid contents and breakdown of cell materials due to respiration (Sharma and Singh 2000).

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