EFFECT OF HYDROCOOLING AND STORAGE DURATION ON POSTHARVEST QUALITY OF SABA BANANA

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2017

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: EFFECT OF HYDROCOOLING AND STORAGE DURATION ON POSTHARVEST QUALITY OF SABA BANANA

IJAZAH: DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

SAYA: TEO WEI TING SESI PENGAJIAN: 2016/2017

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ACKNOWLEDGEMENT

I would like to express my sincere thanks to all the people who contributed in some way to the work described in this project. First and foremost, I would like to express my greatest appreciation and gratitude to Dr. Jupikely James Silip for acting as my supervisor, and for his committed guidance and assistance during the preparation of my project. Helpful suggestions and comments on this project given by him are highly appreciated by me.

I would also like to thank two of the coordinators of final year project which are Miss Shahida Mohd Sharif and Miss Izyan Ayuni Mohamad Selamat for their guidance and help during the completion of this project. I would also like to thank my fellow friends namely Pui Khee, Jian Xiang, Tao Phiaw, Ning Wei and Phaik Sim who have given constant help and encouragement to me during the completion of this project. Without them, my project would not be completed in time. I am also grateful to laboratory staff especially Miss Nurul Shakina and Mr. Razali Shahirin for being there for me when I need their help.

Last but not the least, I would like to say thanks to my parents for their love and unconditional support given to me. My project would not have been possible without their helps.

ABSTRACT

A study was conducted at Faculty of Sustainable Agriculture, University Malaysia Sabah, Sandakan to determine the effect of different hydrocooling time and storage duration on postharvest quality of Saba banana. Fully matured unripe Saba bananas were precooled at 1/8, 1/4, 1/2 and 0 cooling time using a portable hydrocooler and stored at 13±2°C for 0, 1, 2, 3, 4, and 5 weeks. The experimental design was CRD with a factorial arrangement of treatments (4 cooling times x 6 storage duration) with three replications and three fingers of fruits for each replication. The data was analysed using SAS statistical computer package Version 9.4 and two-way analysis of variance (ANOVA) was carried out to determine significant effect between two factors. Duncan's multiple range tests (DMRT) was performed for mean comparison. The results indicated that interaction between cooling time and storage duration has significant effect on the visual appearance, peel colour, firmness, weight loss, pH, and total soluble solid but it does not affect the titratable acidity. Storage duration for fruits to have acceptable visual appearance was up to 3.2 weeks for control treatment (non-hydrocooled) compared to only 0.7 weeks, 1.3 weeks and 2.4 weeks for 1/2, 1/4, and 1/8 cooling time respectively. Hydrocooled Saba bananas also shown a high weight loss and poor performance on peel colour across storage duration. Only firmness, pH, titratable acidity and total soluble solid seemed to gain the benefits from hydrocooling over storage duration but these might be related to chilling injury. The results of this study did not suggested hydrocooling Saba banana using 1/2, 1/4, and 1/8 cooling time at cooling medium of 2±1°C as it caused chilling injuries which negatively affect most of the physical quality of fruits.

KESAN PENYEJUKAN AIR DINGIN DAN TEMPOH PENYIMPANAN TERHADAP KUALITI LEPAS TUAI PISANG SABA

ABSTRAK

Satu kajian telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah, Sandakan untuk menentukan kesan masa penyejukan air dingin yang berlaianan dan tempoh penyimpanan terhadap kualiti lepas tuai pisang Saba. Pisang Saba yang matang sepenuhnya sebelum masak telah diprasejukkan dengan 1/2, 1/4, 1/8 dan 0 masa penyejukan menggunakan mesin penyejukan air dingin mudah alih dan disimpan pada 13 ± 2 ° C bagi 0, 1, 2, 3, 4, dan 5 minggu. Reka bentuk eksperimen ini ialah reka bentuk rawak lengkap dengan susunan faktorial (4 masa penyejukan x 6 tempoh penyimpanan) dengan tiga replikasi dan 3 tiga buah digunakan bagi setiap replikasi. Data telah dianalisis menggunakan perisian statistik pakej komputer SAS Versi 9.4 dan analisi varians (ANOVA) dua hala telah dijalankan untuk menentukan kesan signifikasi antara interaksi dua faktor. Perbandingan Keputusan kajian ini menunjukkan bahawa interaksi antara masa penyejukan dengan tempoh penyimpanan mempunyai kesan yang signifikan terhadap penampilan visual, warna kulit, kekerasan, kehilangan berat buah, pH, dan jumlah pepejal larut tetapi ia tidak mempunyai kesan signifikan terhadap keasidan tertitrat. Tempoh penyimpanan buah mempunyai penampilan visual yang boleh diterima ialah selama 3.2 minggu bagi rawatan kawalan (tidak desejukan dengan air dingin) berbanding dengan hanya 0.7 minggu, 1.3 minggu, dan 2.4 minggu bagi 1/2, 1/4, dan 1/8 masa penyejukan masing-masing. Pisang Saba yang telah disejukkan dengan air dingin juga menunjukkan penurunan berat buah yang tinggi serta prestasi yang kurang memuaskan pada warna kulit sepanjang tempoh penyimpanan. Hanya kekerasan, pH, keasidan tertitrat dan jumlah pepejal larut yang kelihatan mendapat manfaat daripada penyejukan air dingin tetapi ia berkemungkinan berkaitan dengan kecederaan penyejukan. Keputusan kajian ini tidak mencadangkan menyejukkan pisang Saba menggunakan 1/2, 1/4, dan 1/8 masa penyejukan di medium penyejukan 2±1°C kerana ia menyebabkan kecederaan penyejukan yang memberi kesan negatif terhadap kebenyakan kualiti fizikal buah.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

ANOVA	Analysis of variance
C*	Chroma
CRD	Completely Randomized Design
CA	Controlled atmosphere
DMRT	Duncan Multiple Range Test
MA	Modified Atmosphere
PE	Polyethylene
RH	Relative humidity
H°	Hue
L*	Lightness
NaOH	Sodium Hydroxide
SSC	Soluble solid concentration
TA	Titratable acidity
TSS	Total soluble solid
VA	Visual appearance
MA	Modified atmosphere
CT	Cooling time
SD	Storage duration
°Brix	Degree Brix
kg F	Kilogram Force
°C	Degree Celcius
n.d.	No date
NS	Not significant
g	Gram
mm	Millimeter
mL	Millilitre
N	Normality
O_2	Oxygen
CO_2	Carbon dioxide
kcal	Kilocalories
mg	Milligrams
µg	Microgram
RAE	Retinol activity equivalents
DFE	Dietary folate equivalents
IU	International unit

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.1 Introduction

Banana (*Musa* spp.) is one of the major fruit crops that widely cultivated in tropical and subtropical regions of the world, with a global annual production over 102 million metric tonnes in which Asia contributes about 63 million tonnes (Amin and Hossain, 2012). Bananas constitute a major staple food for millions of people in the world. It has a high consumer demand worldwide because of its availability throughout the year, affordability, taste, varietal range, nutritive and medical values. In Malaysia, banana is the second largest cultivated fruit crop and Saba banana is one of the popular cooking cultivars. Malaysia produces about 535000 metric tonnes of banana annually. It is ranked second in terms of production area and fourth in export revenue based on the balance of trade figures. Out of the 250000 ha of land which is used for fruit cultivation and banana plantation covers 11% (27500 ha) from that (Husain and William, 2011).

Banana is a climacteric fruit which has a relatively short shelf life after ripening (Maqbool and Alderson, 2010) and subjected to various postharvest problems which greatly affect its quality. Generally, the deterioration rate of fresh produce after harvest is closely related with their respiration rate and the respiration rate on the other hand is dependent on temperature. (Valero and Serrano, 2010). At high temperature, respiratory activity is increased and consequently caused a depletion in food reserves and an acceleration of fruit ripening and senescence (Silip, 2003).

Since the respiratory and metabolic activity are influenced by temperature, precooling before storage to remove field heat is therefore essential in reducing the respiration rate and hence maintain the quality of fresh produce (Senthilkumar *et al*, 2015). According to Hardenburg *et al.* (cited in Silip, 2003), field heat is the temperature of fruits measured in the field and consists of 75% from the total heat in harvested fruits. 1986). Total heat in harvested fruits increased with the intensity and length of exposure time of fruit to sunlight (Silip, 2003). Temperature of fruit could reached as high as 35°C at harvest and lowering this as soon as possible to recommended level could be a decisive initial step in storage management.

Precooling or rapid cooling is one of the postharvest methods that primarily used for rapid removal of field heat. It involved the removal of field heat from freshly harvested produce to slow down metabolic activity and reduce deterioration prior to transport or storage (Brosnan and Sun, 2001). The benefits of precooling is that it can helps to preserve quality and prolong storage life of fruits by restricting enzymatic and respiratory activity, reducing ethylene production, slowing the rate of water loss, and inhibiting the growth of decay-causing microorganisms (Valero and Serrano, 2010).

Hydrocooling is one of the precooling technique which involves the cooling of fruits by spraying or immersing them in an agigated bath of chilled water. Intimate contact of the fruits with chill water enable the field heat to be removed quickly from them. It has been reported that hydrocooling is more effective than other precooling methods such as room cooling, top icing or fan-driven cold air cooling in reducing weight loss, retarding surface colour changes, and improving storage life of various fresh produce (Piriyaphansakul and Kanlayanarat, n.d.). Determining the specific cooling time is utmost important in order to gain benefits from precooling as it has been reported that prolonged exposure to low temperature during precooling have negative effects on fruit quality. Cooling time is usually described in terms of half cooling time, 1/4 cooling time and 1/8 cooling time. Half cooling time is the time required to reduce the temperature difference between the commodities and the cooling medium to half (Silip, 2005).

1.2 Justification

Postharvest loss of banana is one of the major problems faced by banana producer as it is climacteric fruit which degrades rapidly after harvesting. Temperature has the greatest effect among the postharvest conditions that have influence on postharvest quality and longevity of fresh produce. Hence, to reduce postharvest losses and enable the banana to meet the market requirements, its preservation in fresh state by using proper temperature management is of commercial importance.

Precooling is the first step in temperature management that can be used to prolong the shelf life of fresh produce. Although hydrocooling has been recognized as one of the most efficient and economical methods among various precooling techniques, however, there is still lack of information about the effectiveness of hydrocooling in removing filed heat and preserving the postharvest quality of bananas. Determination of cooling time is important in hydrocoooling because the cooling time not only depends on precooling method used but also depends on the initial and final temperature of the products, the flow and the temperature of medium used. Too long exposure to precooling will bring negative effect on fruit quality.

Therefore, this research was carried out to determine the effect of different hydrocooling time and storage duration on postharvest quality of Saba banana. Saba banana was chosen for my study due to its high nutritive value. It is also one of the cultivar that have potential market in Malaysia. Besides that, it is a popular cultivar that easily available for my study in which it can be found easily in the market. Through this research, more information related to postharvest quality of Saba banana as affected by hydrocooling time and storage duration could be available. The results of this study can be used by the banana producer in deciding the suitable hydrocooling time and storage duration for good quality banana and hence to reduce the postharvest loss of banana.

1.3 Objective

To determine the effect of different hydrocooling time and storage duration on postharvest quality of Saba banana.

1.4 Hypothesis

H_O: There is no significant difference in the effect of different hydrocooling time and storage duration on postharvest quality of Saba banana.

H_A: There is a significant difference in the effect of different hydrocooling time and storage duration on postharvest quality of Saba banana.

CHAPTER 2

LITERATURE REVIEW

2.1 Botany of Banana

Banana (*Musa* spp.) is probably originated in Southeast Asia. It is a large, perennial, monocotyledonous herb with a succulent pseudostem composed of leaf sheaths and arising from a fleshy rhizome or corm. The plants producing suckers which are outgrowths of the vegetative buds set on the rhizome. It is the suckers that the banana plants used to propagate themselves (TFNet, 2006).

Banana inflorescence is a complex spike that borne on a pseudostem on which the flowers are arranged in nodal cluster in two rows and will develop into fruits. Each pseudostem only produces a single inflorescence which may also referred to as "banana heart" before dying. The formation to emergence of the inflorescence takes about one month (Thompson, 2015). The inflorescence contain male flowers at the upper (distal) nodes and these male flowers remain tightly enclosed in bracts forming a conical structure called the "bell". The female flowers are at the basal (proximal) nodes and there are 5-18 of these nodes (Robinson, 1996). There are several hermaphrodite flowers which do not develop into fruit in between the female and male nodes (Thompson, 2015). Ovary of the female flower develops into seedless fruit by parthenocarpy (without pollination). As it lifts, the bract exposes a cluster of female flowers that are usually arranged in two rows and these double rows of female flowers will then develop into a hand of fruit. The individual fruits that develop from the female flowers are known as 'fingers'.

The banana fruit can be characterized as a berry with a pericarp. Banana fruits are variable in size, shape and colour. Generally, they are oblong, cylindrical, straight to strongly curved, which can vary from 3–40 cm long, and 2–8 cm in diameter. Its fruit apex which may be tapered, rounded, or blunt are normally used in variety identification. The fruit skin is thin and tender to thick and leathery, turns from deep-green to yellow or red, or, in some forms, green-and white-striped (TFNet, 2006). The flesh colour can be ivory-white to yellow or salmon-yellow and the flavour range from starchy to sweet.

2.2 Taxonomy of Banana

Banana (*Musa* spp.) is belongs to the genus Musa from family Musaceae of the order Zingiberales (Thompson, 2015). The genus Musa can be further divided into four sections which are *Callimusa, Australimusa, Eumusa* and *Rhodochlamys*. Bananas and plantains are belong to the largest section in the genus which is *Eumusa*. The basic chromosome number in this section is 2n=22. This section is characterized by horizontal or dropping bunches, male axes and milky or watery juice (Stover and Simmonds, 1987).

Almost all modern cultivated cultivars of edible bananas are hybrids and polyploids of two wild, diploid species, *Musa acuminata* (AA) and *Musa balbisiana* (BB) (Stover and Simmonds, 1987). Hybridisation between these two species gave rise to various diploid, triploid and tetraploid subspecies. The taxonomical hierarchy of banana is rather confusing and it does not conform fully to the Linnean system of plant classification. Musa species are usually grouped according to their ploidy and the relative proportion of *Musa acuminata* (A) and *Musa balbisiana* (B) in their genome. Most of the edible varieties are derived from *Musa acuminate* and are triploid, although there are some being diploid and a few being tetraploid (Robinson and Sauco, 2010). *Musa balbisiana* contributed to the origin of edible bananas and plantains by hybridisation with *Musa acuminata* (Stover and Simmonds, 1987).

The role of *Musa acuminata* and *Musa balbisiana* in the evolution of edible bananas is illustrated in Figure 2.1. It projects the important role of interspecific hybridization in the proliferation of edible clones.

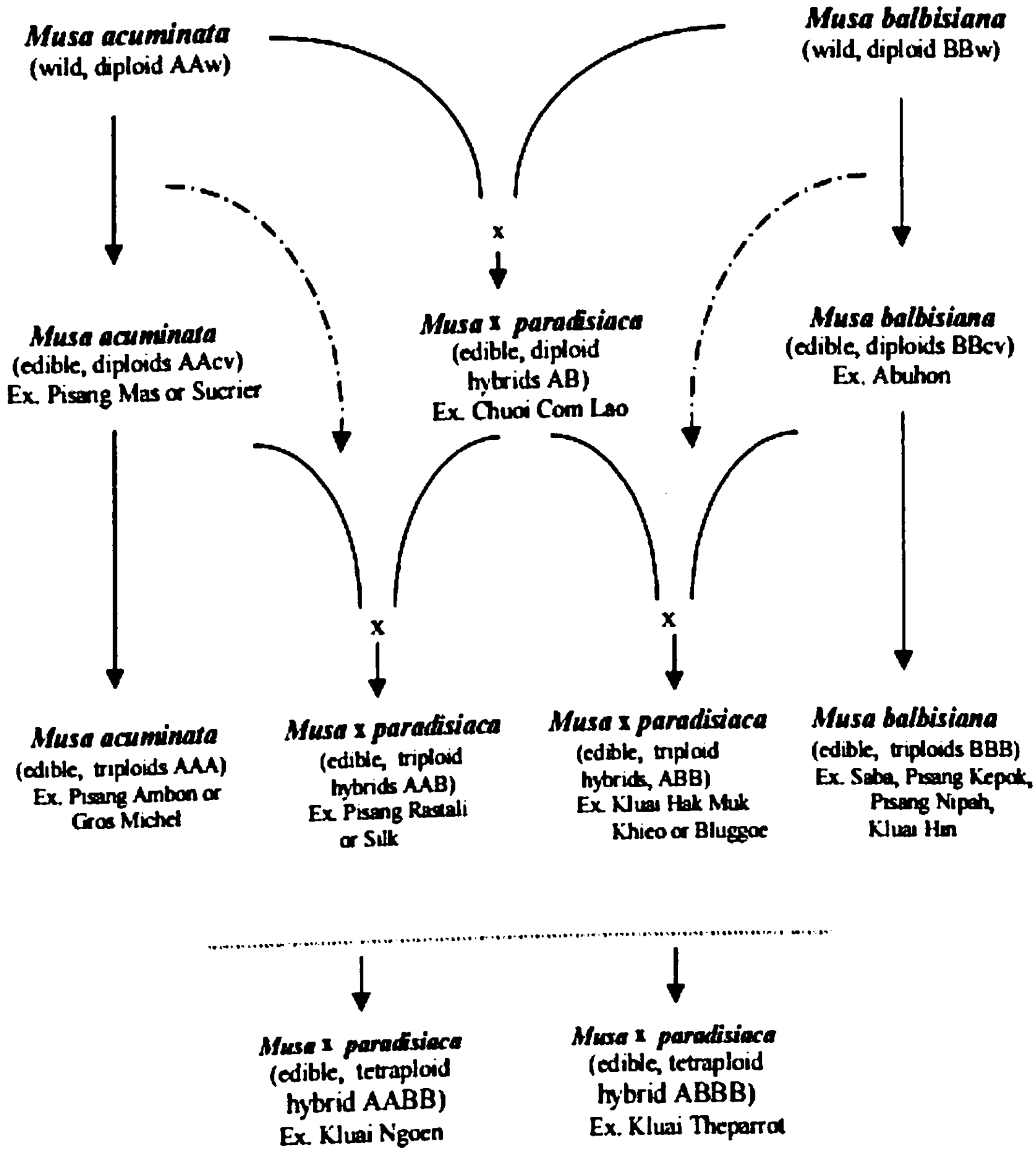

Figure 2.1 Various pathways leading to the development of edible banana
Source: Valmayor *et al.*, 2000

2.3 Types of Banana

Generally, cultivar varieties of bananas is classified based on the dessert and cooking varieties. The eating bananas refers to those softer and sweeter varieties in which they are consumed usually as ripe fruits. This type of banana is also known as dessert banana. On the other hand, the cooking bananas which also known as plantains refers to firmer and starchier varieties. They are often boiled or fried before consumed regardless ripe or unripe (TFNet, 2006). In Malaysia, the popular cultivars of dessert bananas included

Mas (AA), Pisang Lemak Manis (AA), Berangan (AAA), Rastali (AAB), Embun (AAA) and Cavendish (AAA); while the popular cooking cultivars are Nangka (AAB), Raja (AAB), Awak (ABB), Abu (ABB), Tanduk (ABB) and Relong (AAB) (FNCA, 2011).

2.2.1 Saba Banana

Saba banana is a triploid (BBB) hybrid of the seeded banana *Musa acuminate* and *Musa balbisiana* in the genus *Musa* of the family Musaceae (Robinson and Sauco, 2010). It is a type of cooking banana or plantain originated from Philippines and belongs to the Saba subgroup (Valmayoe *et al.*, 2000). The fruits of Saba banana is relatively starchy and the pulp is creamy white in colour. According to Wang and Kepler (2009), the Saba banana fruit shape is straight, plump, strongly ridge longitudinally, highly angular, squashed together sideways, and average 6 inches long x 1.5 inches in diameter with blunt tips.

Saba banana is also known by other local names such as 'Pisang Nipah' in Malaysia, 'Pisang Kepok' in Indonesia, and 'Kluai Hin' in Thailand (Ploetz *et al.*, 2007). It is especially popular in Philippines where the male bud is also consumed as vegetable (Vezina and Crichton, 2015). Saba banana with BBB genome is tolerant to drought and generally resist the Sigatoka leaf spot diseases (Ploetz *et al.*, 2007).

2.4 Nutritional Values of Banana

Bananas have a very good nutritional value with 1.09g protein; 0.33g fat; 22.84g carbohydrates; 5 mg calcium; 22 mg phosphorous and 0.26 mg iron per every 100g of any edible portion (Table 2.1). They contain rich source of carbohydrate which are essential in providing energy to human body. It is also known as a cheap source of carbohydrate. According to Kutinyu (2014), banana is an important source of energy that are also cholesterol free and has very high of fibre content. Low fat, low sodium and low cholesterol of banana fruits make them suitable to be consumed by people who suffer from high blood pressure, cardiovascular diseases or kidney problems.

It is also an excellent source of potassium. It has been reported by Lee (2008) that banana contain high potassium in which 450 to 467 mg of potassium were contained in an average sized banana. He also stated that potassium is vital to keep normal blood pressure in human and also to help in proper heart functioning. Banana also have a high fibre content which can help in prevent the problems of constipation in human. In addition, ripe banana fruit is also a good source of Vitamins A, B and C as well as other minerals such as Ca and Fe.

Table 2.1 The composition of banana fruit for $100g^{-1}$ fresh weight

Composition	Amount
Water	73.91 g
Energy	89 kcal
Protein	1.09 g
Total lipid (fat)	0.33 g
Carbohydrate, by difference	22.84 g
Fibre, total dietary	2.6 g
Total sugars	12.23 g
Calcium	5 mg
Iron	0.26 mg
Magnesium	27 mg
Phosphorus	22 mg
Potassium	358 mg
Sodium	1 mg
Zinc	0.15 mg
Total ascorbic acid	8.7 mg
Thiamine	0.031 mg
Riboflavin	0.073 mg
Niacin	0.665 mg
Vitamin B-6	0.367 mg
Folate	20 µg DFE
Vitamin B-12	0.00 µg
Vitamin A	3 µg RAE
Vitamin A	64 IU
Vitamin E (α-tocopherol)	0.10 mg
Vitamin D (D2+D3)	0.0 µg
Vitamin D	0 IU
Vitamin K (phylloquinone)	0.5 µg
Fatty acids, total saturated	0.112 g
Fatty acids, total monosaturated	0.032 g
Fatty acids, polysaturated	0.073 g

Source: (Thompson, A.K., 2015)

2.5 Factors Affecting Postharvest Quality

2.5.1 Physical Damage

Physical damage such as surface injuries, abrasion and bruising that often involved in harvesting and postharvest handling of fresh produce are the major contributors to deterioration of fruits. Physical damage not only upset the appearance of fresh produce but also increase the potential for diseases infection. (Dadzie and Orchard, 1997).

According to Aked (2002), the most important factor that causes loss in quality of fresh produce is possibly the physical injury that create a wound on the surface of fresh produce. This wound becomes an entrance point for many postharvest pathogens at the same time causes moisture loss which compromises the quality of fresh produce. Besides that, physical damage leads to an increase in respiration rate as well as increase in ethylene production rate which can hasten ripening. Thus, damaged fruits generally ripen earlier than those non-damaged fruits (Dadzie and Orchard, 1997). The effects of different types of bruise on the ripening of plantains indicate that the abrasion has caused the greatest effect. Ferris *et al.* (cited in Thompson, 2011) has stated that abrasion has caused ripening rate of French, true Horn and false Horn in ambient conditions with 28°C and relative humidity of 82% to increase.

2.5.2 Temperature

Temperature has a significant effect on the respiration rate of fresh produce and hence has impact on their deterioration rate. At temperatures above optimum, every 10°C rise in temperature increases the deterioration rate by 2-to 3-fold (Kader, 2013). Since respiration rate is associated with deterioration rate of fresh produce, the higher the respiration rate, the higher the rate of deterioration and hence the shorter the postharvest life. Exposure to undesirable temperature can leads to many physiological disorders.

Thompson and Burden (cited in Kerbel, n.d.) has stated that 13 and 14°C are the optimum storage and holding temperature for green bananas. Green bananas are shipped or stored at 13 to 14°C to delay ripening according to Hailu *et al.* (2013). Mercantilia (cited in Thompson, 2011) has recommended a storage conditions of 12 to

14°C and 90 to 95% RH for green bananas to be stored for two to three weeks. Bananas and plantains suffer from chilling injury to an extent that is proportional to the time they are exposed to chilling temperatures.

The pre-climacteric duration of banana is shortened and fruit quality is altered when storage temperature exceed 25°C as there is modification to metabolism during ripening. The development of the peel and the pulp is desynchronized, with softening of the pulp proceeding faster than the colouring of the peel at temperature above 35°C. This leads to banana fruit with a soft pulp but a green peel (Hailu *et al.*, 2013).

2.5.3 Controlled Atmosphere Storage

Abdullah (cited in Hailu *et al.*, 2013) stated that controlled atmosphere (CA) storage is a technique to maintain the produce quality in an environment that differs from air with respect to the proportion of O_2 and CO_2. Thompson (2003) has stated that reduced O_2 and increased CO_2 can delay ripening of fresh produce and reduce chilling injury systoms. A decrease in oxygen of fresh produce will slow down the respiration rate of fresh produce (Hailu *et al.*, 2013).

It has been stated by Quazi and Freebrain (cited in Hailu *et al.*, 2013) that ethylene production and banana ripening rate can be slow down by CA storage condition. However, care has to be taken because low oxygen can cause fermentation/anaerobic respiration (Hailu *et al.*, 2013). Also, too high CO_2 above certain concentrations can be toxic to banana (Thompson, 2003). Ahmad *et al.* (2006) reported that unripe fruit did not synthesize significant amount of ethylene at 18°C unless the oxygen level was above 7.5 to 8.0. Generally, storage in reduced oxygen and increased carbon dioxide can reduced the respiratory activity and slowed down the ripening processes.

2.5.4 Modified Atmosphere Packaging

A modified atmosphere (MA) can be defined as one that is created by altering the normal composition of air (78% nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of noble gases) to provide an optimum atmosphere for increasing the storage length and quality of food/produce (Hailu *et al.*, 2013).

Various forms of modified atmosphere packaging are commonly used in the banana industry. For instance, individual cluster of six fingers are packed individually in small polyethylene (PE) film bags that are packed together into a large carton. They are transported by sea freight then ripened and marketed while still in the same bags. PE is classified by its medium, low and ultra-low density, which indicates increasing resistance to water transmission (Valero and Serrano, 2010). Chamara *et al.* (cited in Hailu *et al.*, 2013) has reported that packaging of a banana cultivar called 'Kolikuttu ' as individual hands in low density polyethylene (LDPE) bags with a wrapped ethylene absorber could be recommended to extend their shelf life at ambient temperature. Tongdee (cited in Thompsom, 2003) reported that packaging in polyethylene bags at 13°C can maintained green life of Kluai Khai bananas for more than 45 days.

2.5.5 Relative Humidity

Relative humidity (RH) is the moisture content of the atmosphere, expressed as a percentage of the amount of moisture that can be retained by the atmosphere (moisture holding capacity) at a given temperature and pressure without condensation (Kader, 2013). As the relative humidity (RH) decrease, the greater the loss of water and the shorter is the duration of the preclimacteric (Hailu *et al.*, 2013). Low humidity leads to the increase production of ethylene and the respiratory rate, but its effect on the intensity of ethylene production seems to be dependent on variety. Relative humidity changes in the weight relationship between peel and pulp, in the peel colour, in pulp softening and in the soluble sugar content (Gowen, 1995). According to Kader (2013), RH can influence water loss, decay development, incidence and severity of some physiological disorders, and uniformity of fruit ripening.

2.5.6 Chilling Injury

Chilling injury is the permanent or irreversible physiological disorder to plant or fruit tissues, cells or organs when exposed to temperature below critical threshold which would cause them to freeze. Bananas are easily susceptible to chilling injury. In banana, chilling injury may occur at temperature at, or below 12°C (Dadzie and Orchard, 1997). Green banana fruits will develop a dull, often grey skin colour at temperature at, or below 12°C. This causes disruption in the conversion of starch into sugar which subsequently leads to failure in ripening and the fruits eventually turn black and decay

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